PROFIT BASED UNIT COMMITMENT INTEGRATED WITH PLUG-IN ELECTRIC VEHICLES USING MODERN HYBRID META-HEURISTICS SEARCH ALGORITHMS

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY
in

ELECTRICAL ENGINEERING

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2022

Dedicated

To

God, Guide,

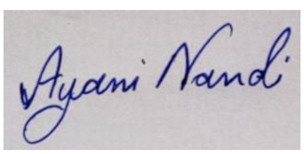
Co-guide, My Husband

&

My Parents

DECLARATION

I declare that that the work which is being presented in the thesis, entitled **"Profit Based Unit Commitment Integrated with Plug-in Electric Vehicles Using Modern Hybrid Meta-heuristics Search Algorithms"** in fulfillment of the requirements for the award of the degree of Doctor of Philosophy in Electrical Engineering and submitted to Lovely Professional University, Phagwara is an authentic record of my own research work carried out during a period from August 2018 to August 2021 under the supervision of Dr. Vikram Kumar Kamboj and Dr. Megha Khatri. The matter embodied in this thesis has not been submitted by me for the award of any other degree of this or any other University/Institute.



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THESIS CERTIFICATE

Certified that the dissertation entitled "**Profit Based Unit Commitment Integrated with Plug-in Electric Vehicles Using Modern Hybrid Meta-heuristics Search Algorithms**", which is being submitted by Ayani Nandi to Lovely Professional University, Phagwara, in fulfillment of the requirement for the award of the degree of Doctor of Philosophy in Electrical Engineering, is a bona-fide record of the candidate's own work carried out by him under our supervision and guidance. The matter contained in this thesis has not been submitted neither in part nor in full to any other university or institute for award of any other degree.

This is further declared that the candidate has worked during the period from August 2018 to August 2021, for the preparation of this dissertation.

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Date: 25/04/2022 **Ayani Nandi**

ABSTRACT

Electric power plays a major contribution to the economy and growth of every nation. Power sectors are the major contributors to the nation's development, as modern societies are fully dependent on electricity. The main sources of electricity are conventional energy sources, i.e., thermal plants, nuclear plants, hydroelectric plants, oil, and natural gas-based plants. The modern power system also consists of various non-conventional energy sources along with conventional sources, which include energy from solar, tidal, geothermal, wind, etc. In India, the load demand is changing very rapidly. To fulfill the rising power demand, massive power generation capacity is required, which can be filled through the economic operations of the power system. Further, due to the extensive transportation of conventional vehicles, environmental issues are increasing day by day. The harmful emission from conventional vehicles is not good for the health of living beings. To facilitate the climate and energy emergency, there has been an increasing interest in electric vehicles especially Plug-in Electric Vehicles (PEVs). Therefore, the prospect of integration of conventional power systems with renewable energy sources (RES) and PEVs has been presented.

The presented research work is to investigate the novel methodologies to solve the profit-based unit commitment problem (PBUCP). The impact of PEVs and the uncertain nature of renewable energy sources (specifically solar PV unit is taken into consideration) for both summer and winter days. The novel methodologies have been designed by hybridization of optimization algorithms. These hybrid optimization algorithms are based upon a combination of local and global search optimizers. Thus, the new algorithms have a better-searching ability to explore and exploitation in the entire search space.

The 10-, 40- and 100-unit generating systems have been taken into consideration. These new hybrid metaheuristics optimization techniques are inspired by the hunting nature of Harris hawks birds, the food searching and wrapping behavior of slime mould,

trigonometric sine/cosine functions, and various chaotic maps. The chaotic map strategy has been applied to Harris hawks optimizer, sine cosine algorithm, and slime mould algorithm to improve the exploitation search capability of the existing optimizers. Further, by combining these chaotic strategies, these optimizers have better exploitations capabilities, i.e., CHHO, CSCA, and CSMA. The hypothesis tests are taken into consideration to check the effectiveness of such hybrid optimizers. Using the hybrid combination of those hybrid chaotic Harris hawks optimizer-sine cosine algorithm (hCHHO-SCA) and hybrid chaotic slime mould algorithm-sine cosine algorithm (hCSMA-SCA) have been developed to increase the capability of exploration as well as exploitation over the whole search space.

PBUCP has been solved considering the impact of PEVs and solar PV units on summer days and winter days using CHHO, CSCA, hCHHO-SCA, and hCSMA-SCA. The test systems consisting of 10-, 40- and 100-unit generating systems have been tested successfully for maximum profit and fuel cost. From the simulated results of the hCHHO-SCA optimizer, it is analyzed that the performances are better than the other existing as well as recently established heuristics, meta-heuristics, and evolutionary search optimizers. Further, it is seen that the suggested optimizer determines the satisfactory profit value with commitment scheduling within a reasonable time of computation. Such a powerful optimizer can be applied to get a solution of profit-based unit commitment for modern power sectors. Analysis of the variation in profit value, i.e., best, average, and worst value with its standers deviation and median value are taken into consideration. Some of the hypothesis testing including the Wilcoxon rank-sum method and t-test are taken into consideration through which p-value and h-value can be determined. The computational times are also analyzed as the best, average, and worst times of simulations.

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LIST OF SYMBOLS

$X_m(\text{iter})$ = Positions of the present solution

m = dimensions

$iter$ = number of iterations

$r_{1,} r_{2,} r_{3,} r_4$ = Random numbers

D_m = Location of the destination in mth dimensions

| | = Absolute value indicators

a = Constant

$iter_{Current}$ = Current iterations

$iter_{MAX}$ = Maximum number of iterations

$Upper_B$ = Upper limit of boundaries

$Lower_B$ = Lower limit of boundaries

ℓ = Parameter setting for experiment

$X(iter+1)$ = Position of rabbit

P = Entire number of Harris Hawks

EN = Evading energy meant for the rabbit

EN_0 = Premature circumstance for energy

DP = Dimension for the specific problem

X = Random vector's dimension with magnitude $1 \times dp$

$\overrightarrow{S^*}$ = Position of Slime Mould

$\overrightarrow{S_b}$ = Individual position with highest number of concentration presently found

$\overrightarrow{ub}$ = Parameter range from –a to a

LIST OF SYMBOLS (Continued…)

$Y_{sequence}$ = Value of fitness sequence

$\overrightarrow{uc}$ = Parameter decrease from 1 to 0 linearly

$\overrightarrow{S_A}$ & $\overrightarrow{S_B}$ = Randomly selected individuals from the Slime mould

R_N = Interval of random no. from 0 to 1

$\overrightarrow{Y}$ = Weights of the Slime mould

$X(i)$ = Fitness value of $\vec{S}$

$Best_F$ = Best value of fitness from every iteration

$Optimal_{FIT}$ = Optimum fitness

$Worst_{FIT}$ = Worst fitness

RV = Revenue

$F_{\cos i,h}(P_{i,h})$ = Cost of Fuel for a particular generating unit ith at that particular time'h' hour

$SUC_{i,h}$ = Cost of Start-up for i^th unit within'h' hours

$SDC_{i,h}$ = Cost of Shutdown for i^th unit within'h' hours

$P_{i,h(\max)}$ = Maximum electrical power generation by unit i

$P_{i,h(\min)}$ = Minimum electrical power which generation by unit i

$P_{i,h}$ = Electrical power generation of unit i^th at the time span'h'

PD_h = Load Demand at'h' hours

INS_i = Initial status of unit n at time'h'

LIST OF SYMBOLS (Continued…)

$T_{i,h}^{OFF}$ = Initial OFF status for n^{th} unit at time'h'

$T_{i,h}^{ON}$ = Initial ON status for n^{th} unit at time'h'

T_i^{UP} = UP condition for i no. of power generating unit

T_i^{DW} = DOWN condition for i no. of power generating unit

R_h = Spinning reserve necessity

T_i^{COLD} = Time span for COLD start of i no. of generating unit

Np = Population Number

H = No. of hours

NG = No. of generators

$P_h^{Renewable}$ = Power generation considering renewable energy source at time 'h'

$D_h^{EVs/BEVs}$ = Power demand considering the impact of BEVs/EVs at time 'h'

LIST OF ABBREVIATIONS

AI - Artificial Intelligence

AF - Artificial Flora

ACC - Adaptive Congestion Control

ACO - Ant Colony Optimization

AEBO - Artificial Ecosystem-Based Optimization

ALO - Ant Lion Optimizer

ANFS - Adaptive Neuro-Fuzzy System

ANN – Artificial Neural Network

BA - Bat Algorithm

BB - Branch and Bound

BBA - Binary Bat Algorithm

BBO - Biogeography Based Optimization

BEPO – Binary Emperor Penguin Optimizer

BGWO - Binary Grey Wolf Optimizer

BSGA - Binary Gravitational Search Algorithm

BWOA - Binary Whale Optimization Algorithm

BABCA - Binary Artificial Bee Colony Algorithm

BCFA - Binary Coded Fireworks Algorithm

BDE - Binary Differential Evolution

BEV – Battery Electric Vehicle

BHC - Binary Hill-Climbing

BMO - Barnacles Mating Optimizer

LIST OF ABBREVIATIONS (Continued…)

BSA - Binary Successive Approach

BSCA – Binary Sine-Cosine Algorithm

BFSA - Binary fish swarm algorithm

BFO-FA - Bacterial Foraging Optimization with Firefly Algorithm

BAMFO - Binary Alternative Moth-Flame Optimization

BRCFF - Binary Real Coded Fire-Fly

BMRFO - Binary Manta Ray Foraging Optimization

BSO - Boundary Strategy for Optimization

CBO - Colliding Bodies Optimization

CEA - Cultural Evolution Algorithm

CHHO - Chaotic Harris Hawks Optimizer

CSO - Civilized Swarm Optimization

CKHA - Chaotic Krill Herd Algorithm

CSCA – Chaotic Sine-Cosine Algorithm

CSA - Cuckoo Search Algorithm

CICA-SCM - Chaos based Imperialist Competitive Algorithm-Sinusoidal Chaotic Map

CICA-ICM - Chaos based Imperialist Competitive Algorithm-Iterative Chaotic Map

CICA-LCM - Chaos based Imperialist Competitive Algorithm-Logistic Chaotic Map

CHHO-SCA - Chaotic Harris Hawks Optimizer with Sine-Cosine Algorithm

LIST OF ABBREVIATIONS (Continued…)

CSMA-SCA – Chaotic Slime Mould Algorithm with Sine-Cosine Algorithm

DA-PSO - Dragonfly algorithm with Particle Swarm Optimizer

DER - Distributed Energy Resources

DP - Dynamic Programming

DPS - Distributed power systems

DR - Demand Response

DT - Dynamic Technique

DSSA - Dynamic Salp Swarm Algorithm

DWD - Dantzig-Wolfe Decomposition

EO - Equilibrium Optimizer

EOA - Equilibrium Optimization Algorithm

EHO - Elephant Herding Optimization

EPSO - Evolutionary Particle Swarm Optimizer

EFO - Electromagnetic Field Optimization

EPPSO - Evolutionary Parallel Particle Swarm Optimizer

ELD - Economic Load Dispatch

EMA - Exchange Market Algorithm

EA – Evolutionary Algorithm

EVs – Electric Vehicles

ESF - Energy storage facilities

FCR - Frequency Containment Reserves

FPA - Flower Pollination Algorithm

LIST OF ABBREVIATIONS (Continued…)

FPGS - Field Programming Gate Array

G2V – Grid-to-Vehicle

GA – Genetic Algorithm

GA-PSO - Genetic Algorithm with Particle Swarm Optimization

GSA - Gravitational Search Algorithm

GENCO – Generation Company

GEPSOA - Generalized Particle Swarm Optimization Algorithm

GWO – Grey Wolf Optimizer

GDE-GWO - Greedy differential Evolution Grey Wolf Optimizer

GLF-GWO - Greedy Levy-Flight Grey Wolf Optimizer

HS – Harmony Search

HAIS - Hybrid Artificial Immune System

HAGOA - Hybrid Artificial Grasshopper Optimization

HHGSOA - Hybrid Henry Gas Solubility Optimization Algorithm

HGO - Human Group Optimizer

HLBDOA - Hyper Learning Binary Dragonfly Algorithm

HCPSO-GWO - Hybrid Crossover Oriented Particle Swarm Optimization and Grey Wolf Optimizer

HHO - Harris Hawks Optimizer

HN-BB - Here-Now Battery Bank

hGWO-RES – Hybrid Grey Wolf Optimizer with Random Exploratory Search

hHS-RES – Hybrid Harmony Search with Random Exploratory Search

LIST OF ABBREVIATIONS (Continued…)

hDE-RES – Hybrid Differential evolution with Random Exploratory Search

hPSO-GWO- Hybrid Particle Swarm Optimization with Grey Wolf Optimizer

IBPs - Incentive Based Programs

ICA - Imperialist Competitive Algorithm

ICLBO - Imperialist Competitive Learner-Based Optimization

IGA – Iso-Geometric Analysis

IGS - Integrating Gradient Search

IGDT - Information Gap Decision Theory

IIMPC - Improved Intelligent Model Predictive Controller

IPPs - Independent Power Producers

IPPD - Integrated Product and Process Development

IJOALV - Improved Jaya Optimization Algorithm with Lévy flight

IAFDO - Improved Algorithm Fitness - Dependent Optimizer

ISFLA - Improved Shuffled Frog Leaping

ISA - Interior Search Algorithm

ISCA - Improved Sine Cosine Algorithm

ISJA - Improved Shuffled Jaya Algorithm

IWO - Invasive Weed Optimization

IWOA - Improved Whale Optimization Algorithm

IHHO – Integrated Harris Hawks Optimizer

LR-DE - Lagrange Relaxation – Differential Evolution

LSA - Lightning Search Algorithm

LIST OF ABBREVIATIONS (Continued…)

LSTM - Long Short-Term Memory

LCA - League Championship Algorithm

LCBO - Life Choice-Based Optimizer

MBA - Mine Blast Algorithm

MBO - Monarch Butterfly Optimization

MGWO - Modified Grey Wolf Optimizer

MGSCA - Memory Guided Sine Cosine Algorithm

MAPE - Mean Absolute Percentage Error

MDE - Modified Differential Evolution

MHTSA - Multi-objective Heat Transfer Search Algorithm

MDP-PSO - Modified Dynamic Programming with Particle Swarm Optimization

MFO-SVM - Moth Flame Optimizer with Support Vector Machine

MFO-HHO – Moth Flame Optimizer - Harris Hawks Optimizer

MILP - Mixed Integer Linear Programming

MO - Multi-objective Optimization

MOGA – Multi-Objective Genetic Algorithm

MOMBO - Multi-Objective Migrating Bird Optimization

MM – Muller Method

MSESCA - Multi-Strategy Enhanced Sine Cosine Algorithm

MVO - Multi-Verse Optimizer

NACO - Nodal Ant Colony Optimization

NNRL - Neural Network based Reinforcement Learning

LIST OF ABBREVIATIONS (Continued…)

NSGA - Non Dominated Sorting Genetic Algorithm

NWOA – Novel Whale Optimization Algorithm

OOBL - Orthogonal Opposition-Based-Learning

OAGO - Orthogonally-designed Adapted Grasshopper Optimization

OIO - Optics Inspired Optimization

PABC - Parallel Artificial Bee Colony

PBUCP – Profit Based Unit Commitment Problem

PNACO - Parallel Nodal Ant Colony Optimization

PEV – Plug-in Electric Vehicle

PSO - Particle Swarm Optimization

PEM – Point Estimate Method

QIBGWO - Quantum Inspired Binary Grey Wolf Optimizer

QBGSA - Quantum-Inspired Binary Gravitational Search Algorithm

RES - Random Exploratory Search

RETs - Renewable Energy Technologies

RESs – Renewable Energy Sources

RMG - Renewable Energy Sources based Micro Grid

RRA - Runner-Root Algorithm

RPBMO - Reference-Point-Based Multi-objective Optimization

RSHO - Refined Selfish Herd Optimizer

RWGWO - Random Walk Grey Wolf Optimizer

SA - Simulated Annealing

LIST OF ABBREVIATIONS (Continued…)

SADABC - Self Adaptive Differential Artificial Bee Colony

SCA - Sine-Cosine algorithm

SCUC - Stochastic security-Constrained Unit Commitment

SCHOA - Sine and Cosine with Chimp Optimization Algorithm

SFS - Stochastic Fractal Search

SHO - Spotted Hyena Optimizer

SOA - Seeker Optimization Algorithm

SPV - Solar photovoltaics

SIT - Swarm Intelligence Techniques

SFLA - Shuffled Frog Leaping Algorithm

SFOA - Smart Flower Optimization Algorithm

SHSLTLBO - Self-adaptive Hybrid Self-Learning based Teaching-Learning-Based Optimization

SSSA - Simplified Salp Swarm Algorithm

TS - Tabu Search

TS-RP - Tabu Search-Random-Perturbation

TS-IRP - Tabu Search-Improved Random-Perturbation

TS-EPSO - Tabu Search - Evolutionary Particle Swarm Optimization

TBR - Time-Based Rate

TLBO - Teaching-Learning-Based Optimization

UC – Unit Commitment

UCP – Unit Commitment Problem

LIST OF ABBREVIATIONS (Continued…)

VCS - Virus Colony Search

VNS - Variable Neighborhood Search

V2G - vehicle-to-Grid

V2H - vehicle to Home

VTSPEPSO - Variable Tabu Search-Parallel Enhanced Particle Swarm Optimizer

WCA - Water Cycle Algorithm

WDO - Wind Driven Optimization

WEG - Wind Energy Generators

WMA - Woodpecker Mating Algorithm

WSA - Weighted Superposition Attraction

WOA - Whale Optimization Algorithm

WWO - Water Wave Optimization

WIC-PSO - Weight-Improved Crazy Particle Swarm Optimization

LIST OF DEFINITIONS

Algorithm- It is a technique of giving the specific solutions for the particular problem followed by specific step and guidelines to find out the outcomes in iterative way. Algorithms are separated in two classifications one is neighborhood search calculation named as local search technique and other is worldwide pursuit calculation named as global search technique. Definitions

Local Search- It begins from an arbitrary arrangement and afterward iteratively moves to a neighbor arrangement. This is just conceivable if neighborhood arrangement is characterized in the region under the search space. At the point when no improvement in the local arrangement happens, neighborhood search is stuck at a local optimum point.

Local Minima- It is defined by function of a point where the value of that function is equal or smaller than the point which are in nearby positions. But the value of that function is more than the distant point which are absent in the neighborhood space within the search region.

Exploitation- It intends to focus the space at that search region in a neighborhood locale area that a present decent solution can be found around there. Exploitation comprises of exploring a restricted locale of that search area with a hope for further developing favorable solutions.

Global Search- it likewise start from an irregular random solutions and afterward moves to the following neighborhood arrangement iteratively in the whole search region. The search region for global search isn't characterized to discover the best arrangement in the total search Area. It discovers the universally best solutions for the specific problem.

Global Minima- It is a specific point where the value of function is smaller than the value of all of the feasible point and none of the smaller value could not find the further within that search region.

LIST OF DEFINITIONS (Continued…)

Exploration- It produce different types of solutions in order to investigate the search area on a global or worldwide scale. It comprises of examining a lot bigger segment of that search region with the expectation of discovering further good solutions which are yet to be created

Optimization Technique – It is characterized as the way toward getting the positive condition which bring about the minimization or expansion of the appraisal of results containing desired benefit of the functions. It focused upon various findings an alternatives way that is one of the best solution within the specified constraints by increasing the factors which are mostly desired as well as minimize the factors which are mostly undesired one.

Stochastic Optimization- It depends on generation of random variable that appear in formulation of optimization problems itself that involves randomly objective functions or some constraints in random manner. The iterations are also taken as randomly for this type of optimization problems.

Heuristic Optimization- It is designed to get solutions in faster way and it is too efficient than the traditional method by accuracy, better optimality, precision and completeness for the speed. It is basically followed by trial and error methods which are problem dependable. The main disadvantage is that it stuck into local optimal point easily, thus it is unable to find better solution within the global search region.

Metaheuristic Optimization- It is one of the higher-level modified heuristic optimizations considered to generate, find or choice a heuristic, i.e. partial searches algorithms which may offer a sufficiently decent solutions for optimization difficulties, especially with imperfect as well as incomplete information with limited computational capacity. It is one of the problem independent method that have capability to search in global region also.

LIST OF DEFINITIONS (Continued…)

Benchmarks- Those are specific standard test function that are used to verify the originality of proposed algorithms. The algorithms which are performed good for that standard functions are said to be good optimizer to solve other optimization issues.

Mean Value- It is an arithmetical average value that is one of the central value of the specific finite numbers of set, specifically sum of the values that are divided by the numbers of that values.

Median Value- It is the value which are separating half of the higher value from the half of the lower value of the sample data or population or probability of the distributions. It can also know as "the middle" value for the specific data sets.

Standard Deviation- It is measured by amount of the variations and dispersions of the set. The lower value indicates the closest positions to the mean value of that set, although high value indicates spread out above the wider ranges of the data sets.

Best Value- It is the specific value that indicates the best location of the solutions with the entire data sets.

Worst Value- It is the specific value that indicates the worst location of the solutions with the entire data sets.

Minimum Fitness- It measures that usually used for such type of cases, the specific minimum value, i.e. how much amount, on averages of an individual fitness could increase if that behaved like optimally by new information which compared to the average value of the fitness itself.

Maximum Fitness- It measures that usually used for such type of cases, the specific maximum value, i.e. how much amount, on averages of an individual fitness could decrease if that behaved like optimally by new information which compared to the average value of the fitness itself.

Convergence Graph- it displays the modification in the positions from each of the iterations having its respective value for fitness which fulfil all the constraints.

LIST OF DEFINITIONS (Continued…)

Engineering Design Problem- It is an emergent area to get solution of design as well as optimization issues incorporating numbers of discipline in various engineering fields from mechanical to civil i.e. to get solution over different types of problems parallel that can save the efforts as well as time.

Economic Load Dispatch- It is important to establishment of the optimum arrangements of electric power output of all the power generators so as to accumulate the essential electricity demand at lowest minimum cost considering satisfaction of all constraints.

Unit Commitment- It is the issues related with scheduling of power generation units over certain time span so that total operational costs can be minimized as well as all operational constraints are also satisfied.

Profit Based Unit Commitment- It is the issues related with scheduling of power generation units over certain time span so that total operational costs can be minimized and maximized the value of profit maintaining all the constraints.

Power Scheduling- It controls on/off position of power generation units for each hour of scheduling horizon concentrating to the systems requirement, including spinning reserves and constrained on the start-up as well as shut-down of power units.

Plug-in Electric Vehicle- It is one type of vehicle which can rechargeable from external sources of electric power and the electric power stored in rechargeable battery pack drives and contributes to drives the wheel. It is a subset of the electric vehicle that contains all types of electric as well as battery electric vehicles in addition to plug-in hybrid vehicles.

Vehicle to Grid- It defines the system where plug-in electric vehicles, like battery electric vehicles as well as plug-in hybrids or hydrogen fuel cell vehicle communicate with electrical grid for sell the demand services by returning electric power to grid or by regulating the charging rates.

LIST OF DEFINITIONS (Continued…)

Grid to Vehicle- It defines the system where plug-in electric vehicles, like battery electric vehicles as well as plug-in hybrids or hydrogen fuel cell vehicle communicate with electrical grid for buy the electric power from the grid or by regulating the charging rates.

Renewable Energy Sources- It includes the sources that are always nature friendly as well as not effect or harmful for environmental purpose and it also free of cost. They may contain solar, wind, geothermal or tidal sources.

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2. Ayani Nandi and Vikram Kumar Kamboj, *"A meliorated Harris Hawks optimizer for combinatorial unit commitment problem with photovoltaic applications",* Journal of Electrical Systems and Information Technology (2020). DOI: https://doi.org/10.1186/s43067-020-00026-3.

3. Kamboj, V. K., Nandi, A., Bhadoria, A., & Sehgal, S., *An intensify Harris Hawks optimizer for numerical and engineering optimization problems*, Applied Soft Computing, 89, 106018, 2020.

4. Ayani Nandi, Vikram Kumar Kamboj, *"HGWO-RES: A Hybrid Algorithm with Improved Exploitation Capability for Profit Based Unit Commitment Problem"*, Think India Journal (ISSN: 0971-1260), Vol-22-Issue-16-August-2019.

5. Ayani Nandi, Vikram Kumar Kamboj, *"E-HHO: An Enhanced Harris Hawks Optimizer with improved Local Search Capability for Multi-Disciplinary Engineering Design and Optimization Problems"*, JETIR (ISSN-2349-5162), Volume 6, Issue 3, March 2019.

6. Ch. Leela Kumari, Ayani Nandi, Vikram Kumar Kamboj, *"An Optimal Solution To Single Area Economic Load Dispatch Using Multi-Verse Optimizer"*, International Journal of Emerging Technologies and Innovative Research (www.jetir.org), ISSN:2349-5162, Vol.6, Issue 1, page no.271-281, January 2019, Available :http://www.jetir.org/papers/JETIRDX06045.pdf.

LIST OF PUBLICATIONS (Continued…)

7. Ayani Nandi, Vikram Kumar Kamboj and Megha Khatri, "*Metaheuristics Approaches to Profit Based Unit Commitment for GENCOs",* Materials Today: Proceedings, Available: https://doi.org/10.1016/j.matpr.2021.12.526.

8. Ayani Nandi, Vikram Kumar Kamboj and Megha Khatri, "*Hybrid Chaotic Approaches to Solve Profit Based Unit Commitment with Plug-in Electric Vehicle and Renewable Energy Sources in Winter and Summer",* Materials Today: Proceedings, Available: https://doi.org/10.1016/j.matpr.2021.12.525.

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1. Ayani Nandi and Vikram Kumar Kamboj, "*Comparative Overview of Profit Based Unit Commitment in Competitive Electricity Market*", Proc. of International Conference on Intelligent Computing and Smart Communication (ICSC-2019), THDC-Institute of Hydro Power Engineering and Technology, Tehri, U.K., Paper_ID_25_ICSC_2019. DOI: https://doi.org/10.1007/978-981-15-0633-8116.

2. Ayani Nandi and Vikram Kumar Kamboj, "*A New Solution to Profit Based Unit Commitment Problem Considering PEVs/BEVs and Renewable Energy Sources*" in 2nd International Conference on Design and Manufacturing Aspects for Sustainable Energy-2020 (ICMED 2020) organized by department of Mechanical Engineering and Electrical Engineering. Gokaraju Rangaraju Institute of Engineering and Technology (GRIET), Hyderabad during 10-12 July, 2020. doi: https://doi.org/10.1051/e3sconf/202018401070.

3. Ayani Nandi, Vikram Kumar Kamboj, "*Profit Based Unit Commitment using Hybrid BGWO-SA Algorithm*", Proc. of International Conference on Clean and Renewable Energy (ICCARE 2019), 10-12th July, 2019, National Institute of Technology, Durgapur, West Bengal, India., Paper_ID_61_ICCARE 2019.

LIST OF PUBLICATIONS (Continued…)

4. Ayani Nandi, Vikram Kumar Kamboj and Megha Khatri, "*Metaheuristics Approaches to Profit Based Unit Commitment for GENCOs",* in International Conference on Latest Developments in Materials & Manufacturing-2022 (ICLDMM 2022) organized by department of Mechanical Engineering, Amritsar Group of Colleges, during 24-25 March, 2022. Available: https://doi.org/10.1016/j.matpr.2021.12.526.

5. Ayani Nandi, Vikram Kumar Kamboj and Megha Khatri, "*Hybrid Chaotic Approaches to Solve Profit Based Unit Commitment with Plug-in Electric Vehicle and Renewable Energy Sources in Winter and Summer",* in International Conference on Latest Developments in Materials & Manufacturing-2022 (ICLDMM 2022) organized by department of Mechanical Engineering, Amritsar Group of Colleges, during 24-25 March, 2022. Available: https://doi.org/10.1016/j.matpr.2021.12.525.

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1. Ayani Nandi and Vikram Kumar Kamboj, *"hHHO-RES: A Random Exploratory Search Centered Harris Hawks Optimizer with Improved Exploitation Capability"*, Diary No. 1835/2020-CO/SW. [Status: Approved & Registered].

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CHAPTER-1

INTRODUCTION

1.1 INTRODUCTION

Electric Power is a crucial challenge for every nation. The economic operation, control, and planning of electric power generation systems are considered the most important concerns in the electric power industry. Optimal scheduling of generating units is therefore plays a prominent role in cost and profit concerns of power economics. Thus, a good schedule to operate the units' status is required to determine, which is known as unit commitment. Apart from determining the on/off states, this problem also involves deciding the hourly thermal output power (known as economic load dispatch) as well as satisfying a large set of system and operational constraints while keeping the fuel cost as minimum as possible. A good number of discrete (on/off status of thermal units) and continuous (hourly thermal power output) variables are required to be solved in the unit commitment problem (UCP). The demand for electrical energy is rising day by day, thus there is an urgent need to generate an adequate amount of power that can satisfy our demand. In India, most of the electrical power is supplied by thermal power plants which have the drawback of harmful environmental effects and high fuel costs in corporations with limited coal reserves available. So, there is a need to use the thermal power plant in coordination with other power supplying plants such as hydro, nuclear, solar and wind, etc.

Power generation through thermal power plants plays an important role and contains a huge percentage of generating companies. Thermal power plants are over 70% of total electricity production throughout the world. From the previous research in the power sector, it states that, globally, in 2006, among the total amount of electrical power, 80% of the electricity was comprised by thermal power companies. These days the cost minimization problem in traditional aspects is transformed into a profit-based maximization problem, which is termed profit-based unit commitment (PBUCP). The main objective of PBUCP is to maximize the total profit of generated power by minimizing the total operating costs and meeting the power demand. Thus, the total profit for power industries is increased by solving the PBUCP related issues. There are some system constraints and unit constraints that need to maintain to solve PBUCP.

In recent years, renewable energy sources have been one of the rapidly growing energy conversion systems. Large wind power penetration puts an increased burden on the system operation due to the intermittency of wind power output. The deep penetration of wind and solar power is a critical component of the future power grid. However, the intermittency and stochasticity of these renewable resources bring significant challenges to the reliable and economic operation of power systems.

The Central Electricity Authority (CEA) has reported that with this generation level of about 2, 37,742.94 MW and leaving a gap of about 35,661 MW and it would be 85% only in the total installed capacity. Hence, the Indian power sector needs to cope with demand and supply. As per the CEA report, around 68% of power is contributed by the thermal power plant. So, it is suggested that there is an immediate need for sustainable economic growth.

Division of Heavy Industries had established our prior FAME approach for PEVs in India. Now Ministry of Power and Renewable Energy has been brought into conventional for PEVs by the NITI Ayog. The Ministry of Urban Development has been bound by NITI Ayog to create municipality-level projects as well as to remember EVs and EV framework for the smart cities program. Ministry of Finance is included by the NITI Ayog to finance different activities in the transformative portability crucial India. Ministry of Roads and National Highway has acquired the mission by NITI Ayog to outline certain strategies and impetuses for PEVs in wording path get to, stopping infra, and so forth. Department of Science and Technology was roped in by NITI Ayog to set out the determinations intended for different viewpoints identified with EVs and EV charging. Global Wind Energy Council (GWEC) says that global wind energy generation is about 318.14GW worldwide and contributes around 19% of the total power generation. China is at the topmost with the highest installed capacity of about 91.42 GW followed by the USA, Germany, Spain, and India. Globally, India ranks 5th in position with an installed capacity of about 20.15 GW. USA and China are having ~3% and ~2%

integration with the existing power system while India is ahead with 3 to 4% penetration.

The complication of conventional PBUCP has increased due to discharging and charging behaviour of plug-in electric vehicles (PEV). To minimize the environmental pollution and economic cost, the execution of the smart grid needs more tools for computation with the fastest development of the generation of RES, PEVs, and other modified energy storage in power systems. The ever-rising demand for energy has led professionals to look out for RES and its growing influence. Global warming, degradation of the ecosystem, and quality of air require a serious plan of action. More work needs to be done in this sector.

1.2 PROFIT BASED UNIT COMMITMENT

Electrical Power is a fundamental challenge for every country. India is a developing country and the development of any state is nudged by the expanse of electric power used by that state [1]. The electricity demand is increasing step by step so there is a need to produce a satisfactory amount of electrical power on an urgent basis that can fulfill our electricity demand. In India, the vast majority of the electric power is provided by thermal energy stations, which has some drawbacks of environmental as well as ecological impact and high fuel cost in partnership with restricted coal save accessible. So there is a need to use the Thermal power plant in coordination with other power supplying plants such as hydro, nuclear, solar and wind, etc. [2]. Fig.1.1 shows the scenario of the modern power system.

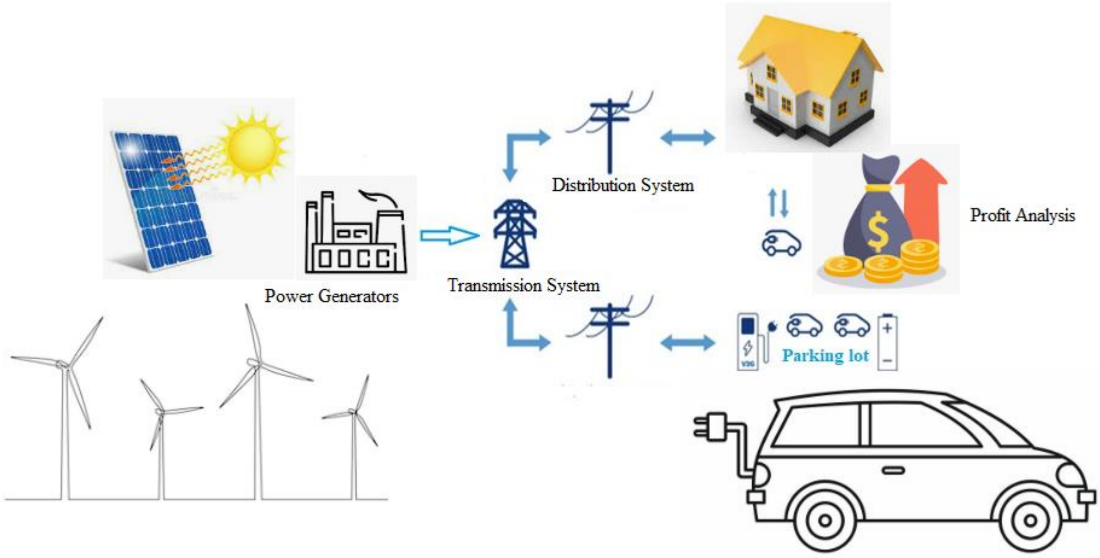


Fig.1.1: Scenario of Modern Power System

The most significant and basic problem for PBUCP is controlling, operating, and monitoring the power plants. Due to the deregulation of the electrical power sector, the competition is increased in-between the suppliers of electricity. The competitions offer the reliability and good organization of electric power in low-priced. Good opportunities for economic resources are produced in the power sector. The many power companies are growing by their proper utilities, roles, and objectives. The optimum power generation schedule is another important task for power suppliers to increase their profit, so this problem is recognized as PBUCP.

In PBUCP, the problem of scheduling has to be solved by consideration of production cost and by satisfying the total system of operating constraints which reduce the independence of the selection of the units for starting up or shutting down [3]. Not only this scheduling but also those constraints need to be satisfied the status of the units for the minimum uptime and minimum downtime to the production of power limit and limit of the capacity to increase the maximum ramp-up rate and to maximum ramp-down rate to such another operating characteristic and spinning reserve.

1.3 RENEWABLE ENERGY IN PROFIT BASED UNIT COMMITMENT

Renewable energy sources play a major role in meeting load demand and environmental protection. But, due to the stochastic nature and uncertain behavior of wind power generation, daily generation scheduling becomes a challenging task in modern energy management systems. Conventional UCP consists of thermal generating units and its participation schedule, which is a stimulating and significant responsibility of assigning produced electricity among the committed generating units matter to frequent limitations over a scheduled period view to achieving the least price of power generation.

The procedure of thermal power generation is consisting of burning fossil fuel, the energy from that is converted to electricity. Nowadays researchers are more focused on alternative energy sources. The concern upon negative environmental impacts of conventional energy produces more focus on alternative energy sources. Also, the reduction of fossil fuels causes an increase in unit costs for fossil fuel-based electricity production.

However, the modern power system consists of various integrated power generating units including nuclear, thermal, hydro, solar, and wind. The scheduling of these generating units in optimal condition is a tedious task and involve a lot of uncertainty constraints due to time carrying weather conditions.

1.4 PROFIT BASED UNIT COMMITMENT WITH ELECTRIC VEHICLE

In the modern power sector, it is important to gain optimal scheduling to solve profit-based unit commitment problems as the actual objective is associated with the maximization of profit. Also, the complication of the conventional profit-based unit commitment problem has increased due to discharging and charging behavior of PEV. To minimize the environmental pollution and economic cost, the execution of the smart grid needs more tools for computation with a faster improvement of the generation of renewable energy sources, PEVs, and further modified electricity storage in the power system [4]. An unnatural weather change, corruption of the environment, and nature of air require a genuine game plan. More work should be done right now [5] [6].

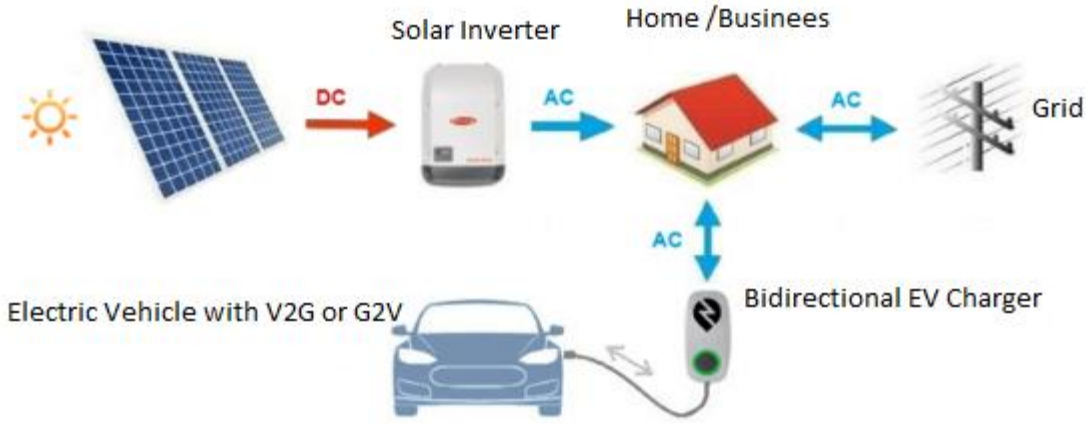


Fig.1.2: Basic Operation of Plug-in Electric Vehicle

The government is now of much concern on low-cost generation, utilization of available resources, optimization of generated possibilities such as fuel-mix technology, and promoting more and more utilization of renewables and V2G technology. The basic operation of the plug-in electric vehicle is shown in Fig.1.2. This suggests that there is a lot of scope for utilizing more and more renewable energy sources for power production which ultimately results in reducing greenhouse gases and climate change.

1.5 METAHEURISTICS TECHNIQUES AND OPTIMIZATION

The optimization technique is the procedure through which a system can perform iteratively by comparing different types of solutions. This execution of the problem is going to continue until it can find the optimal solution. The problems are consisting of some undesired and desired factors. By using optimization techniques, the undesired factors are minimized and desired factors are maximized to get optimal solutions.

The major three types of optimization techniques are stochastic, heuristic and metaheuristics. Metaheuristics optimization is more efficient to solve many optimization issues. It is one of the higher-level modified heuristic optimizations considered to generate, find, or choose a heuristic, i.e. partial searches algorithms which may offer sufficiently decent solutions for optimization difficulties, especially with imperfect as well as incomplete information with limited computational capacity. It is one of the problem independent methods that can search in the global region also. The metaheuristics methods are measured which can deal with a huge no. of problems related to optimization fields. Some other existing researches in the area of optimization are in still initial conditions and contain some problems that must be solved, otherwise, there is little uncertainty to stay away from very few nearby or local optima.

Optimization is a vast area of research in which research is going on very fast. The researchers are doing continuous work on different problems to implement various techniques for different problems and can find the solutions successfully. The work is going on to find the new algorithms and also the hybrid forms of the algorithms to mitigate any drawbacks in the present existing techniques.

1.6 OUTLINE OF THE DISSERTATION

The present research work is based on optimizing and solving PBUCP in the power sector. The chaotic hybrid metaheuristics optimizer is used to solve the PBUCP by considering the impact of charging and discharging of PEV and the uncertainty of RES in summer and winter. The main objective is to maximize the profit while satisfying some time-varying constraints, the demand for electricity, technical constraints, and physical constraints. Two-hybrid algorithms and three chaotic algorithms have been tested to find an optimal solution for PBUCP under different scenarios. The potentiality of the suggested work has been explored by testing different IEEE test systems consisting of small, medium, and large systems. The detailed research work has been organized chapter-wise in the thesis as follows:

Chapter-1 is represented the introductory aspect of PBUCP with its significance in modern power sectors. The several kinds of stochastic, heuristics, and metaheuristics search algorithms are discussed here. The combination of stochastic search algorithm and conventional algorithm including the hybrid method and the bio-inspired algorithm has been suggested for PBUCP. The market of power sector deregulation of power involved a composition among some companies for generation of power is profitable.

Chapter-2 deals with explanations of various methodologies in optimization techniques. The different kinds of optimizers used to solve PBUCP related issues are discussed in the chapter. The review of some testing benchmarks that are used to solve PBUCP includes the charging as well as discharging nature of PEVs. The literature on RES is also discussed in this chapter in detail.

Chapter-3 signifies some new metaheuristics optimization techniques which are motivated by the hunting nature of Harris hawks' birds, food searching and wrapping behavior of slime mould, a function of sine and cosine wave, several numbers of the chaotic map, and adaptive search techniques. The hypothesis tests are taken into consideration to check the effectiveness of such hybrid optimizers. Using the hybrid combination of those techniques CHHO, CSCA, CSMA, hCSMA-SCA, and hCHHO-SCA have been developed to increase the capability of exploration as well as exploitation over the whole search space.

Chapter-4 represents the phase of exploitation of the existing HHO optimizer that has been upgraded successfully using chaotic singer function, i.e., CHHO, CSCA, CSMA, and updated the phase of explorations by HHO and SCA techniques, i.e., hCHHO-SCA. The SMA optimizer was also upgraded with singer chaotic map with SMA and updated by SCA optimizer, i.e., hCSMA-SCA have been successfully tested for unimodal, multimodal, fixed dimension standard benchmark problems, and multidisciplinary engineering design problems.

Chapter-5 shows the efficiency and validity of CHHO, CSCA, hCHHO-SCA, and hCSMA-SCA optimization techniques to solve PBUCP and evaluated the performance of the suggested hybrid optimized method for a standard test system, which consists of thermal generating units for small, medium, and large-scale power sectors. The efficacy of the suggested algorithm was tested for 10-generating unit systems, 40-generating unit systems, and 100-generating unit systems. After a successful experiment, it was observed that the suggested optimizer is more effective to solve continuous, discrete, and non-linear optimization problems compared with another existing optimizer. The comparison of profit for novel hCHHO-SCA and hCSMA-SCA optimizers is better than other existing methods.

Chapter-6 represents the profitable solution for PBUCP with the impact of PEVs and RES (solar photovoltaics) on summer days and winter days using CHHO, CSCA, hCHHO-SCA, and hCSMA-SCA. The test units are consisting of 10-, 40- and 100-generating unit systems that have been scheduled successfully and gain maximum profits using suggested hybrid optimizers. From the simulated results for the profit of hCHHO-SCA optimizer, it is analyzed that the performances are better than the other existing as well as recently established heuristics, meta-heuristics, and evolutionary search optimizer, i.e., CHHO and CSCA. From the simulation outcomes, it is seen that the suggested optimizer determines the satisfactory profit value with commitment scheduling within a reasonable time of computation. Such a powerful optimizer can be applied to get a solution of profit-based unit commitment for modern power sectors. Analysis of the variation in profit value, i.e., best, average, and worst value with its standers deviation and the median value is taken into consideration. Some of the hypothesis testings including the Wilcoxon rank-sum method and t-test are taken into consideration through which p-value and h-value can be determined. The computational times are also analyzed as best, average, and worst times of simulations.

The last chapter discusses the summary of the significant conclusions of that research work carried out by the preparation of the current thesis. The utilizations and contributions of CHHO, CSCA, hCHHO-SCA, and hCSMA-SCA both are represented as well as summarized adequately. Suggestions are given for further research which is also discussed in this chapter.

CHAPTER-2

LITERATURE REVIEW

2.1 INTRODUCTION

Profit based unit commitment has major concern due to deregulations and privatization of electricity. Transportation technology are causing serious health issues. The harmful gases produced through conventional vehicles. Profit based unit commitment problem is used to define the maximum profit for power units in economical way to satisfy the time varying power demand. Over the past some years, the profit based unit commitment issues have been involved so many number of researchers. In previous some years, researchers mostly worked with classical unit commitment problem. But now they are looking for something new methodologies to solve profit based unit commitment problem.

In the field of optimization, the research is increasing in rapid manner. The various new methodologies or techniques for different optimization issues are need to solve successfully. The research is going rapidly to develop hybrid combination of optimization algorithms to withstand with the drawbacks in existing methods. This chapter represents the literature review of different types of optimization methodologies those are able to solve the profit based unit commitment problems successfully.

The involvement of renewable energy sources increased the complexities of the PBUCP related issues. Also, including the charging and discharging of PEVs the complexities for PBUCP have been more increased with huge number of constraints. The selections and allocations of the power scheduling are more important things to increase the profit of generation companies.

2.2 REVIEW OF LITERATURE

In power system, the optimization is the huge research field where the research activities are applied to design various optimization techniques. The development of optimization methods have been done by many researchers to solve various problems in different field. So many researches are successfully going on to invent new optimizers, modified the existing algorithms with various techniques, i.e. chaotic and hybrid techniques to increase the efficiency of the existing optimizer. For real world issues the effectively implemented methods including PBUCP falls into few categories, i.e. conventional techniques, non-conventional techniques and hybrid techniques. In depth review of literatures has been discussed for the following sub-sections:

- A comprehensive review on PBUCP.
- A comprehensive review on PBUCP with renewable energy sources in summer and winter.
- A comprehensive review on PBUCP with considering the charging and discharging nature of PEVs/BEVs.

2.2.1 Comprehensive Review on Profit Based Unit Commitment Problem

The first research paper in area of PBUCP was implemented by R. Billinton *et al.* [7]. This research paper discussed about the maximum profit with satisfying the power demand. In the deregulated market, power sectors need to increase efficiency of production of electricity and distribution of electric power at low price with high quality and more reliable and provide security for product. Catalão *et al.* [8] have presented a multi-objective method to determine PBUC problem with struggle in profit in a competitive energy market and objectives of emission. This methodology can be tested on standard IEEE 30 bus system.

Chandram and Subrahmanyam [9] have invented a novel approaches to get solution over PBUCP by Muller Methodology (MM) that have two different steps. Firstly data was taken from the committed power generating units of a power plants. The power units which were committed, that had been taken into consideration. Secondly the problems related to ELD considering nonlinearity were resolved by

MM optimizer which had already tested over three to ten numbers of generating units in power system.

J. P. S. Catalão *et al.* [10] have discussed on PBUC in practical field with some limitations of emission due to fossil fuel in power plant. This methodology address the profitable market of power including emission in practically with the help of multi-objective optimization (MO) problem. So, between emission and profit, the trade curve was defined for profiles of different types of energy files. Delarue *et al.* [11] have invented a model associated with PBUC which had been utilized and developed by implementing Mixed Integer Linear Programming (MILP) to get expected profit in price based UCP when inappropriate price projection was applied. This technique was useful to find out the relation between Mean Absolute Percentage Error (MAPE) for price projection and profit or loss.

Columbus and Simon [12] have invented an algorithm based on a parallel artificial bee colony (PABC) using cluster of workstation to solve PBUC problem and maximize the profit. The effectiveness to use this method in power sector to compute the resources to reducing the complexity of time period for system use for large-scale power generation. Power systems ranging from 10 to 1000 generation units are tested for this technique to get the solution of quality and complexity of time with respect to number of the formation of cluster can be analyzed thoroughly.

Columbus and Sishaj Simon [13] have created parallel nodal ant colony optimization (PNACO) technique which follows the method of intelligences of ants which had used to develop resolution for non-committed power generating unit in the power plant. The problem including economic load dispatch which was followed by using parallel artificial bee colony (PABC) technique represents the behavior like bees and described a technique used to perform operation of parallel distribution for solving the problem of PBUC.

Vasiyullah *et al.* have discussed to solve PBUCP by using payment for electric power allocated technique and electricity delivered techniques [14]. It was examined on 3 unit test systems by maintaining only three constraints, such as, power balanced constraints, and spinning reserve and power limit constraints. In our proposed research was upgraded by all constraints including initial operating status of each units from small scale to large scale power sectors.

S. C. Selvi *et al.* have discussed about up-gradation of LR multiplication. LR with EP [15] which used to get solution of PBUCP. From the comparison of other research work to increase the profit in generation of electricity market, this study was done by including losses and it should be added the revenue of power. For real time operation in the market of power deregulation, forecasting of electricity market and PBUC problems are most important. D.S.H.T. Sreerengaraja have implemented SI method [16] with limits of production for solving PBUCP. This modified technique was used for controlling and modification purposes or sometimes replacements of generating units. For emission one of the vital contributions of greenhouse gases to the environment through increasing the usages of fossil fuel in power plants.

A review of Stochastic Optimization technique for unit commitment was constructed by Zheng *et al.* [17]. In industry of power sector the optimization technique had been broadly used to support the process of decision making for dispatch and scheduling the generation of electric power resources which was known as unit commitment which had two major types of innovations on research based on unit commitment and real time operations. Prakash and Yuvaraj [18] have designed a table based on IPPD to solve PBUCP. This methodology was verified on system of IEEE 30 bus through 6 numbers of power generating units.

Wang and Hobbs [19] have analyzed about hypothetical unit commitment in the market of real time for Flexi-ramp or ramp capability. This technique proposed about need for flexible generator due to increase in the penetration of renewable energy where Flexi-ramp was defined as the capacity of reserve committed unit to accommodate abrupt ramp. To get improved optimization technique while integrating large and complicated number of constraints including meet the load demand, limit of power generating, minimum up/down time plus spinning reserves.

Abdollahi and Moghaddam [20] have designed a program which include load management (LM) and its expansion and DRPs. This was separated into mainly two sections, such as incentive based programs (IBPs) with time-based rate (TBR). The model was derived on basis of price of elasticity demand and benefits of customer. A. Shukla *et al.* have implemented MDP-PSO technique which was designed to get solution over PBUCP. This method was divided into some kind of sub problems like interior and exterior including continuous and discrete nature, respectively. This methodology had an advantages to discover the maximum amount of profit in power sector almost how much amount of electricity can be taken into consideration for reserve and sale [21].

Singhal *et al.* [22] have presented a new method on DED and BFSA for increasing profit of the generation companies (GENCOs) to solve PBUCP consisting reserve capacity and electricity generate throughout the day in competitive power market. The effectiveness of validation of these techniques on 100-generating unit system and 10-generating unit system of thermal power plant in a whole day in power generation market for increase time of computation and the rate of profit of GENCOs. Venkatesan *et al.* [23] have implemented a new method to get solution on PBUCP using EA method on EPSO technique which had an operation depend on cost-saving. This technique was implemented an IBM PC through which in a reasonable time period large types of systems can proceed.

Morales-España *et al.* [24] have designed basic action in power based unit commitment of capabilities of quickly start and slow unit using some basic constraints for power generation limit minimum down-time and up-time, start-up and shut down of electric power. The schedule of power represents the step for energy schedule which leads unattainable delivery of electrical energy. The imperialist competitive algorithm (ICA) was used to solve PBUC problem in reorganizing energy market [25]. This technique was basically upgraded version of the evolutionary algorithm which reduces complexity in computation.

M. Jabbari Ghadi *et al.* have proposed imperialist competitive algorithm (ICA) based technique to solve PBUCP [26]. The main objective of this new technique was to decrease the complexity for computation and produced successively enhance convergence and optimum electricity generation for 10 unit and 100 unit by maintain generating units constraints and system constraints including ramp rate also. So, for the others generating unit need to be tested. Saravanan *et al.* [27] have implemented a technique which includes Some of the units in generating station have their convinced ranges where restricted operation was included limitations in component of machines and insecurity due to vibration occurred in shaft bearings or steam valve.

Wang *et al.* [28] have invented a new methodology for tackle some issues created by non-dispatch able generation of wind power including the reliable operation and considered a variation of wind including the robust unit commitment (RUC). The most common drawback for these kinds of dispatch which increased load demand on adaptability of resources which is also associated with cost. Thus, the requirement of ramp should be decreased and increased the capability of ramp-up for wind power generation and it also increased the profit which is gained by wind power generation by as long as capabilities of ramp-up with other services of auxiliary unit.

K. S. Reddy et al. have discussed about the solution quality [29] which was taken into consideration to deciding the status of commitment and make profit obtain by GENCOs. Nowadays in the market of deregulation there is freedom of GENCOs for generator scheduling based on profit in energy market. This methodology can be tested for the various reserve market participated scenarios of the unit system for thermal power plants. Adline Bikeri *et al.* have presented Evolutionary Particle Swarm Optimizer (EPSO) to solve PBUCP for 10-generating unit system in deregulated electricity markets [30]. All types of operational constraints were applied to get the better output and it also upgraded by Lagrange multipliers to achieve the profit of GENCO.

A. V. V Sudhakar *et al.* [31] have developed LR-DE algorithm used to solve PBUCP by using LR is used to get solution to the problem of UCP and the algorithm. Aghaei *et al.* [32] were designed a heuristic methodology on Wind-Thermal Unit Commitment of Bi-objective Probabilistic Risk-Based. To minimize the operational risk and cost this model was implemented using risk-based unit commitment model. A new formulated method, i.e., cycle-based unit commitment algorithm presented a new method of process of power re-dispatch to satisfy the ramp rate constraints including up-time and down-time [33].

A. Bikeri *et al.* have implemented Evolutionary Particle Swarm Optimization (EPSO) to solve PBUC problem [30] for maximum profit in the environment of deregulation and it's done by applying forecast demand of electrical energy and other additional services containing supply also. The design of these methodology shows for 10th units of thermal power plant with GENCOs that this implemented methodology should be performed for quality solution and characteristics of convergence which were superior to the algorithm based on classic PSO methodology.

Srikanth Reddy K *et al.* have developed Binary Grey Wolf Optimization algorithm to solve PBUCP [34]. In this research work had difference with respect of the transfer functions, i.e. tangent hyperbolic and sigmoid, which were used to estimate the real position of wolf into binary variables. The feasibility of the method was verified only two test system, such as, 3 and 10 power generating test units. The main objective of this research was increased difference between absolute total operating costs with revenue of GENCO in deregulated market. In this work included systems constraints along with initial status of the generating unit, ramp up-down constraints, minimum up-down time, and reserve and electricity generation limit of the power generating units. But for the medium and large scale power sector were not defined here. So, it need to take consideration to solve the PBUCP for medium and large scale power sector with maintaining all the constraints which describe thoroughly with commitment status in our proposed research work.

K Srikanth Reddy *et al.* have designed a new combination of Sine Cosine Algorithm with Binary Variant to get solution of applications and development of PBUCP under the several cases with payment developments [35]. Here in this paper the sigmoid transfer function was modified to map the binary continuous real value throughout the entire search space. And this specific technique was tested on 10-generating unit system by maintain all the constraints. But the feasibility for other generating units need to be tested in future.

A. Senthilvadivu *et al.* have implemented Exchange Market (EM) optimization method to solve PBUCP in an economical power market [36]. This technique had tested on IEEE 39 bus system to check its feasibility and it was compared with other techniques. The foremost objective functions for this research work were to get maximum rate of overall profit by reducing the emission. Here emission constraint was taken into concern with the constraints related with power balance, power limit constraint and minimum up-down time constraints. But for initial status of the unit were not taken into consideration which described by our research containing all the constraints not only for small scale power sector, but also large as well as medium types of power sectors and to reduce emissions, the impact of EVs are also discussed with RES in our research work.

Using algorithm of EM is used to solve the two major problems including reduction of emission of environment and maximize the profit. This access has more capability and stability to solve PBUC problem. After testing this methodology on testing system of 10 units within 24 h of IEEE 39 bus and its results are substantiated about the effectiveness of the methodology for the solution of constraints of emission PBUC in an ambitious market of electricity.

Srikanth Reddy K *et al.* have designed a new metaheuristic approach, i.e. BWOA to solve non-convex, binary-nature and complex constrained PBUCP in electricity market [37]. This research article presented three types of variations of BWOA tangential inversed, transfer function with sigmoid and hyperbolic. Here tangential inversed transfer function was effective to gain profit. The viability of the BWOA approaches was analyzed in test frameworks with various mechanisms available in electricity market, for example reserve and energy market, only-energy market cooperation with various reserve payments strategies.

Reddy *et al.* [38] have proposed a new technique in scheduling for generation in thermal power plants rigged with Amine-based post-combustion carbon capture technology, which develops the sensitivity of resource of coal and fuel used in fuel combustion or coal combustion through interpreted model for planning of operation the unit in thermal generators over unit commitment.

Anand *et al.* [39] have implemented a new integrated optimization process using civilized swarm optimization (CSO) and binary successive approach (BSA) procedure for solving the PBUC problem to get maximum profit which was obtained by GENCOs. PBUC problem deals with continuous and binary variables. These optimization techniques were tested on some system units including various types of operated constraints like minimum up and downtime, balance of load and ramp rate of the unit, etc.

Reddy K. *et al.* [37] [34] have presented binary whale optimization algorithm (BWOA) for solving no convex, complicated, complex, constrained and binary nature of problem of PBUC. The variants including hyperbolic tangential, sigmoid and inverse tangent transfer functions were introduced by BWOA which was tested by systems with various mechanisms of electricity market, i.e. a reserve and energy market and only energy market with different types of methods of reserve payment. The simulated outputs including quality of solution, consistency, and characteristics are compared and discussed with other approaches.

Senthilvadivu et al. [36] have constrained emission for PBUC which were defined as bi-objective function of optimization for transition of global warming and variation of climate in environment by emission of greenhouse gases from the unit of thermal power plant. K. S. Reddy *et al.* have implemented binary variant of sine cosine algorithm [35] to solve PBUC problem in competitive market of electricity. In a day, market of energy as well as reserve market by thermal unit scheduling and commitments of thermal units, the PBUC problem can be solved by GENCOs with aim of maximize profit for forecasts of load.

J. Olamaei *et al.* have implemented a heuristic algorithm [40] for optimization on environmental economic unit commitment for combined cooling, heat, and power (CCHP) thermal power system which is integrated with production unit of power to meet the market demand, traditional separate cooling and heating application for valve- point effect for turbine.

Yang *et al.* [41] have constructed a new method based on analysis of gap theory to appraise the strategy of operation of profitability for united power and heat units in a liberalistic market of electricity. The level of risk can be evaluated using this methodology which is taken into discussion whether there is any kind of risk arises for generating company. The sale price is taken into consideration of uncertainty when there is implemented some information about decision of gap theory to model its vaporization around predicted value. The brief review of aforesaid literature is presented in Table-2.1.

Table-2.1: Brief review on Profit Based Unit Commitment

Reference	**Year**	**Indexing of journal (Scopus/ SCI index etc.)**	**Conclusion or outcomes of relevant research works**	**Remarks**
[42]	2021	IEEE	The problem related with PBUCP were successfully solved by using the new integrated optimizer. This integrated optimizer is consisting of ISO based BDE and LBSO optimizer.	To validate the efficiency of the novel optimizer, the 10 unit system was taken into consideration.
[43]	2021	Science Citation Index	The concentrated solar unit and energy storage with compressed air were equipped with GENCOs to solve PBUCP.	Mixed-integer linear programming (MILP) was tested.
[44]	2021	Science Citation Index	The PBUCP related issues had been solved by considering the ramp constraints.	General algebraic modeling system (GAMS) was designed to solve.
[45]	2021	Science Citation Index	The multi objectives PBUCP issues were solved by BDE combined with local search optimizer.	Binary local search optimization (BLSO) algorithm was created by author to solve PBUCP.
[46]	2020	Science Citation Index	Price based unit commitment related problem had been taken into consideration. It helps to develop ecological smart cities.	A novel rapid transit system was implemented.
[47]	2019	Science Citation Index	The effectiveness of Binary Differential Evolution algorithm had been verified on PBUCP system with 10 gen unit, 40 gen unit and 100 gen unit over the time schedule.	Collection of records power demand and electric market value for 10th Gen. test system, 40th Gen. test system and 100th Gen. test systems
[48]	2019	UGC care	Hybrid GWO and Random Exploratory Search (RES) technique had been useful for PBUCP.	The proposed algorithm has been tested on IEEE Test units

				consisting 10-generating units and results has been discussed with the overall generation cost of those units.
[39]	2018	Science Citation Index expanded	Using hybrid optimization technique for PBUCP based on CSO and BSA method	society civilized algorithm (SCA) including (PSO)
[36]	2018	Scopus	Thinking about change emission and global warming in the struggle of power generation market used to take care of such problem including decrease environmental emission with continuous maximize the rate of profit	Exchange Market Algorithm (EMA)
[34]	2018	Science Citation Index	Another philosophy was developed to solve PBUCP using optimization method dependent on Binary whale to become the results as parallel for the problem related with PBUCP	Binary Whale Optimization Algorithm (BWOA)
[29]	2018	Science Citation Index expanded	Right now output including arrangement quality and consistency were contrasted and another approached utilizing nature roused Constrained optimizations and optimizations	Binary Grey Wolf Optimizer (BGWO)
[49]	2018	Scopus	This research paper choose about the profit of GENCOs with described the quality arrangements.	A Binary coded fireworks algorithm was used here.
[40]	2018	Scopus	An combined method used including manufacture of electricity in thermal-unit to meet the demand as well as useful for heating and separate cooling for valve-point effect.	CCHP including valve point effects
[37]	2017	Science Citation Index	Another application to take care of the issue of PBUC in serious electricity market of power by GENCOs including	BSCA was applied to solve PBUCP

		expanded	point of enlarge rate of profit for estimates load	
[30]	2017	Scopus	This approach appeared for 10th unit of intensity plant includes actualized the technique that should accomplished for quality prearrangement.	EPSO Algorithm was used to solve PBUCP.
[31]	2016	Science Citation Index expanded	For continuous activity for the power market of intensity deregulation, forecasting of power and PBUCP issues were taken.	LR- DE algorithm
[22]	2015	Scopus	The adequacy of the systems for 100 power generating units and 10 power generating units of thermal plant for unit in an entire day for increment the simulated time and the pace benefit for GENCOs.	BFSA and DED method
[21]	2015	Science Citation Index expanded	This methodology was intended to discover the greatest benefit in power advertise about how much power must be taken in available to be purchased and save	MDP-PSO
[23]	2015	Science Citation Index	This method was actualized an IBM PC through which in a sensible timespan an enormous sorts of framework can be continue	EPPSO Algorithm
[24]	2015	Scopus	This paper fundamentally examined about rapidly begin and moderate unit utilizing some essential limitations which helps in Power Scheduling and represent to the progression for plan for vitality to leads unreachable conveyance of electrical framework	Mixed-integer programming [MIP]
[25]	2015	Science Citation Index	This system was redesigned form for evolutionary optimization that lessen unpredictability in calculation to acquire arrangement in PBUCP	Imperialist Competitive Algorithm [ICA]
[50]	2016	Science Citation	Commitment of power generation including stochastic market prices	Collection of data about market price of

		Index		8 unit test system
[51]	2014	Science Citation Index	GENCOs planned generator to develop greatest revenue instead of get fulfillment in power demand	IPPD and genetic algorithm
[52]	2014	Scopus	Here PBUCP in deregulate power market in segment of intensity framework to expand proficiency of creation of power and conveyance of electricity force in little cost include higher caliber with increasingly dependable that give security to item.	Dynamic Programming (DP)
[16]	2013	Science Citation Index	This changed strategies used to control and adjust reason or some of the time substitutions of units which likewise utilized for emission in one of the radiation to nature through expanding the utilizations of fossil fuel	Swarm Intelligence
[13]	2013	Scopus	The proposed system represented to the conduct like honey bees and depicted a procedure use to perform activity of equal dissemination	PNACO
[15]	2013	Science Citation Index	Right now the correlation of additional research effort to build benefit in electricity generation in power market.	LR-EP
[15]	2013	Scopus	Integrating gradient search [IGS], ANN and logistic regression had been implemented to solve PBUCP	Collection of data for market price of 3 generation unit test system

2.2.2 Profit Based Unit Commitment with Renewable Energy Sources: A Comprehensive Review

The PBUCP with system constraints limitations can be proposed to encourage high entrance level of RES assets and PEVs. This might be demonstrated to solve PBUCP in our research work by proper constraints handling strategies including RES and charging and discharging nature of PEVs/BEVs with novel methaheristics search optimization technique.

Tomonobu Senjyu et al. proposed a new method using Genetic Algorithm Operated PSO to solve the thermal UCP considering wind and solar energy system. This method was able to minimize production cost and produce high quality solutions [53]. K. Chandrasekaran et al. proposed FF algorithm to get solution of the SUC problem for thermal /solar power sector considering issues regarding smart grid. The research paper included some critical review on reliable impacts of major resources of smart grid considering demand response (DR) and solar energy. Thus it was essential to implement method for an integration of thermal and solar generating system [54].

K. Srikanth Reddy et al. formulated a scheduling issue accommodating in power market support of solar-and wind based independent power producers (IPPs) treating both ordinary and Renewable Energy Technologies (RETs) as indistinguishable elements [55]. The main objective was reduction of total production price for the electricity generating unit and this paper also explained the variances by considering solar energy and non-considering the solar power [5]. Saleh Y. Abujarad et al. discussed a review on current methods for commitment of generating unit in existence of irregular renewable energy resource [56]. Hao Quan et al. proposed a comparative review on integrated renewable energy generation uncertainties which were captured by list of prediction intervals, into stochastic unit commitment considering reserve and risk [57].

Kai Ma et al. discussed about appliances scheduling via cooperative multi-swarm PSO under Photovoltaic (PV) Generation and Day-Ahead Prices. This research work studied about the problem including scheduling appliances in residential system unit. The model of an appliance-scheduling was established for home energy management system which was based on day-ahead electricity price and PV generation [4]. A.V.V. Sudhakar et al. designed a new hybrid LR with DE optimization technique to solve the PBUCP and Secant method was used to solve economic load dispatch (ELD) problems [31]. The suggested technique was verified on 3 unit, 10 unit and 20 unit test system. The research included some constraints, such as, electricity demand, the maximum as well as minimum amount of capacity of the generators, reserve capacity and constraints related with minimum down time as well as up time. But this research unable to described or solved the PBUCP optimization problem for large scale power sector which are tested in our proposed research work with a novel hybrid optimization technique.

K. Selvakumar et al. implemented a new strategy to solve UCP for power generation units with thermal plants integrated with solar energy system. There would be changes in the cost of power generation considered solar energy. Maryam Shahbazitabar and Hamdi Abdi were implemented a new priority-based stochastic unit commitment as parking lot cooperation and renewable energy sources. This paper discussed about the fastest nature of heuristic method which was established on list of priority selections to get solution for stochastic nature of the problem related with unit commitment and useful this to simple 10 unit system where the study was addition considering electrical vehicles parking allocation considering wind farm and solar farm over 24 hour time horizon [58].

Faisal Rahiman Pazheri et al. presented Scheduling of power station with energy storage facility. Utilities of power are stimulated by converting the present conventional power plant into hybrid power plant by install available energy storage facilities and renewable electric power unit to come across the sudden increase the power demand. Facility of energy storage maintain a level of the penetration of renewable power to 10% of required load demand throughout the period of operation for hybrid power plant [59].

Jasmin.E.A. et al. implemented an optimization technique about Reinforcement Learning to solve unit commitment problem considering photovoltaic sources. For stochastic behavior of the associated power and solar irradiance, the arrangement of the different types of power generating sources considering solar energy turned to be an optimization problem stochastic in nature. This paper discussed about the optimization technique, reinforcement learning that can provide uncertainty of the environment of the nature which is very effective [6] . Saniya Maghsudlu and Sirus Mohammadi were proposed a method to solve the problem in optimum scheduled of commitment unit as appropriate control of EVs and PV uncertainty. The meta-heuristic approach, Cuckoo search algorithm was developed by greatest convergence speed to attain the optimal solution and get solution of UCP. The research discussed about case study of IEEE 10 unit system which was used to examine the impact of PV and PEVs on scheduling of generating unit [60].

Moreover, constraints relating to curtailments of penetration and abridgements of RETs were rebuilt. Furthermore, a suitable objective function for profit brought about by conventional asset IPPs over reserve markets support as renewable energy curtailment power decreased. The proposed idea was simulated with a test framework containing ten conventional power generating units related with wind energy generators (WEG) and Solar Powered photovoltaic (SPV). But using this methodology, the reliability parameter was affected. So there are a huge gap in research, i.e. how to maintain the proper parameter. In our proposed research work describes the maintaining constraints and maximize the profit by maintain the proper scheduling all over the day considering RES in summer and winter session. Jatinder Singh Dhaliwal et al. represented a memetic approach by combining Binary Differential Evolution (BDE) with Binary Hill-Climbing (BHC) optimization technique to solve PBUCP [47].

The Literature survey of Unit Commitment are listed on Table-2.2a. Table-2.2b and Table-2.2c shows the survey of wind power uncertainty and survey of Solar Uncertainty respectively.

Table-2.2a: Brief review on Unit Commitment Problem

Reference	Methods	Year	Conclusion or outcomes of relevant research works
[61]	ANFS	2021	This novel method was designed to solve uncertainty of load and autocorrect as well as auto detection of falsification of data.
[62]	MFO-HHO	2021	The new technique was implemented to maintain control over Multi area frequency with multi source in power industries.
[63]	PEM	2021	Standard 33 bus test system was used to test the feasibility of the novel technique. To get solutions with PV system correlated with POPF issues which was highlighted here, i.e. verified with Monte Carlo Simulation (MCS) technique.
[64]	BFO	2021	Standard IEEE 3 unit bus, 6 unit bus and the 10 units' bus systems were tested by considering RES and transmission

			losses to solve ELD problems in power sector.
[65]	BAMFO	2021	The novel technique was created to get short term schedule for operational units by attaining the specific unit constraints.
[66]	GA	2020	This new method was implemented for get solution over optimal energy scheduling in power sector.
[67]	WMA	2020	This novel bio inspired technique was invented to get solution on ELD issues. And comparison about this is discussed in this research work.
[68]	WOA	2020	The new method was designed and tested on IEEE-30 standard, IEEE-57 standard and practical 75-bus test systems to solve its bidding issues.
[69]	Hybrid technique	2019	Near introductions on some benchmark functions were investigated
[70]	PSO	2019	IEEE-9 bus system was applied to analyze the capacity of power generation technique about various goals
[71]	SCA	2019	Small, medium and large unit test systems were implemented to get solution over UCP related problems
[72]	FQIBGWO	2019	FQIBGWO method was designed to solve UCP related issues
[73]	DA-PSO	2019	An Better DA-PSO method was used to resolve UCP and the 5^{th} -, 6^{th} -, 10^{th} -, and 26^{th} power units test system which were were useful to check the effectiveness of the recommended research
[74]	hGWO-RES	2018	Hybrid GWO joined with RES method which was considered to resolve UCP as well as it had been verified on standard 23 benchmarks and 7^{th} -, 10^{th} -, 19^{th} -, 20^{th} - and 40^{th} -test systems were taken to authenticate the efficiency of the intended method
[75]	GSA	2017	GSA was planned to resolve UCP besides the feasibility of the recommended technique was verified on 10 unit system future extended up to 40 unit system with 24 hours’ time prospect
[76]	SFLA	2016	SFLA was produced for small duration optimal schedule of thermal generation units counting prohibited Operational zone (poz) constraints as well as emission restraint
[77]	resolve the UCP	2016	4, 10, 20, 40, 80, 100 test systems which were useful to check usefulness of this work
[27]	FA	2016	10 units as 24 hours assessment system was recycled to check the usefulness of this research

[78]	HS	2016	The recommended memetic technique was confirmed for standards IEEE benchmarks comprising of 4th , 10th , 20th and 40th power unit
[79]	WIC-PSO	2016	WIC-PSO was planned to resolve UCP and usefulness and feasibility of the recommended method which were proved on scheme as besides not including extra pumped storage plant.
[80]	HN-BBs	2015	This method was valuable to decrease entire functioning price and achievement total profit. Here 12 situations had been restrained in the being of battery bank as well as without them in 2 working modes: stand-alone mode and grid-connected mode
[78]	hHS-RES	2015	The novel search method was developed to resolution of single-area UCP and the recommended technique had been confirmed on standards IEEE systems enclosing of 4th, 10th, 20th and 40th units to test the usefulness of the method.
[78]	DR	2015	Demand Response Based approach including ramp rate constraints was designed to solve large scale UCP
[81]	hDE-RS	2015	A hybrid DE–RS optimization technique was designed to solve unit commitment problem and it was tested on IEEE benchmark systems consisting of 4 unit, 10 unit, 20th and 40th test systems.
[82]	hybrid PSO–GWO	2015	A new hybrid PSO–GWO method was implemented to solve UCP and it was tested on 30-bus system, 14-bus system and 10th power generation model
[83]	-	2015	56 MW 1 gas turbine and 1 steam turbine, 2L 2 gas turbines, 530 MW and 1 steam turbine and 530 MW, 1 steam turbine and 3LR—2 gas turbines were considered to examination the viability of the research
[83]	DPSs-IRESs	2015	10th power gen. unit was considered to checked the efficacy of the research
[84]	FCCP	2015	3rd and 8th gen. units were considered to check the efficacy of the research has taken the wind power predicting errors.
[85]	BABCA	2015	10,20,30,40,60,80,100 unit system were applied to check effectiveness of research work
[86]	ISFLA	2014	Improved Shuffled Frog Leaping procedure was considered to solve UCP considering a constrained including multi objective combined emission

[87]	BGSA	2014	To authenticate the viability and efficacy of the submitted method (BGSA) to solve UCP, the suggested BGSA was verified on dissimilar systems size created on basic systems of 10^{th} gen. unit, 20^{th} , 40^{th} , 60^{th} , 80^{th} and 100^{th} gen. unit
[87]	QBGSA	2014	Model of thermal UCP with wind power addition was recognized and constrain programming was useful to mimic the special belongings of wind power variation.
[88]	DT	2014	Validate the ability of used the algorithm to solve the UCP, it was applied on a 10-, 20-, 40-, 60-, 80- and 100 unit systems
[89]	CSA	2013	Cuckoo Search Algorithm was implemented to solve UCP and model power system including 10 power plant with generating units had been used in this study
[90]	MOGA	2013	Classical model of the Dynamic Combined Economic–environmental was implemented for optimum power generation scheduling in the electricity market with consideration of availability of power generation units
[91]	VNS	2012	10,20,40,60,80,100 unit test system were used
[92]	SFL	2012	Shuffled Frog Leaping Algorithm was designed to solve UCP. To validate the enactment of the suggested method was useful for standard IEEE 14-, 30-, 56-, 118- slandered bus and 10^{th} gen. test unit, 20^{th} gen. test unit for 1 day forecast period

Table-2.2b: Brief review on wind power uncertainty and UCP

Refer ence	**Year**	**Indexing of journal (Scopus/ SCI index etc.)**	**Conclusion or outcomes of relevant research works**	**Remarks**
[93]	2018	Scopus	Multi objective GA method was invented to find optimal solution for UCP including lowest emission.	Multi objective GA was used and data regarding load demand considering renewable energy schedule are collected from the proposed research work.
[94]	2018	Science Citation Index	FCUCP technique was designed to solve UCP considering wind power generation including ramp limit	Frequency-Constrained Unit Commitment Problem [FCUCP] was used to solve UCP and Forecast wind power data are collected for day ahead

[95]	2018	Science Citation Index expanded	ABC-CSA for cost assessment considering wind power were implemented and the effectiveness had been tested in IEEE 30 buses of six generator test systems with 10 generating unit test systems	Artificial Bee Colony and Cuckoo Search Algorithm [ABC-CSA] were applied and cost estimated data was collected
[96]	2016	Scopus	MTLBO technique was invented to solve UCP by using standard IEEE ten-unit test system and 26-unit reliability test system	Modified Teaching–Learning-Based Optimization algorithm [MTLBO]
[97]	2016	Science Citation Index expanded	MDE method was useful to solve unit commitment problematic considering impact of plug-in EVs	Modified Differential Evolution [MDE]
[98]	2016	Science Citation Index	BASA technique was implemented to solve unit commitment problem including renewable energy sources and hydro electric energy pump storage	BASA was used and data of forecasted wind power and photovoltaic power has been collected from the proposed research work
[99]	2016	Scopus	IEEE 118-bus test system with 54 power generating units used to validate the proposed method	Artificial Computational Intelligence [ACI] was used
[100]	2015	Science Citation Index	The proposed research work had been implemented about the collective and individual impact of 3 DERs, including generation for wind power, EDRP and PEV on unit commitment.	Data regarding energy price and hourly electricity demand considering hourly electric vehicle power in charging and discharging mode were collected
[101]	2015	Scopus	A fuzzy technique was used to solve UCP has taken load demand retort, EVs and wind power	Data collection for load demand considering wind power
[102]	2015	Science Citation Index	The proposed research work was implemented to find out the PDF of a resolute commitment of power generators or not.	Priority List (PL) method
[103]	2014	Science Citation Index	The proposed research method was used to solve UCP including pumped hydro energy storage and wind power	Constraints of pumped storage power plant were collected

[87]	2014	Science Citation Index	To authenticate the viability and efficacy of the submitted method (BGSA) to solve UCP, the recommended method was verified on various system	BGSA with the Lambda-Iteration method was applied and the data regarding system load and wind power prediction were collected
[104]	2013	Scopus	LR- PSO Method was designed to solve scheduling of power generation problem for thermal, wind-solar system for deregulated electrical power system	LR- PSO Method

Table-2.2c: Brief review on of solar uncertainty for UCP

Reference	**Year**	**Indexing of journal (Scopus/ SCI index etc.)**	**Conclusion or outcomes of relevant research works**	**Remarks**
[105]	2021	Scopus	The stochastic nature of UCP had been maintained by using a novel optimization technique for large scale power sector. The new optimizer can optimize under the uncertainties also.	Updated modern optimization algorithm with stochastic programming were taken into consideration. The Demonstration of the efficiency of the new technique on TAMU Texas 7K synthetic power transmission networks, leveraging accurate high-resolutions forecast based upon NREL renewable resources obtainability data.
[43]	2021	Science Citation Index	Concentrated solar unit and air compressed energy storage units were associated with GENCOs to solve PBUCP. The profitability had been measured for day-ahead scenario in electricity market.	Conventional thermal power plants were connected with concentrated solar power as well as air compressed energy storage units.
[106]	2021	Scopus	The new optimizer, i.e. modified version of GWO were used to solve UCP considering the uncertainty of the environment. The efficiency of the new MGWO optimizer was tested and it was performing better than the classical optimization	MGWO methods had been implemented to solve UCP related issues. The output of the results were compared with classical GWO and PSO. The 10 –thermal units were taken into consideration to solve the problem.

			techniques.	
[107]	2021	IEEE	The size of power storage units was implemented for UCP related issues. The renewable energy was also taken into consideration.	Economic values for power storage units had been taken into consideration. IEEE 118 and IEEE 9 bus systems were taken into considerations.
[108]	2021	Scopus	Modified HHO techniques had been implemented to solve UCP considering solar power energy in summer and winter.	The 4^{th}, 5^{th}, 6^{th}, 7^{th}, 10^{th}, 19^{th}, 20^{th}, 40^{th} and 60^{th} unit test systems were used to validate the efficacy of the proposed optimization method.
[60]	2018	Science Citation Index	Optimum scheduling for unit commitment problem considering photovoltaic insecurity and suitable power of EVs and output showed the reduction of production cost and improved load flow.	Collection of data regarding hourly evidence of solar power on the day of summer and winter day. Also collected data for UC without PV, UC with PV and PEV, PEV and UC with PEV.
[58]	2018	Science Citation Index	Priority-based method was designed to solve stochastic UCP considering parking lot cooperation and renewable energy sources	Priority-based method
[59]	2018	Scopus	Dynamic programming technique was used to discover realistic conditions of power generating units, while consecutive quadratic programming algorithm was applied for ELD of committed gen. units	Energy storage facilities [ESF]
[4]	2017	Science Citation Index	Cooperative Multi-Swarm PSO was used to solve UCP under Photovoltaic Generation including day-ahead prices	Cooperative Multi-Swarm PSO
[57]	2016	Science Citation Index	Addition of renewable energy, power generation indecisions into stochastic nature of unit commitment considering risk and reserve	SCUC
[56]	2016	Science Citation Index	The proposed method was invented to solve UCP considering presence of discontinuous renewable energy resources	Proposed research work helps to gain knowledge about the benefits of the present methodologies avoiding the obtainable weaknesses
			Proposed research work was	Collection of data regarding

[5]	2016	Science Citation Index expanded	designed to solve UCP considering solar power system. IEEE 39 bus system and forecasted solar radiation with 24 hour load demand had been taken to validate	solar irradiance data for 150 MW power plant
[6]	2015	Scopus	The proposed research work was based on function approximation methodology of reinforcement learning to solve UCP with photovoltaic energy sources	The research work proposed a Neural Network based Reinforcement Learning method [NNRL]
[84]	2015	Science Citation Index	10^{th} generating power systems unit was applied to check the efficacy of the research	A whole computational outline of addition considering quantification of vacillations in DPSs with IRESs
[109]	2014	Science Citation Index	BRCFF technique was implemented to solve security-constrained UCP considering solar power	Binary Real Coded Firefly (BRCFF)
[53]	2008	Scopus	GA functioned PSO method was designed to solve UCP considering wind and solar Energy Systems	[GA-PSO] Genetic Algorithm operated Particle Swarm Optimization

2.2.3 Profit Based Unit Commitment with Electric Vehicles: A Comprehensive Review

Pengcheng You et al. [110] discussed about a new method of cooperative strategy of charging for EV through smart charging station in dynamic type of electricity pricing market. Mixed integer linear program (MILP) is formulated for the scheduling problem to capture the nature of battery including charging and discharging. Ning Zhang et al. [101] designed a new method including fuzzy chance-constrained program to solve the UC problem considering wind power, EVs and demand response. The other existing optimization techniques has good development prospect, but their research are still at initial condition and included so many problems which need be solved or other instance there are several uncertainties, such as, how to adequately stay away from nearby or local optimum.

P. Goyal et al. [111] explained that in smart grid framework, EVs are integrated part. This paper is included with the scheduling problem of charging the PEVs considering changing of load and electricity tariff throughout the day. This is important for efficient integration of such kind of units which can provide regulated services to power grid and applied the scheme for the service to compensate EVs through an aggregator. The EV can additionally add to the vehicles to household, vehicle to network kind of connection which can decrease the electric payments with their reciprocal electricity transaction [112].

Shalini Pal and Rajesh Kumar [112] presented a new strategy of scheduling EVs in the program of response for electricity demand with neighbour connection. A complete structure is designed including transactions of energy capacity of household consumer and invented a household model including some appliances which are shiftable and non-shiftable. M. Hadi Amini et al.[113] implemented a new methodology based on Charging Strategyof Hierarchical Electric Vehicle aggregator by Dantzig-Wolfe Decomposition (DWD) which is used to solve the problem including formulated in linear programming. In this paper authors assumed that EVs are not able to add power to system that means here unidirectional charging is measured for 100-1000 EVs and its efficiency is estimated using a charging aggregator for this system.

Vishu Gupta et al. [114] presented a new charging scheme for scheduling based on multi aggregator having situations based on realistic and charging included incorporative collaboration with charges for cancelation and variable energy purchase (VEP). In practical situation using VEP, the authors came to know where the aggregator purchase energy which was based on the request for average scheduling per day, which addressed the problem about scheduling of charging from the point of aggregator which maximize the number of scheduled EVs and the total profit.

This research investigated the optimum energy management's issues of RMG in presence of BEVs/PEVs [115]. RMG taken incentives from owner of BEVs/PEVs to participate in load demand response (DR) program which could bring benefit for both owners RMG and PEVs. Here, in our proposed research work includes optimum scheduling with profit based unit commitment including uncertainty of renewable energy sources and the impact of EVs for summer time as well as winter time.

Maghsudlu S. and Mohammadi S. [60] developed a new method about renewable energy producer for the problem of scheduling present in UC. To solve the UC problem, a Meta heuristic algorithm with the speed of high convergence is used name as Cuckoo search algorithm. IEEE 10 unit system is engaged to examine the impact of PEVs scheduling. This paper presented the work of vehicle-to-Grid (V2G) framework for security-constrained unit commitment problem (SCUCP) [116]. SCUC had increased exceptional consideration from specialists in the field of electricity generation scheduling, expecting to decide the power generation plan in which the system administrator augments the system security and limits the power generation costs, while fulfilling the system and units' constraints.

The objective functions included opportunity and robustness for considering uncertainty related with electric power consumptions of BEVs/PHEVs, whereas the objective function of the proposed research work is to maximize the profit by minimizing the total operating cost with maintain the unit constraints with consideration of charging/discharging nature of BEVs/PEVs. Another technique, i.e. RMG (Renewable Energy Sources based Micro Grid) had been furnished with a parking garage to aggregate and control BEVs/PEVs. Another research paper designed a new optimization technique i.e. Field Programming Gate Array (FPGA) [117]. A new algorithm is suggested for solving the MILP using Benders decomposition and dual decomposition. A new Priority Based Stochastic UCP solved by considering parking area cooperation and impact of RES [58].

This research discussed about optimum scheduling for UCP including uncertainty of PV and reasonable intensity of electric vehicle [60]. A new hybrid optimization strategy was used to solve mixed integer UCP integrated with PEVs [41], in another research, Security Constrained UCP solved only consideration of the wind power generation [118], whereas our proposed research is more efficient to solve this kind of problem with maximize the profit, minimize the fuel cost and limit the constraints and maintain the time varying load demand by consideration the impact of EVs.

Mixed integer linear programming was used to solve the problem. Moreover in another research work was implemented a new model which consider the uncertainty related with the electric power utilization of BEVs/PEVs using IGDT (Information Gap Decision Theory) to make the proper decisions about optimal operations [119].

Zhile Yang et al. [41] implemented Meta heuristic hybrid method to solve UC problem including mixed integer problem in optimization integrated with PEVs.10 unit of power system is taken into consideration with 50,000 PEVs to find the impact of transfer function which is utilized for binary optimization to solve the integrated problem based on UC and PEVs. The most significant issues is that it comes up short on a bound together and complete hypothetical framework. So, using this novel proposed methodology, those problems are easily solved.

S. F. Syed Vasiyullah et al. presented model of Market Clearing Price (MCP) to solve PBUC problem [120]. The other contribution of this paper was a newly combined methodology, i.e. Analytical Hierarchy technique (AHP) with Improved Pre-prepared Power Demand (IPPD) table had used to solve the optimal scheduling including smart grid environmental aspects. The PBUC approach accomplished high benefit of GENCOs in a Day ahead planning on account of its serious nature when contrasted with CBUC approach. However less emission were not thoroughly descried and how much cost can be saved by GENCO were less described. Electric Vehicle batteries have enormous size and high mass because of which it requires some investment to charge completely. So it is important to focus much more in that case. Smart grid operations were taken into consideration for demand response program in domestic purpose which had been highlighted now a days. This research presented main framework of domestic users which was able to power transaction among load serving and consumers entity. Analytical Hierarchy Process based optimal scheduling was implemented to solve PBUCP problem with EVs and renewable energy in power sectors [120]. Table-2.3 shows some brief review of literature on PEVs/BEVs.

Table-2.3: A brief review on PEVs/BEVs

Reference	Year	Conclusion or outcomes of relevant research works	Technique
[121]	2021	This novel technique was designed to forecast electric vehicle speed and maintained the accuracy of that vehicle.	LSTM
[122]	2021	This new methodology was invented to get solution by increasing the rate of learning for better solution as well as no stationary internal noise of PEVs.	ALRT-CNNs

[123]	2021	The new method was implemented to get routes order as well as proper information about battery recharging or charging station of electric vehicles.	GA
[124]	2021	This method was designed for management of energy in multi objective purpose for HEVs to maintain the energy saving and increase the efficiency of electricity.	NSGA-II
[125]	2021	The new technique was implemented to solve dispatch of emission as well as dynamic nature in economic schedule in electricity market considering impact of PEVs/BEVs/HEVs.	CSA
[126]	2021	The novel method was designed for cooling purpose and controlling the temperature error of EVs to maintain the evaporator.	IMPC
[127]	2021	This research was implement new method to control the charging of EVs in smart grid purpose.	ACC
[128]	2021	The new strategy was developed for power industries to get the charging nature with proper estimation of EVs a day ahead.	FCR
[129]	2020	This new technique was designed to decrease the maintenance cost for electric sector as well as evaluated and handled the uncertainty of the wind power.	IGDT
[130]	2020	This research work discussed with the flexibility of electricity in power industries for Norwegian region.	EV
[131]	2019	IWOA method was implemented to resolve the problem involved Finding EVs charging station through service ability	IWOA
[41]	2019	A binary symmetric based hybrid meta-heuristic strategy was intended to take care of blended whole number unit commitment problem coordinating with critical module electric vehicles	PEV
[60]	2018	Optimal scheduling for UCP seeing photovoltaic uncertainty and appropriate control of PEVs as well as productivity presented the decrease of manufacture costs and better power flow.	UCP-PEV-RES
[114]	2017	Multi-aggregator cooperative charging Schedule for EVs and more prominent number of EVs were scheduled through joint effort	-

[132]	2017	Hybrid Optimization Algorithm was used for Ideal Forecasting of PEVs Charging Stations at the Distributed Systems	HOA
[133]	2017	The research paper was based on review of charging system for EVs using solar power	PEV
[133]	2017	The research paper was based on review of charging system for EVs using solar power	PEV
[113]	2017	Dantzig-Wolfe Decomposition technique was used as charging aggregator strategy for EVs.	DWD
[112]	2017	Scheduling Strategy of EVs in housing demand reaction curriculums considering neighbor connection	EV
[111]	2016	Aggregator and customer balanced the charging scheduling of EVs considering the impact in smart grid	-
[97]	2016	MDE method was useful to get solution for UCP as the impact of PEVs	MDE
[134]	2016	Swarm Intelligence Techniques were used to find out the optimum power distribution outline for PHEVs.	SIT
[135]	2015	Demonstrating of market diffusion of EVs including driving data – German market	EV-real data
[136]	2015	The proposed research work was based on some novel strategies for rise the cost benefit of EVs by decreasing its remuneration time by discovering probability of vehicle to home (V2H) outline and to rise readiness to recompense of the purchaser.	Penetration Level of EV
[100]	2015	The proposed research work had been implemented about the collective and individual impact of 3 distributed energy resources (DERs).	DERs
[137]	2014	Case studies were done for Brazil and India about Exhaust emissions of transit buses uses of EVs.	-
[138]	2014	Impending profits of EVs arrangement as receptive reserve in unit commitment	EV
[101]	2014	A fuzzy technique was used to solve UCP considering PEVs, wind power reaction and load demand response.	Wind power
[139]	2013	Proposed work was used to predict the influence of EVs in Indian grid which permit the improved preparation of fresh infrastructure on distribution & generation	EV

[140]	2012	Influences of charging of EVs in electricity market operations	EVs charging
[141]	2011	Control Strategies were discussed for EVs and studied for better strategy which was further appropriate to Exploit the performance of Plug-in HEVs.	Control Strategies for EVs.
[142]	2011	Assessment of vitality desires for all-electrical variety of PEVs/HEVs/BEVs two-wheeler	PEVs/HEVs/BEVs two-wheeler
[143]	2010	Effect of EVs on power grid excellence and regulating the schedule for charging to moderate voltage inequity and decrease power losses.	Maintain losses and Grid Power Quality

2.2.4 Metaheuristics Optimization Techniques: A Comprehensive Review

In the field of research area, the optimization method is the vastest region of research through which the research works are effectively moving forward. Now a days, researchers are working with multiple works for various problems using different techniques and they are capable to measure the output successfully. To discover the new algorithms, the research work is successfully running condition and to mitigate the drawbacks of present existing techniques. In this paper the literature survey is discussed some tabular form for different area of research where Table-2.4 shows the assessment of several heuristics and meta-heuristics search optimization techniques.

Table-2.4: Assessment of several recent heuristics and meta-heuristics search optimization techniques

Conclusion or outcomes of relevant research works	**Reference. No**	**Name of the optimizer**	**Publication's year**
BEPO method was designed to solve optimization problems with automatically features assortment technique. To validate the efficiency of the method, the 25 standard benchmarks were used.	[144]	BEPO	2021
BMRFO technique was implemented to get solution over feature selections issues. The efficacy of this novel method was tested on 18 dataset of standard functions.	[145]	BMRFO	2021

BSO optimizer was established to solve the problem related to optimization with damage detection of structure as well as it was used to identify the data related with noisy contaminated.	[146]	BSO	2021
DSSA technique was designed to get the solution over optimization related issues. With this method, the exploitation phases were improved to find the better optimal point within the search space.	[147]	DSSA	2021
EOA method was implemented to solve the issues in power distributed network reconfigurations and generated electricity allocated in distribution systems.	[148]	EOA	2021
GEPSO optimizer was designed to get solution over optimization related problems in local as well as global search space. To verify its efficacy, this method was tested over several well-known standard benchmark functions.	[149]	GEPSO	2021
HHGSO was designed to solve the optimization related issues and this technique was used to improve the phase of exploitations over the search space.	[150]	HHGSO	2021
HLBDA was implemented to get solution over feature selections in the area of optimization. A case study was related with COVID-19, which is discussed in this research work.	[151]	HLBDA	2021
A novel IJOA-LV method was designed to get solution over existing swarm optimizer and the viability of this technique was tested over CEC 2011 and CEC 2014 standard functions.	[152]	IJOA-LV	2021
IS-JAYA technique was implemented to solve optimization problem as well as exploitation and exploration in the search space.	[153]	IS-JAYA	2021
MOMBO method was designed to get solution on cost focused on balancing problem associated with robots.	[154]	MOMBO	2021
NWOA method was implemented to solve optimization	[155]	NWOA	2021

issues and 25 standard benchmarks were used to test the feasibility of the technique.			
OOBL optimizer was designed to solve engineering optimization problems. 23 standard benchmarks were used to check the efficiency of this optimizer.	[156]	OOBL	2021
RPBMO was implemented to get solution on multilevel features selections issues.	[157]	RPBMO	2021
SChoA method was designed to solve engineering design optimization problem.	[158]	SChoA	2021
SHSLTLBO technique was implemented to get solution in optimization related problem and it also improved the exploration as well as exploitation in the search space.	[159]	SHSLTLB O	2021
MFO-SVM method was designed to get solution over optimization problem with related to forecasting in rate of advancement of TBM.	[160]	MFO-SVM	2021
m-GWO optimizer was designed to get suitable balanced between exploration and exploitation phases. It was tested on IEEE CEC 2017 and IEEE CEC 2014 standard functions. And it also verified on multilevel thresholding problems in real world as well as Eng. Design problems.	[161]	m-GWO	2020
MG-SCA technique was implemented to solve optimizations problem which was verified upon standard IEEE CEC 2014 benchmark function to check the efficiency of this algorithm.	[162]	MG-SCA	2020
OAGO method had been implemented to get the solution over real world optimization issues which was verified over 30 IEEE CEC2017 standard test problems to find out the efficacy of this newly method.	[163]	OAGO	2020
A newly made optimizer was designed to get solution over standard engineering problems including CEC 2015 benchmarks with statistically analyzer and Wilcoxon's test	[164]	SFOA	2020

This hybrid method was implemented to get solution of such kind of problems over global optimization.	[165]	HC-PSOGWO	2020
ICLBO had been developed to get solution over such kind of problem related with engineering design.	[166]	ICLBO	2020
BMO was implemented to get solution over such kind of problem related with engineering design.	[167]	BMO	2020
EO method was created to get the solution over real world issues in optimization area and it was verified over 58 types of various benchmarks including uni-modal, multi- modal and composite standards function as well as three kinds of engineering problems.	[168]	EO	2020
IFDOA technique was developed and verified over CEC 2019 test system to check its viability to withstand with real world issues.	[169]	IFDOA	2020
SHO optimizer was one of the most important swarm based technique to get solution over optimizations related issues by execute its novel exploratory search technique.	[170]	SHO	2020
IWOA was implemented by expending the new tool of the joint search technique to get the solution over optimization problem towards global search regions.	[171]	IWOA	2020
MSESCA had been designed to get solution over engineering optimization issues in real world as well as developed the optimization method in global regions.	[172]	MSESCA	2020
RSHO was implemented and verified to get the solution over various optimization issues in global level.	[173]	RSHO	2020
IHHO had been designed by combination of SCA as well as HHO methods to solve engineering and numerical issues in optimization field.	[174]	IHHO	2020
GLF–GWO was implemented with leadership based quality to get solution over global optimizations issue. The leadership quality was improved by Levy-flight (LF)	[175]	GLF–GWO	2019

searching techniques. It was verified on standard benchmark with IEEE CEC 2006 as well as IEEE CEC 2014.			
GWO optimizer had been modified with DE to avoid trapped in local optima and solve optimization problems. It remained proved on 23 kinds of standard functions.	[176]	gDE-GWO	2019
AEBO was designed to solve unidentified space of region over the entire search space.	[177]	AEBO	2019
I-GWO & Ex-GWO novel methods were developed which is an updated form of GWO technique to resolve optimization issues in global region.	[178]	I-GWO & Ex-GWO	2019
LCBO technique was applied to solve the difficulties related with optimizations area and it had been verified over six numbers of CEC 2005 benchmarks.	[179]	LCBO	2019
MHTSA was designed to resolve the issues related with engineering problems.	[180]	MHTSA	2019
SSSA had been developed to get solution over optimization related issues as well as tested upon 23 types of standard problems to verify its efficacy.	[181]	SSSA	2019
SA-DABC technique was implemented and verified over 28 Nos. of benchmarks to get solution over various optimization issues.	[182]	SA-DABC	2019
Modified SCA technique was developed by opposition based learning and added the self-adaptive factor to resolve global optimizations problem in real world which was verified on 23 standard benchmarks and IEEE CEC 2014 standard test functions.	[183]	m-SCA	2018
SCA algorithm was improved with crossover scheme to develop the capability of exploitation to real-world resolve optimizations problems which was tested on standard IEEE CEC 2014 as well as IEEE CEC 2017 test functions.	[184]	ISCA	2018

There were so many methods to solve optimization problems. Such as, Particle Swarm Optimization (PSO) [185] was one kind of stochastic algorithm used to get solution over the optimization problem on the global and local best particles by introducing the mutation operators and improved its performance. Branch and Bound (BB) [186] was a new method based on branch-and-bound techniques and had been used to solve unit commitment problem. Simulated Annealing (SA) [187] was another kind of deep as well as useful connections in between combinatorial or multivariate with statistical mechanics optimizer.

Tabu Search (TS)[188] was the metaheuristic optimization technique which gives good results on combinatorial optimization problems such as quadratic assignment. Genetic Algorithm (GA) [189] motivated since biological evolutions by comparisons which based on principles appliances such as ordinary natural type selections, recombination of the genetic formations and the fittest survival.

Some of these research paper includes Ant Colony Optimization (ACO) algorithm [190] was one of the nature inspired metaheuristics optimization method mimics the foraging manners of the ant specie. The ant's insects store pheromone on the ground to stamp some good pathway which ought to be trailed by different types of ants of that colony. This related mechanism was used to solve optimization problems. Imperialist Competitive Algorithm (ICA) [191] was another novel evolutionary type search method that was depend upon imperialist competition. Seeker Optimization Algorithm (SOA) [192] was depended upon perception of pretending the performance of humans' intelligence search through their experience, reasoning of uncertainty as well as memory.

Biogeography Based Optimization (BBO) [193] technique inspires the presentation of the biogeography for solving optimization problem. This unique optimization technique was used to solve the problem based on a real-time sensor selections for the aircraft engines healthiness estimations. Hopfield method [194] technique is used to solve ramp rate constrained for unit commitment problem. Gravitational Search Algorithm (GSA) [195] was one of heuristic search algorithms inspired by swarm behaviours in nature. This algorithm was created upon law of the gravity plus interactions of mass. Bacterial Foraging Optimization Algorithm (BFOA) [196] was a global optimizer technique stimulated by societal foraging manners of Escherichia coli which is used for solving the real-world optimization problems rising in various application domains.

Binary Gravitational Search Algorithm (BGSA) [197] was one of the optimization technique which based on the mass interactions and law of gravity. Firefly Algorithm (FFA) [198] was a nature inspired optimization algorithm which had been significant developed and its applications based on real-world problem. Forest Optimization Algorithm (FOA) [199] was implemented by insufficient trees are in the forest which can live for numerous decades, although supplementary trees could alive for some of the limited time span. Invasive Weed Optimization (IWO) [200] a statistical stochastic type optimizer technique which was motivated from inhabiting weeds and this was suggested for Electromagnetic applications. Wind Driven Optimization (WDO) [201] was bio inspired optimizer technique used for solving optimization difficulties in global region and encouraged through the motion of wind in the Earth's atmosphere.

Human Group Optimizer (HGO) [202] swarm intelligence optimization method is inspired by pretending human behaviours and especially human searching/foraging behaviours with local search technique. Binary Bat Algorithm (BBA) [203] was a bio-inspired piece selection method which established on the bats performance used to combine the exploration power of bats considering the speediness of Optimum-Path Forest classification to find out the sets of feature which increased accurateness in the authenticating set. Flower Pollination Algorithm (FPA) [204] was stimulated by the fertilisation procedure of the flowers. Krill Herd Algorithm (KHA) [205] was depend upon simulation of the collecting behaviours of each and every krill individual. Mine Blast Algorithm (MBA) [206] was such kind of optimization technique which were basically based upon populations that were followed by the mine bomb explosion concept.

Backtracking Search Optimization (BSO) [207] was one of the stochastic new evolutionary algorithm based on the strategy to generate a trial solution with two new operators including mutation as well as crossover that used as maintenance purpose, the magnitude of search area or boundaries including the matrix of search direction which improved capabilities of the influential exploration as well as exploitation. Cuckoo Search Algorithm (CS) [208] was one of the metaheuristic bio inspired optimizer founded on the oblige brood dependent behaviour of certain cuckoo species in grouping with Levy flight behaviour of certain birds. Shuffled Frog-Leaping Algorithm (SFLA) [209] was another kind of population-based compliant search type metaphor stimulated by nature or environment which was memetics in nature. Water Cycle Algorithm (WCA) [210] was stimulated since environment and created on the surveillance of cycle of water process as well as how streams and rivers flow into sea in real world.

Cultural Evolution Algorithm (CEA) [211] was the population-based algorithm based on cultural evolution goal. Grey Wolf Optimizer (GWO) [212] was one type of metaheuristic optimization technique motivated by some number of grey wolves that mimics that leadership hierarchy then mechanism of hunting of that few grey wolves in environment. Teaching-Learning-Based Optimization (TLBO) [213] was based on the learning as well as teaching phenomenon of classrooms for solving nonlinear, multi-dimensional with linear difficulties with considerable efficacy.

Chaotic Krill Herd Algorithm (CKHA) [214] was a new metaheuristics optimizer technique which announced the theory of chaos obsessed by Krill Herd Optimizer technique with the acceleration of its global convergence speed. Adaptive gbest-Guided Search Algorithm (AGG) [215] was a heuristic evolutionary search algorithm which inspired by gravitational forces between masses in nature.

Exchange Market Algorithm (EMA) [216] was a new approach of evolutionary algorithm for continuous non-linear optimization problems that enthused by the process of exchange shares on stock markets. League Championship Algorithm (LCA) [217] was a stochastic population based algorithm which was used to get solution over continuous type of global optimizer related problem. Interior search algorithm (ISA) [218] was a metaheuristic type optimizer that inspired through interior design as well as decoration. Optics Inspired Optimization (OIO) [219] technique was depended upon the law of reflection. Symbiotic Organisms Search (SOS) [220] was a strong and influential metaheuristic procedure be subject to the approaches adopted through animals to propagate as well as survive in the environment. Chicken Swarm Optimization algorithm [221] was a metaheuristic nature-inspired optimizer, that mimics nature of the chicken swarm.

The Ant Lion Optimizer (ALO) [222] mimic the mechanism for hunting of ant lions in the nature. The leading steps are such as hunting of target like unsystematic walk of ant, build the trap, trapped the ants in a specific manner, catch the prey, as well as again build the traps which were applied. Earthworm Optimization Algorithm (EOA) [223] was a natural inspire metaheuristic optimizer to solve the optimization problem in global sear area. Fireworks Algorithm (FA) [224] was a swarm intelligence optimization technique based on two types of processes and the mechanisms in explosion for keeping diversity of sparks were also well designed.

Colliding Bodies Optimization (CBO) [225] algorithm was a multi-agent type metaheuristics method, which was intellectualised using single dimension collision in between the bodies including each of the agent solutions measured as body or objective with the mass. Elephant Herding Optimization (EHO) [226] was based on a swarm methodology as well as one kind of popular metaheuristic optimizations method encouraged by the collecting behaviour of the group of elephant. Water Wave Optimization (WWO) [227] was inspired by the lovely phenomena of the waves of water, such as breaking propagation as well as refraction of water.

Lightning Search Algorithm (LSA) [228] was a novel metaheuristic kind of optimization technique which used to resolve the constraint for optimization related problems, which is constructed on the normal phenomenon of the lightning as well as the contrivance of the steps leader proliferation with the idea of the fast particle recognised as the projectiles. Runner-Root Algorithm (RRA) [229] was a metaheuristic optimization method which inspired through roots as well as runners of the plants in environment. Stochastic Fractal Search (SFS) [230] was a metaheuristic algorithm used a mathematic concept known as fractal which explore the search space more efficiently. Search Group Algorithm (SGA) [231] was a metaheuristic optimization technique to deal with the optimization of truss structures.

Vidhya Sathish and P. Sheik Abdul Khader proposed hybrid modal of GWO to recover the accuracy parameter for detection in designing the Efficient Intrusion Detection Model [232]. Bird Swarm Algorithm (BSA) [233] was a nature-inspire technique which based on the swarm astuteness extracted since the societal behaviours and societal interactions in bird swarms. The Dragonfly Algorithm (DA) [234] was motivated from static as well as dynamic behaviours of swarming of few dragonflies in environment. Electromagnetic Field Optimization (EFO) [235] was a physics inspired metaheuristic optimization technique that is created upon behaviours of electromagnets with different polarities. Isogeometric analysis (IGA) [236] and density of mapping methods for the topology optimizer of the flex electric or piezoelectric resources.

V. Soni et al. implemented hybrid grey wolf optimization-pattern search (hGWO-PS) to solve the problem related to load frequency control considering interconnected thermal power plant. This system was consisted by 2DOF-PID controller which was optimized by the new proposed technique. This method was performed better than existing optimization techniques in sensitivity analysis of 2DOF-PID controller [237].

Nitin Mittal et al. designed modified GWO (mGWO) to solve the global optimization problem in the area of optical engineering and real mechanical multidisciplinary engineering design problems. This method was used to maintain proper balance between exploitation and exploration to get appropriate optimal solution [238].

Multi-Verse Optimizer (MVO) [239] was a nature-inspired heuristic search algorithm which was based on three most important concepts in the Cosmology: wormhole, black hole and white hole. SCA [240] was one of the most important population based optimization method that were created multiple initial random solutions. Virus Colony Search (VCS) [241] was a nature-inspired technique which mimics infection and diffusion strategies for host cell accepted through virus toward survive as well as propagate in that cell atmosphere. Whale Optimization Algorithm (WOA) [242] was a bio inspired another type of meta-heuristic optimizer technique that mimics the societal behaviours of the humpback whales.

N. Singh and S.B. Singh proposed a new hybrid optimization technique named as GWO-SCA to solve the optimization problem. The efficiency of the novel optimizer was verified on twenty-two standard benchmark and five standard bio-medical dataset. And the resul was compared with other existing optimization algorithms i.e. PSO, GWO, HAGWO, WOA, MGWO, SCA and ALO algorithms [243]. Further research proposed a hybrid combination of PSO and GWO, named as HPSOGWO, to solve the optimization problem and improve the convergence rate. To verify the better performance of this new technique, it had been tested on standard benchmark functions including unimdal. Multimodal and fixed dimension benchmark functions [244].

The Grasshopper Optimization Algorithm (GOA) [245] imitators the behaviors of some grasshoppers swarm in environment to get solution over real time problems. The multi material type level set (LS) [246] dependent topology optimizer of the flex electric amalgams were designed to extend the point wise density mapping technique. Salp Swarm Algorithm (SSA) [247] was a nature stimulated heuristic search algorithm to get solution over optimization problems with single and multiple objectives. Weighted Superposition Attraction (WSA) [248] was created upon the main two types of simple mechanisms, one was "superposition" then another one was "attracted movement of agents". Sankalap Arora and Mehak Kohli had designed Chaotic GWO to solve constrain optimizer problems. The paper brings chaos theory obsessed by GWO method through aim of better acceleration on its speed of convergence for global optimal [249].

Hossam Faris et al. discussed about the recent variant of GWO and its applications in different area of research. The applications belongs to, power engineering, the domains of global optimization, bioinformatics, machine learning, networking, image processing and environmental applications etc. [250]. R. Rajakumar et al. implemented a unique meta-heuristic optimizer GWO-LPWSN to solve the problem related with Wireless Sensor Networks (WSN). This technique was used to solve the main localization problem through wireless sensor networks. The goal of this technique was to look out the geological position of nodes which were unknown with the assistance of anchor nodes in WSN [251].

Narinder Singh and SB Singh proposed Modified Mean GWO optimizer for biomedical and 23 standard benchmark problem including unimodal, multimodal and fixed dimension problems. The outcomes obtained were contrasted and numerous other meta-heuristic approaches, i.e., GWO, PSO, population-based incremental learning, ACO and so on. The outcomes had been showed that the exhibition of altered variation can discover best arrangements regarding best level of exactness in characterization and improved nearby optima shirking [252].

Narinder Singh and Hanaa Hachimi designed hybrid approach of GWO algorithm by combined Hybrid Whale Optimizer Algorithm (WOA) with Mean Strategy of GWO to slove the global optimization problem. The effectiveness and feasibility of this novel optimization technique was tested on standard benchmark, some biomedical problems and some multidisciplinary optimization problems [253]. Random Walk Grey Wolf Optimizer (RW-GWO) [254] was another novel types of optimizer in the field of swarm intelligent technique for solving the continuous type of problems and real time problems related with optimization methods. To improve the search capability through grey wolves, an improved technique hRW-GWO depend upon in random walk technique. Artificial Flora (AF) Optimization Algorithm [255] was one of the stochastic method in optimization which enthused by the procedure of reproduction and migration of flora. Supernova Optimizer [256] was inspired by the supernova phenomena in nature.

The aftereffects of CGWO on compelled designing issues demonstrated its appropriateness for real-world complex type of problem. The fundamental explanation for the superior presentation of C-GWO that lies overdue the disarray prompted through chaotic map in search area. That chaos encourages the regulatory boundary to locate the ideal arrangement more rapidly and subsequently improve the rate of convergence of the optimizer. Jie-Sheng Wang and Shu-Xia Li proposed an improved GWO optimizer with combination of Elimination Mechanism and Differential Evolution to accomplish the best possible trade off among exploitation and exploration, further quicken the convergence and increment the improvement of accuracy for existing GWO [257]. Test results showed that IGWO gets the better combination speed and improvement accuracy. From another perspective, the reception of advancement activity can expanded the wolves assorted variety and made the algorithm had a decent investigation capacity in the early looking through stage and had a decent exploitation capacity in the later search stage. Benoit Martin et al. designed Improved Discrete Grey Wolf Optimizer to solve the discrete problem in the area of optimization technique. Here random leader selection was performed, and the probability for the fundamental head to be chosen increments at the weakness of different pioneers across iterations [258].

Heba Al Nsour et al. proposed hybrid GWO algorithm to solve the problem related with Time Series Classification. In this research, the researchers explored the search ability of the GWO algorithm for deciding the improved estimations of the probabilistic neural network (PNN) loads. This method was also used for improving the characterization accuracy and upgrading the harmony among exploration and exploitation in this new algorithm [259]. N. Singh proposed a modified variant of GWO to solve the optimization problem. The better performance of convergence and better accuracy in results were provided the best optimal solution [260] .

Artificial Neural Network [261] and an adaptive collocation strategy was implemented to solve the partial differential equation. This method raised the strength of the network estimate and the result were important for computational savings, particularly when the solution was non-smooth. Bat Algorithm (BA) [262] was a novel optimization technique based on Levy flights path and differential operator which was presented to increase speed of convergence. Modified Dragonfly Optimization Algorithm [263] was a nature inspired algorithm based on random flying behavior of dragonflies. Crow Particle Optimization Algorithm [264] is the hybrid form of PSO and Crow Search method. Improved Electromagnetic Field Optimization algorithm [265] was a metaheuristic physics inspired method, which mimics the performance of electromagnets considering different polarities. Quasi-Opposition-Based Learning and Dimensional Search algorithm [266] was inspired by the attachment process of lightning in environment.

Hybrid Artificial Grasshopper Optimization (HAGOA) [267] was a metaheuristics optimization algorithm inspired by grasshopper to recover the exploration and exploitation in given search space. Harris Hawks optimizer (HHO) [268] was recently proposed nature-inspire search type algorithm, which was reinvigorated from the obliging normal behaviours of the most intellectual bird Harris Hawks for its ordinary behaviours of hunting as well as the avoiding or escaping nature of prey (rabbit).

Zhendong Wang et al. proposed upgraded version of GWO to solve the problem related with wireless sensor network node coverage optimization [269]. The new algorithm was used to improve the weaknesses of moderate assembly, low pursuit accuracy, and simple to fall into neighborhood optimal point. Main weighting technique is improved, so the dynamic update position was more in accordance with the first goal of the main algorithm. The presentation of dynamic mutation procedure expands the assorted variety of wolves, viably extends the inquiry scope of the algorithm, and takes care of the issue that the GWO calculation is anything but difficult to fall into neighborhood optimum in the later stage. Al-Tashi et al. implemented binary variant of hybrid Grey Wolf Optimizer with Particle Swarm Optimization. To locate the best arrangements, the wrapper-based technique K-closest neighbor's classifier with Euclidean detachment matric is used and the performance processes better accuracy, choosing the best optimal feature and the computation time [270].

Shubham Gupta and Kusum Deep implemented enhanced leadership-inspired grey wolf optimizer to solve various optimization problem in global search spaces. In this paper it was discussed about the classical GWO experiences and the issues of premature as well as slow convergence because of the stagnation at problematic arrangements. So the existing GWO algorithm was improved by the search mechanism such as Levy-flight and named as GLF–GWO [175]. This new method was used to solve some real world engineering problem also. The current work centers on improving the main searching capacity of wolf pack in GWO, with the goal that the more effective headings of search can be investigated.

Rashida Adeeb Khanum et al. implemented two novel improved variants of GWO to solve the problem associated with unconstrained optimization. The two variant were consist of different population-based algorithms including particle swarm optimization and fast evolutionary programming [271]. Manta ray foraging optimization [272] was a recently developed bio-inspired optimization technique, which was based on intelligent performances of manta rays.

All the recently developed heuristics, metaheuristics, evolutionary and nature inspired algorithms has its own pros and cons and most of these search algorithms are not applicable to every kind of optimization problems and hence universally cannot be accepted. Certain research works in the arena of optimization contains Adaptive gbest-Guided Search Algorithm (AGG) [215], Ant Lion Optimizer (ALO) [222], Bird Swarm Algorithm (BSA) [233], Ant Colony Optimization (ACO) algorithm [190], Bat Algorithm (BA) [262], Biogeography Based Optimization (BBO) [193], Binary Bat Algorithm (BBA) [203], Backtracking Search Optimization (BSO) [207], Earthworm Optimization Algorithm (EOA) [223], Branch and Bound (BB)[186], Bacterial Foraging Optimization Algorithm (BFOA) [196], Fireworks Algorithm (FA) [224], Dynamic Programming (DP)[274], Binary Gravitational Search Algorithm (BGSA) [197].

Further research work done by using some modern metaheuristics optimizer, such as, Cuckoo Search Algorithm (CS) [208], Colliding Bodies Optimization (CBO) [225], Chaotic Krill Herd Algorithm (CKHA) [214], Cultural Evolution Algorithm (CEA) [211], Electromagnetic Field Optimization (EFO) [235], Dragonfly Algorithm (DA) [275], Elephant Herding Optimization (EHO) [226], Forest Optimization Algorithm (FOA) [199], Gravitational Search Algorithm (GSA) [195], Firefly Algorithm (FFA) [198], Exchange Market Algorithm (EMA) [276], Flower Pollination Algorithm (FPA) [204], Genetic Algorithm (GA)[189], Grey Wolf Optimizer (GWO) [212], Interior search algorithm (ISA) [218], Grasshopper Optimization Algorithm (GOA) [245], Mine Blast Algorithm (MBA) [206], Human Group Optimizer (HGO) [202], Krill Herd Algorithm (KHA) [205], Random Walk Grey Wolf Optimizer (RW-GWO) [254], Hopfield method[194], Imperialist Competitive Algorithm (ICA) [191], Invasive Weed Optimization (IWO) [200], Monarch Butterfly Optimization (MBO) [277].

Some important optimizers were Lightning Search Algorithm (LSA) [228], League Championship Algorithm (LCA) [217], Mixed Integer Programming (MIP)[278], Moth-Flame Optimization (MFO) [279], Sine Cosine Algorithm (SCA) [240], Multi-Verse Optimizer (MVO) [239], Simulated Annealing (SA) [187], Particle Swarm Optimization (PSO) [185], Runner-Root Algorithm (RRA) [229], Shuffled Frog-Leaping Algorithm (SFLA) [209], Optics Inspired Optimization (OIO) [219], Stochastic Fractal Search (SFS) [230], Symbiotic Organisms Search (SOS) [220] also implemented.

Further, other algorithms, which were already designed for research purpose, i.e. Seeker Optimization Algorithm (SOA) [192], Teaching-Learning-Based Optimization (TLBO) [213], Salp Swarm Algorithm (SSA) [247], Whale Optimization Algorithm (WOA) [242], Water Wave Optimization (WWO) [227], Water Cycle Algorithm (WCA) [210], Tabu Search (TS) [188], Weighted Superposition Attraction (WSA) [248], Wind Driven Optimization (WDO) [201], Improved Sine Cosine Algorithm [ISCA] [184], Search Group Algorithm (SGA) [231], Virus Colony Search (VCS) [241], Modified Sine Cosine Algorithm [m-SCA] [183], leadership quality was improved by Levy-flight (LF) search and Grey Wolf Optimizer [GLF–GWO] [175], memory based Grey Wolf Optimizer [mGWO] [161], Greedy differential evolution -Grey Wolf Optimizer [gDE-GWO] [176] and Memory Guided Sine Cosine Algorithm [MG-SCA] [162].

After critically analysis from the above literature survey, it come to know that some of the algorithms have very fast convergence. For TS [188] optimizer, there is no assurance to find an optimal solution nearby the global optimal for high-dimension and complex problems. The SA optimizer [187] needs more simulation time than TS for convergence. These methods need to set the control parameter to get the better fitness value. The GA [53] optimization method need more simulation time than PSO and trajectory-based methods. But the hybrid GA optimization algorithms have several control parameters to solve critical optimization issues. This optimizer is not reliable for large scale systems. Further ACO [190] optimization algorithm can not able to find the best fitness on the global search space although the distributions planning is on small search space. The tuning of the controller parameter is another challenge for this optimizer. Some of the optimizers are not able to find the optimal solutions for the complex problems. The PSO [30] optimizer is not suitable for large-scale network and the control parameters are need to be tuned. But for MDP-PSO [21] have so many control parameters to solve the optimization problems. So, there are lots of issues in existing optimization algorithms that's are need to be solved for further research.

In the proposed research, the initiative has been taken to provide another powerful optimizer, which is based on natural hunting behavior of Harris hawks and trigonometric functions sine and cosine and nature of approaching food for slime mould with chaotic map. The hunting nature of the hawks bird are mathematically implemented [268]. The trigonometric expressions for sine wave as well as cosine wave are taken into consideration [290]. And the mathematical modal for slime mould is depend on the behavior of the approaching and wrapping for food [282]. Further, from several chaotic maps, the singer chaotic functions are used [214].

Further, from No Free Lunch Theorem (NFL) [273], all types of algorithms based on optimization techniques recommended and show average equivalent performance, if it is applied to all probable types of tasks based on optimization technique. According to NFL theorem, it cannot consider theoretically an algorithm as universally best type of optimizer in general purpose. Hence, NFL theorem motivates for penetrating and rising more effective algorithm based on optimization technique. Motivated from these, in the proposed research, the initiative has been taken to provide another powerful optimizer, which is based on natural hunting behavior of Harris Hawks and trigonometric functions sine and cosine and names as hybrid Harris Hawks-Sine Cosine Algorithm.

2.3 RESEARCH GAPS

In the area of research, the optimization strategy is the vastest locale of exploration through which the exploration works are adequately pushing ahead. Presently a day, specialists are working with numerous works for different issues utilizing various methods and they are proficient to gauge the yield effectively. To find the new algorithm, the research work is effectively running condition and to moderate the disadvantages of present existing methods.

Using modern hybrid metaheuristics algorithm is used to get the advanced optimal scheduling and percentage of cost saving by identifying those parameters in proper manner. A new Priority Based Stochastic UCP solved by considering parking area cooperation [58]. The main issues which miss the mark on a certain composed and complete theoretical system.

There are several research gaps including the impact of PEVs with UCP as well as PBUCP. In different weather, the uncertainty of renewable generation has significant impact on economical price of power scheduling due to the distribution and accumulation of renewable generations. So, it is necessary to maintain the economic cost of scheduling. Further, due to the penetration of renewable power generation and the demand side management of charging and discharging of PEVs, both have effect on the best, average and worst cost. Thus, it is still in research that how the optimal generation cost can be achieved. In case of PBUCP, it is more important to achieve maximum profit and reduce the total operating cost. Different types of optimization techniques are need to be implemented and tested to obtain maximum profit considering the effect of discharging and charging of PEVs.

The other existing optimization techniques has good development prospect, but their researches are still at initial condition and included so many problems which need be solved or other instance there are several uncertainties, such as, how to adequately stay away from nearby or local optimum. How the parameters of an algorithm can be efficiently set. How the benefits of several optimization techniques can be optimally combined. One of the most serious issues is the lack of cohesive and comprehensive theoretical theory. The exact time of iteration stop conditions are still in research and so forth. Also, there are multiple ways by which the optimization problems can be solved considering PEVs and RES.

2.3.1 Contributions of Proposed Research

The proposed optimization algorithm is useful to overcome those problems. Further, the profit-based unit commitment problem has not been investigated with respect to all the important parameters like shut down cost and initial status of thermal generating units etc., which seriously affects the optimality of the results. The work is therefore justified in persisting the proposed study. The research proposal therefore presents *"Profit Based Unit Commitment Integrated with Plug-in Electric Vehicles using Modern Meta-Heuristics Search Algorithms".*

2.4 RESEARCH OBJECTIVES

The intent of the proposed research is to develop an efficient and powerful hybrid meta-heuristics optimization algorithm, which will provide the reliable and cost effective solution for profit based unit commitment problem. The objectives of the proposed research work are outlined as below:

(i) To develop a hybrid optimization algorithm by combing local search algorithm with modern global search algorithm for constrained optimization and engineering optimization problem using memetic algorithm approach.

(ii) To evaluate the performance of the proposed hybrid algorithms for standard benchmark and multi-disciplinary engineering design and optimization problems and determination of superior optimization algorithm out of trial combinations.

(iii) To solve profit based unit commitment problem of power system using proposed hybrid optimization algorithm.

The efficiency and validity of proposed CHHO, CSCA, hCHHO-SCA, and hCSMA-SCA optimizer have been tested for PBUCP. The performances have been evaluated for the suggested hybrid optimized method on standard test system, which consists of thermal generating units for small, medium, and large-scale power sectors. The efficacy of the suggested algorithm was tested for 10-generating unit systems, 40-generating unit systems, and 100-generating unit systems.

(iv) To solve profit based unit commitment problem of power system by considering impact of Plug-in electric vehicles and renewable energy sources using proposed hybrid optimization algorithm.

The profitable solution for PBUCP has been tested considering the impact of PEVs and RES (solar photovoltaics) in summer and winter days using proposed CHHO, CSCA, hCHHO-SCA, and hCSMA-SCA optimizers. The test units are consisting of 10-, 40- and 100-generating unit systems that have been scheduled successfully and gain maximum profits by using suggested hybrid optimizers. Analysis of the variation in profit value, i.e., best, average and worst value with its standers deviation and median value is taken into consideration. Some of the hypothesis testing including Wilcoxon rank sum method and t-test are taken into consideration through which p-value and h-value can be determined. The computational times are also analyzed as best, average, and worst times of simulations.

(v) Analysis and Validation of results and publication of research work.

2.5 CONCLUSION

In this chapter various types of metaheuristic approaches are discussed to solve the PBUCP considering RES and impact of charging/discharging behavior of PEVs. The uncertainty of the renewable sources, i.e. solar and wind are discussed in tabular manner. The impact of PEVs with UCP as well as PBUCP both are discussed and find the research gaps. State the research objectives along with research gaps.

CHAPTER-3

OPTIMIZATION METHODLOGIES

3.1 INTRODUCTION

Optimization is a procedure to find better solution in the fields of real world engineering design issues, technology and science. The various types of possibilities outcomes can find by maintain some constraints using optimization methodologies. Any kind of complex or simple can be solved by optimization algorithms. Also, it helps to find out the optimum solution through its expert knowledge. With the help of several optimization techniques the best solution from optimal design problem can be achieved in a systematic manner. There are three types of optimizations methods are mostly used, such as, stochastic, heuristics and metaheuristics. Applied mathematics are also used in optimization techniques which can deals with different types of variables to get best solution.

There are lots of practical real examples of optimization techniques in various fields. In the field of research, the optimization problems are common for various purpose, such as, engineering, designing, manufacturing, uncertainty of some constraints and so on. Thus, there are some difficulties to solve complex problems. By select few specific optimizer with improvement in simulation methodologies have been useful to solve the complex optimization problems. Optimization methods have the ability in expansion to deal the critical decision oriented problem, such as, scheduling of generator and cost for the products.

3.2 OPTIMIZATIONS METHODOLOGIES

All the recently developed heuristics, metaheuristics, evolutionary and nature inspired algorithms has its own pros and cons and most of these search algorithms are not applicable to every kind of optimization problems and hence universally cannot be accepted. Further, from No Free Lunch Theorem (NFL) [273], all kinds of algorithms founded on optimizations technique recommended as well as show average equivalent performance, if it is applied to all probable types of tasks based on optimization technique. Accordingly to NFL, it cannot be considered theoretically the algorithms as universally best kind of optimizer in common purpose.

After critically analysis from the above literature survey, it come to know that some of the algorithms have very fast convergence. For TS [188] optimizer, there is no assurance to find an optimal solution nearby the global optimal for high-dimension and complex problems. The SA optimizer [187] needs more simulation time than TS for convergence. These methods need to set the control parameter to get the better fitness value. The GA [53] optimization method need more simulation time than PSO and trajectory-based methods. But the hybrid GA optimization algorithms have several control parameters to solve critical optimization issues. This optimizer is not reliable for large scale systems. Further ACO [190] optimization algorithm cannot able to find the best fitness on the global search space although the distributions planning is on small search space. The tuning of the controller parameter is another challenge for this optimizer. Some of the optimizers are not able to find the optimal solutions for the complex problems. The PSO [30] optimizer is not suitable for large-scale network and the control parameters are need to be tuned. But for MDP-PSO [21] have so many control parameters to solve the optimization problems. So, there are lots of issues in existing optimization algorithms that’s are need to be solved for further research.

Therefore, NFL theorem inspires for rising and penetrating more effective algorithm constructed on optimizations technique. Motivated from these, in the proposed research, the initiative has been taken to provide another powerful optimizer, which is based on natural hunting behavior of Harris hawks and trigonometric functions sine and cosine and nature of approaching food for slime mould with chaotic map, i.e. CHHO, CSCA and CSMA. Further the hybrid variations are done by combining singer chaotic map of Harris hawks optimizer with sine cosine algorithm, i.e. hCHHO-SCA and combine singer chaotic function of slime mould and sine cosine algorithm, i.e. hCSMA-SCA.

In this research, newly designed optimization methodologies are motivated by the hunting nature of Harris hawks' birds, food searching and wrapping behavior of slime mould, a function of sine and cosine wave, several numbers of the chaotic map, and adaptive search techniques. The hypothesis tests are taken into consideration to check the effectiveness of such hybrid optimizers. Using the hybrid combination of those techniques CHHO, CSCA, CSMA, hCSMA-SCA, and hCHHO-SCA have been developed to increase the capability of exploration as well as exploitation over the whole search space. The exploitation of existing HHO optimizer has been upgraded successfully using chaotic singer function, i.e., CHHO, CSCA, CSMA and updated the phase of explorations by HHO and SCA techniques, i.e., hCHHO-SCA. The SMA optimizer was also upgraded with singer chaotic map with SMA and updated by SCA optimizer, i.e., hCSMA-SCA have been successfully tested for unimodal, multimodal, fixed dimension standard benchmark problems and multidisciplinary engineering design problems. Further the suggested CHHO, CSCA, hCHHO-SCA, and hCSMA-SCA optimization methodologies have been solved for PBUCP related issues and further considering the impact of charging and discharging of PEVs and solar energy in summer and winter. The efficacy of the suggested optimization methodologies was tested for 10-generating unit systems, 40-generating unit systems, and 100-generating unit systems.

3.2.1 Global Optimization Methodologies

Global optimization is a part of numerical analysis and applied mathematics that tries to discover the global maxima or minima of functions or a set of the functions on a given search space. In engineering design application, optimization problems have been taken into consideration from very beginning time. The deterministic process was the first global optimizer which were previously utilized and it is dependable upon overcome as well as isolatable phenomenon. From local optimization techniques, the global optimization methods are distinguished. It have been focused on different types of findings with maxima or minima over the given data set as it opposed to find local maxima or minima. Also it is more difficult to find out the global minima of a function. The analytical methods are not frequently applicable in this situation. The main task for this optimization is to find out a better solution within the data set that the objective functions must be obtained as global minimal. Very few techniques are usable to find out the global optima allowing the track down global regions into the total search space, such as SA [187], ACO [280], PSO [281], SMA [282], SCA [240], HHO [268] and so on.

3.2.1.1 Sine Cosine Algorithm

The sine cosine algorithm is the population based technique that make huge number of random solutions set in the initial conditions as well as expects to differ outwards as well as towards the solution sets which are the best in nature by utilize numerical models that depend upon sine and cosine functional sets. The proposed method SCA is one of the population based optimizer which is recognized established on the mathematical functions of sine as well as cosine. Similarly to the other types searching process by randomly constructing the solutions set. After that, all these types of solution attained randomly so extreme which signifies it as the point of destination and the resolutions or solutions. With the help of this optimization technique, this algorithm stores that solution which is more better and signifies it as the point of destination and the point of the solutions, which update to build a new resolution according to the function depend on sine and cosine, shown in the eqn. (3.1) and eqn. (3.2).

$$X_m(\text{iter}+1) = X_m(\text{iter}) + r_1 \times \sin(\text{r}_2) \times \left| r_3 \times D_m(\text{iter}) - X_m(\text{iter}) \right| \tag{3.1}$$

$$X_m(\text{iter}+1) = X_m(\text{iter}) + r_1 \times \cos(\text{r}_2) \times \left| r_3 \times D_m(\text{iter}) - X_m(\text{iter}) \right| \tag{3.2}$$

After rearrangement these two equations can be written as in eqn. (3.3)

$$X_m(\text{iter}+1) = \begin{cases} X_m(\text{iter}) + r_1 \times \sin(\text{r}_2) \times \left| r_3 \times D_m(\text{iter}) - X_m(\text{iter}) \right|; & if \quad r_4 < 0.5 \\ X_m(\text{iter}) + r_1 \times \cos(\text{r}_2) \times \left| r_3 \times D_m(\text{iter}) - X_m(\text{iter}) \right|; & if \quad r_4 \geq 0.5 \end{cases} \tag{3.3}$$

The random number. i.e., r_1, r_2, r_3, r_4 are main four parameter for the optimizer. r_1 helps to find out directions as well as movement that can dictates and it could be within the destinations and solutions in search area or outside of that area. r_2 helps to find out the direction as well as the movement outward or toward of the destination. r_3 helps to find the random number of the weights to put emphasis on i.e. $r_3 > 1$ as well as deemphasize i.e. $r_3 < 1$, the effect of totally identifying distances. At last, r_4 helps through indicates equality of switches in between the sine function as well as cosine features by the eqn. (3.3). For the usages of the sine function and cosine formulation, this method is known as SCA. The effects of the formulation of sine function as well as cosine functions are shown in eqn. (3.1) and eqn. (3.2) then the effects of this are shown in **Fig.3.1.**

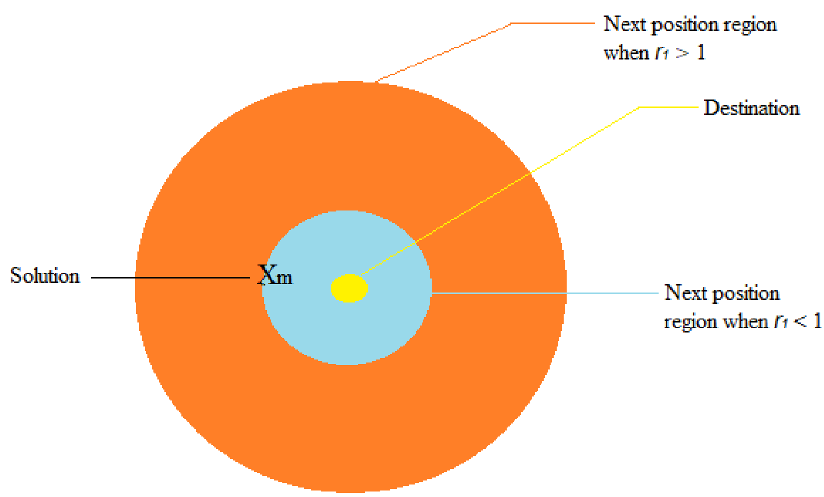


Fig. 3.1: Effects of the SCA method

In search area how the recommended equation state a space among the two kinds of solution are given in **Fig. 3.1.** That must be seen the equations can spread too much in higher dimensions although now only two dimensionally model which are demonstrated in **Fig. 3.1**.

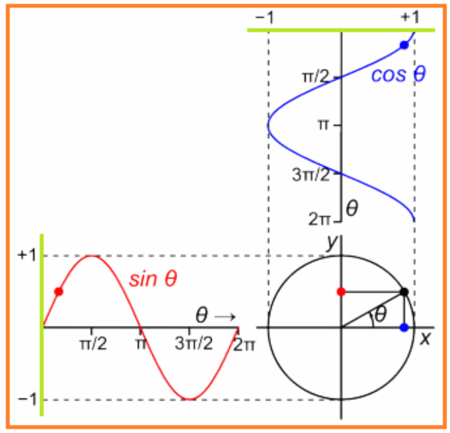


Fig.3.2: Ranges of sine function as well as cosine functions

A prototypical model and the effect of those two function with reflection of the ranges are shown in the **Fig. 3.2.** It shows that how ranges of these functions are required to get updated solution of its position in between search area or outsides from that search region. So, balance of the exploitations as well as explorations, ranges of the sine functions and cosine function in eqn. (3.1) to eqn. (3.3) can be improved adaptively by expending the equation which is shown in eqn. (3.4).

$$r_1 = a - iter_{Current} \frac{a}{iter_{MAX}} \tag{3.4}$$

SCA Algorithm

Step I: State the parameters for this method.

Recognize input parameters which required by SCA technique to get the solutions over the optimization difficulties defined by the eqn. (3.1) and eqn. (3.2). The optimizer progresses and constructs random number of sets in solutions for specified problems which is beneficial for the large explorations.

Step II: Initialize of the search agent, i.e. number of the solutions by (H_m).

Step III: Estimate these search agents over objective function.

Step IV: Advancement of the best solutions from the data sets of entire search area.

Step V: Improvement the value of the random nos. i.e. r_1, r_2, r_3, r_4.

Step VI: Improvement of the positions of search agents by eqn. (3.3).

Step VII: If, $iter_{Current} < iter_{MAX}$, then the best solutions can be obtained as global optimal solutions within the data sets.

3.2.1.2 Slime Mould Algorithm

Slime mould algorithm (SMA) is one of the new established stochastic optimizer depends on oscillation technique of slime mould in nature. As it was firstly categorized as fungus, so that was titled as ''slime mould''. This technique suggested frequently simulates the environmental furthermore change in the morphological patterns of slime mould. In case of the foraging doesn't shows its whole life cycles. Simultaneously, utilization of weights in the optimizer is used for simulated the feedback in the positive and negative manners produced by the slime moulds during the time of searching shown in **Fig.3.3.**

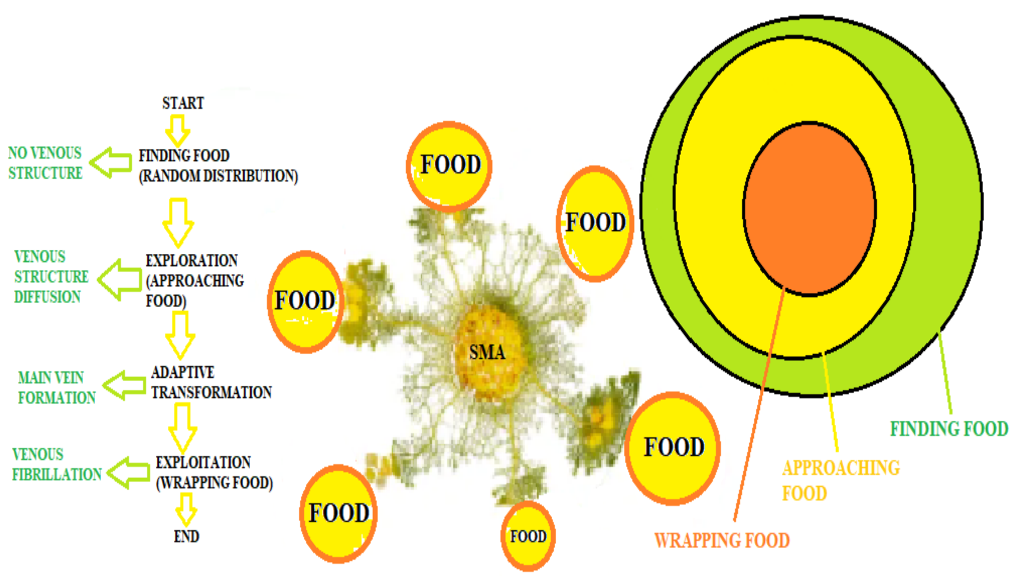


Fig.3.3: Basic technique for SMA optimizer

The construction of the venous for slime moulds improve with the variation of phases in the contraction manners, thus it consist of three kinds of correlation in-between the contraction manners as well as changes of morphological manner in the structure of the venous that are taken into considerations. So that, relations between contraction phases and structures of the venous is more reliable with the natural formed shape of the cells. Slime moulds may regulate dynamically their search mode consequently depend on quality of the food. The scientific modes for that optimizer is deliberated below:

Procedure for approaching of food: Slime moulds can moves toward foods as per smells that noticeable all the around. To connect its moving towards conduct in the numerical formulations, accompanying formulations are proposed to the emulate constriction phases shown in the eqn. (3.5).

$$\overrightarrow{S(\text{iter}_{current}+1)} = \begin{cases} \overrightarrow{S_b} + \overrightarrow{ub}.(\vec{Y}.\overrightarrow{S_A(\text{iter}_{current})} - \overrightarrow{S_B(\text{iter}_{current})}); & R_N < F \\ \overrightarrow{uc}.\overrightarrow{S(\text{iter}_{current})}; & R_N \geq F \end{cases} \tag{3.5}$$

The calculated representations of F is shown Eqn. (3.6).

$$F = \tanh\left|X(i) - Best_F\right| \qquad where \quad i \in 1,2,..n \tag{3.6}$$

$$\overrightarrow{ub} = [-a, a] \tag{3.7}$$

$$a = \arctan h\left[-\left(\frac{iter_{current}}{iter_{MAX}}\right)+1\right] \tag{3.8}$$

Through the eqn. (3.5) to eqn. (3.8) uses to search individually in all of the directions to invention of optimum solution. Thus the circular structures of the slime moulds are ready for the approaching food into the nearby regions. These equations also signifies the sequences of fitness value which are in an ascending order with the minimum number of difficulties. The positions of the search individuals may be advanced accordingly the best position presently attained by changing its current location.

Procedure for wrapping of food: In the section pretends the manner of the contraction of structure of the venous at time of the searching. The calculated formula for procedure of wrapping the food is shown in the eqn. (3.9) to eqn. (3.11).

$$\overrightarrow{Y_{sequence}(i)} = \begin{cases} 1 + R_N \,.\log\left(\dfrac{Optimal_{FIT} - X(i)}{Optimal_{FIT} - Worst_{FIT}} + 1\right); & R_N < F \\ \\ 1 - R_N \,.\log\left(\dfrac{Optimal_{FIT} - X(i)}{Optimal_{FIT} - Worst_{FIT}}\right); & R_N \geq F \end{cases} \tag{3.9}$$

$$Y_{sequence} = sort(X) \tag{3.10}$$

$$\overrightarrow{S*} = \begin{cases} R_N\,(Upper_B - Lower_B) + Lower_B\,; & R_N < e \\ \overrightarrow{S_b(\text{iter}_{current})} + \overrightarrow{ub}.(Y.\overrightarrow{S_A(\text{iter}_{current})} - \overrightarrow{S_B(\text{iter}_{current})}); & R_N < F \\ \overrightarrow{uc}.\overrightarrow{S(\text{iter}_{current})}; & R_N \geq F \end{cases} \tag{3.11}$$

The highly concentrations of foods are communicated by the vein as well as by the bio oscillators thus stronger wave can be generated and the fastest cytoplasm flow over that vein that is thicker given in eqn. (3.9) and eqn. (3.10). After that the arithmetical formulation for advancement the positions of the slime moulds is given in eqn. (3.11).

Procedure for Oscillations: Slime moulds basically depend on wave of propagations created by natural oscillators to changes the cytoplasmic streams in the veins. They will in general can be in the better situations of concentrations for foods. For the simulating variation purposes, $\vec{Y}$, $\overrightarrow{ub}$ as well as $\overrightarrow{uc}$ are used as the realizer of these variation through venous of slime moulds. $\vec{Y}$ is statistically simulates frequency oscillation of slime moulds that close to the one at the various stages of concentrations in food, so it can moves towards food and immediately when discover the higher quality foods, while search the foods all more gradually then the concentrations of the foods are lower in each individual location, accordingly successfully improve productivity of slime moulds in the choose optimum foods sources. These parameters $\overrightarrow{ub}$ create random number by random oscillations in-between –a to +a and when no. of iterations are increased then that continuously upcoming towards the value zero. After that the parameters $\overrightarrow{uc}$ create oscillations in-between the no. [-1, 1] then furthermore it move towards the value zero accordingly growing then iterations numbers. To find out the best sources for foods, if slime moulds can discover better solution, it will be detached from the organic matter for explorations to endeavors to find out highest quality of solution, i.e. sources for foods, moderately exploration of it within the one solution.

SMA Algorithm

Step I: Initializes input parameter as well as maximum no. of iterations.

Step II: Initialize the locations of the Slime moulds.

Step III: Checked whether current iteration value is less than total no. of iterations.

Step IV: Compute the value for fitness of the Slime moulds.

Step V: Upgrade fitness value for finding out $\overrightarrow{S_b}$ for optimal solutions.

Step VI: Estimate $\vec{Y}$ from the eqn. (3.9).

Step VII: Upgrade P, $\overrightarrow{ub}$ as well as $\overrightarrow{uc}$ for the each search agent then upgrade current positions by eqn. (3.11).

Step VIII: Increases current iterations by 1.

Step IX: Discover the best fitness value $\overrightarrow{S_b}$.

3.2.1.3 Harris Hawks Optimizer

Some of the main techniques are used to progress the exploitations phase such as, explorations with conversions, strategy of exploitations including hard encircles and soft encircles, soft encircles considering the advanced fast dives as well as hard encircles considering the advanced fast dives.

Right now component of HHO is talked about. Considering the ordinary chasing methodology of Harris birds of prey, they identify the track and prey it by utilizing the predominant eyes over which the injured individual can't be acknowledge it no problem at all. Presently seeing equivalent possibilities for the each of the adjusting systems which depend upon area for additional individual from to approaches sufficient while confronting as prey, follow in the eqn. (3.12).

$$\mathrm{X(iter+1)} = \{ X_{RND}\,(\mathrm{iter}) - r_1 \times abs(\mathrm{X}_{RND}(\mathrm{iter}) - 2 \times r_2 \times X\,(\mathrm{iter})); \quad b \geq .5 \tag{3.12}$$

The implausible societal nature is surveyed by Harris hawks bird to jumps over the track upon their prey i.e. rabbits. Observing for the rabbits, surprising jump occurred, then the numerous number of attacking method are achieved with exploitative eras of technique. This indistinguishable opportunities b for the every changing base which count upon region for extra individual from to the transfer towards acceptable regions while defying as prey (rabbits) shown in the eqn. (3.13).

$$\mathrm{X(iter+1)} = \{ (\mathrm{X}_{Rabbit}\,(\mathrm{iter}) - X_m(\mathrm{iter})) - r_3 \times (L^{\lim it} + r_4 \times (U^{\lim it} - L^{\mathrm{limit}})); b < .5 \tag{3.13}$$

Where, r_1, r_2, r_3, r_4 & b are random numbers in the range of 0 and 1. $\mathrm{X(iter+1)}$ represents the positions of rabbit and P represents total numbers of the hawks. The average location of Harris hawks are shown in eqn. (3.14).

$$X_m(\mathrm{iter}) = \frac{1}{P}\left(\sum_{n=1}^{N} X_m(\mathrm{iter}) \right) \tag{3.14}$$

In this algorithm, based on HHO optimization technique can transference from exploration condition to exploitation condition and after that alteration between various types of nature base on exploitative behavior which is based on the avoidance energy of the prey. Due to this avoidance behavior, it decreases the energy of the prey. The equation based on the behavior of the energy of the prey is given in eqn. (3.15).

$$EN = 2 \times EN_0 \times \left(1 - \frac{iter}{iter_{MAX}} \right) \tag{3.15}$$

Where, EN represent the energy of escaping meant for rabbit, EN_0 represent the premature circumstances for that energy as well as $iter_{MAX}$ represent the maximum number of the iterations. Due to this softly encircle is occurred by harris hawks, for which the victim rabbit tends to more and more exhausted and after that execute the surprise attack. This kind of natural behavior is demonstrated by some rules which is given in eqn. (3.16) and eqn. (3.17).

$$\mathrm{X(iter+1)} = \Delta X(\mathrm{iter}) - EN \times abs(jX_{Rabbit}(\mathrm{iter}) - X(\mathrm{iter})) \tag{3.16}$$

$$\Delta X(\mathrm{iter}) = \left(X_{Rabbit}(\mathrm{iter}) - X(\mathrm{iter})\right) \tag{3.17}$$

In this situation the Harris hawks performs scarcely enclose the projected victim to do finally shock attack. At this condition, the current locations are changed and updated by using the eqn. (3.18).

$$\mathrm{X(iter+1)} = X_{Rabbit}(\mathrm{iter}) - EN \times abs(\Delta X(\mathrm{iter})) \tag{3.18}$$

With the help of this nature the hawks can increasingly select the best probable dive towards the rabbit at that time when they desire to catch the rabbit in the economic situations. So, for better performance of a soft encircle, the Harris hawks can decide their next movement V, which is based on a rule which is given in the eqn. (3.19).

$$V = X_{Rabbit}(\mathrm{iter}) - EN \times abs(jX_{Rabbit}(\mathrm{iter}) - X(\mathrm{iter})) \tag{3.19}$$

After that they can relate the probable result of such kind of movement to the earlier dives which detect that it will be better dive or not. If they saw that the performance (motion) of the prey (rabbit) was more deceptive in nature, which means they also start to accomplish abrupt, rapid and irregular dives when oncoming the rabbit shown in eqn. (3.20).

$$A = V + Z \times Levy_{ft}^{DP} \tag{3.20}$$

Accepted upon $Levy_{ft}^{DP}$ pattern created with trajectory of given order in eqn. (3.21) and eqn. (3.22). Here, DP represent the dimension of specific problems, Z represents the dimension of random vector with scale $1\times DP$.

$$Levy_{ft}(\text{dim}) = 0.01\left(\frac{\beta\times\alpha}{|\gamma|^{\frac{1}{\sigma}}}\right) \tag{3.21}$$

$$\alpha = \left(\frac{\Gamma(1+\sigma)\times\sin\left(\frac{\pi\sigma}{2}\right)}{\Gamma\left(\frac{1+\sigma}{2}\right)\times\partial\times 2\left(\frac{\sigma-1}{2}\right)}\right)^{\frac{1}{\sigma}} \tag{3.22}$$

Where, α,β are signified as a type of substance that include randomly among sets of (0, 1) as well as σ to 1.5 which acknowledged as an evading constant.

Thus, counting upon those last through real process for explain the genuine section of the Hawks trade through the era for the soft enclose by achieved using Eqn. (3.23) to (3.25) that is seemed as,

$$\text{X(iter+1)} = \begin{cases} V; & if \quad F(\text{V}) < F(\text{X(iter)}) \\ A; & if \quad F(\text{A}) < F(\text{X(iter)}) \end{cases} \tag{3.23}$$

$$V = X_{Rabbit}(\text{iter}) - EN\times abs(jX_{Rabbit}(\text{iter}) - X_a(\text{iter})) \tag{3.24}$$

$$A = V + Z\times Levy_{ft}^{DP} \tag{3.25}$$

Where, $X_m(\text{iter})$ can measured from Eqn. (3.14).

Hybrid arrangement of hCHHO-SCA method is presented in **Fig.3.4** as well as the new hybrid optimizations technique can scientifically described from eqn. (3.26) to eqn. (3.28).

$$X_m(\text{iter+1}) = X_m(\text{iter}) + r_1\times\sin(\text{r}_2)\times\left|r_3\times D_m(\text{iter}) - X_m(\text{iter})\right| \tag{3.26}$$

$$X_m(\text{iter}+1) = X_m(\text{iter}) + r_1 \times \cos(r_2) \times \left| r_3 \times D_m(\text{iter}) - X_m(\text{iter}) \right| \tag{3.27}$$

$$X_m(\text{iter}+1) = \begin{cases} X_m(\text{iter}) + r_1 \times \sin(r_2) \times \left| r_3 \times D_m(\text{iter}) - X_m(\text{iter}) \right|; & if \quad r_4 < 0.5 \\ X_m(\text{iter}) + r_1 \times \cos(r_2) \times \left| r_3 \times D_m(\text{iter}) - X_m(\text{iter}) \right|; & if \quad r_4 \geq 0.5 \end{cases} \tag{3.28}$$

Where, r_4 symbolized like random numbers [0, 1].

The proposed process recognized on that process which have symmetry in exploitations over exploration towards get favorable solutions in region of search as well as lastly meet towards detection of solution related with global optima by eqn. (3.29).

$$r_1 = \left(2 - iter \times \frac{2}{iter_{MAX}} \right) \tag{3.29}$$

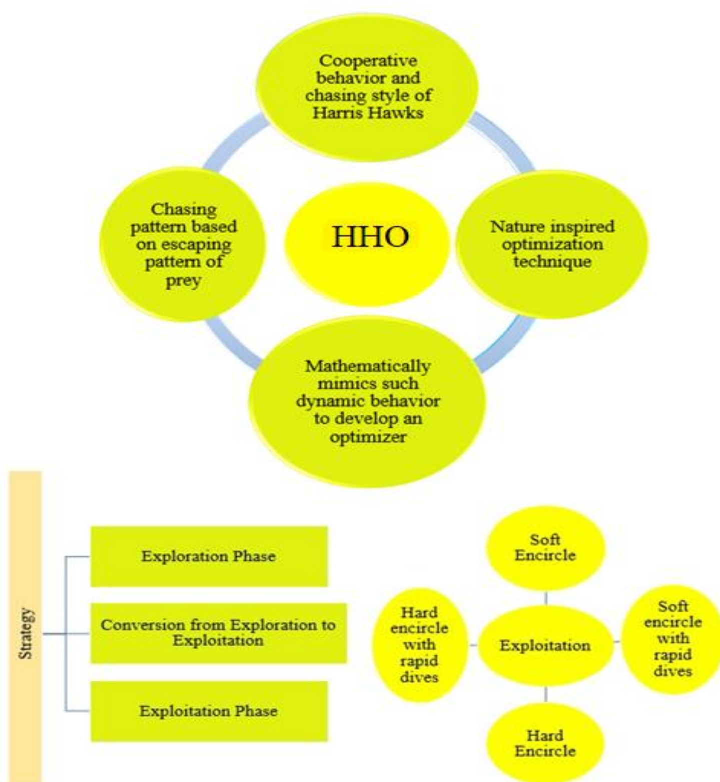


Fig. 3.4: Strategy of HHO technique

HHO Algorithm

Step I: Initialize input parameters, the positions of prey (rabbits) in addition to its significances of the fitness and the population sizes.

Step II: Initialize of the random populations by $X_m(n = 1, 2, 3......., N)$.

Step III: Checked the conditions of iteration < iter_{MAX} then calculate Harris hawks significances of fitness.

Step IV: Upgrade the position in both condition exploration with exploitation.

Step V: Upgrade the locations vector for the soft circles by the advanced fast dives and hard circles by the advanced fast dives.

3.2.2 Local Optimization Methodologies

The local search optimizers are one of the heuristic approach for deal with computationally complex type issues in optimization. It may be developed on such issues that can be defined as determining an answer of expanding model among the various kinds of candidate's solution. This types of search in the area of optimization can moves from a single solution to the another solution in search area by use of neighborhood change, until optimal solutions can be create as well as time periods of this can be elapsed.

The local search techniques are usually applied to many hard simulations issue, including the software engineering particularly in the arena of AI, operation researches, arithmetic, bioinformatics and engineering fields. Most of this optimizer deliberate the side constraints that independently from inequality plus equality limitation. It can be taken care of efficiently by straight implementation in optimizer. The better algorithms won't ever contempt any of given constraints. So, to deal with improvement of the stochastic optimizer, data associated with the distributed types of solutions in the search area that can be useful for understand the authority of exploitation of the optimizer.

There are some local search algorithm are beneficial for the optimization purposes, such as, TS, Random optimizer, SA, HC, Adaptive search, PS and so on. Here some major local search procedures that are applied is defined below.

3.2.2.1 Chaotic Searches Strategies

In the area of computational and mathematical analysis with complexity phenomena, sampling, dynamic plus particularly heuristics optimizers need random grouping through a wide long phase of time with great consistency. The chaos is deterministic random process which found in nonlinear dynamic systems that are non-converging, bounded plus nonlinear in behavior. Moreover this is too much sensitively dependable upon its own parameters and also it has dependency on initial condition.

The performance of chaos has randomness as well as an arbitrary nature with unpredictability and it similarly has component of the consistency. Statistically, chaos is randomly behavior on basic deterministics dynamical frameworks and the chaotic system can be measured as the source of randomness. In this optimization, due to the periodicity of the chaotic system with non-repetitions, that can do in general overall searches at the higher pace than the stochastic searches which rely on probabilities. The eccentric behavior of the chaotic frameworks have been attracted the attentions overall the several numerous types of the scientific researching communities. Several types of the Chaotic Map are given in **Fig.3.5.**

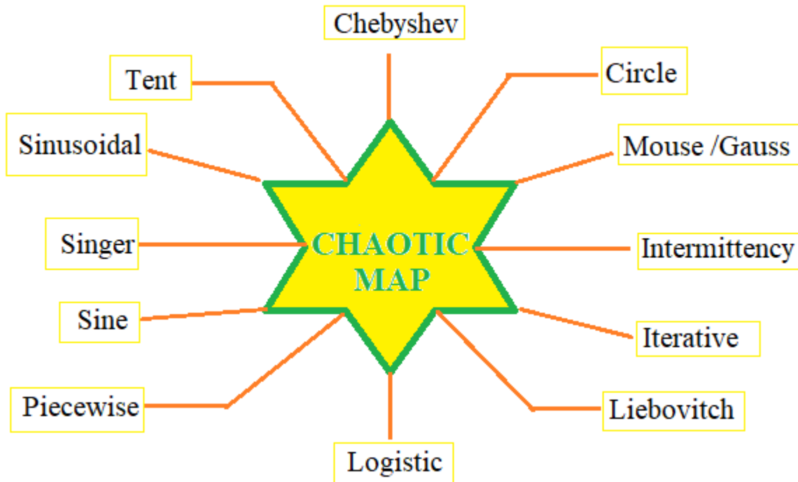


Fig.3.5: Several kinds of the chaotic maps

The chaotic natures had been found in the different kinds of examination fields, for example, science, designing, environment, medication, economy, science, etc. In everyday way, the mayhem have three sorts of various properties which are dynamic in nature which are given underneath:

1. The complexity of the requirements in preliminary situations.
2. The Semi stochastic possessions.
3. Ergodicity of the nature.

Stochastic optimizer regularly escape from close by minima instead of acknowledge some awful arrangement according to specific kinds of likelihood anyway utilizing turbulent inquiry on the consistency of tumultuous development to escape from neighborhood minima. To fulfill this matter, accordingly non-invertible one-dimensional guides are utilized to create turbulent sets. In the going with subsections, we review some of remarkable one-dimensional guides.

(i) Chebyshev of Chaotic Maps

The groups of Chebyshev maps can be well-defined in the eqn. (3.37).

$$X_{K+1} = \cos[K \cos^{-1}(X_K)] \tag{3.37}$$

(ii) Circle of Chaotic Maps

The circle maps can be signified in the eqn. (3.38).

$$X_{K+1} = \left| X_K + b - [a - 2\pi] \sin(2\pi X_K) \right| \tag{3.38}$$

Where, a = 0.5 as well as b = 0.2, it assistances to produces chaotic orders [0, 1].

(iii) Mouse or Gauss of Chaotic Maps

The equation which is recognized as Gauss map is specified in the eqn. (3.39) and the eqn. (3.40).

$$X_{K+1} = \begin{cases} 0 & X_K = 0 \\ 1/K \bmod[1] & otherwise \end{cases} \tag{3.39}$$

$$1/X_K \bmod[1] = \frac{1}{X_K} - \left[\frac{1}{X_K} \right] \tag{3.40}$$

This Gauss map can moreover create chaotic intellect [0, 1].

(iv) Intermittency of Chaotic Maps

This kinds of maps are separated into two amounts with linear along with non-linear which are specified below in the eqn. (3.41);

$$X_{K+1} = \begin{cases} \partial + X_K + CX_K & 0 < X_K \le G \\ \dfrac{X_K - G}{1 - G} & G < X_K < 1 \end{cases} \tag{3.41}$$

(v) Iterative of Chaotic Maps

This kind of chaotic map has immeasurable times of collapse revealed in the eqn. (3.42);

$$X_{K+1} = \sin\left[\frac{a\pi}{X_K}\right] \tag{3.42}$$

$a \in [0,1]$ Constraint is used in the specific chaotic map.

(vi) Liebovitch of Chaotic Maps

The method was considered by Toth also Liebovitch that is specified in the eqn. (3.43);

$$X_K = \begin{cases} \varsigma X_K & 0 < X_K \le G_1 \\ \dfrac{G - X_K}{G_2 - G_1} & G_1 < X_K \le G_2 \\ 1 - \gamma[1 - X_K] & G_2 < X_K \le 1 \end{cases} \tag{3.43}$$

Where $\varsigma < \gamma$ can be well-defined as prearranged below in the eqn. (3.44) as well as Eqn. (3.45);

$$\varsigma = \frac{G_2}{G_1}\left[1 - \left(G_2 - G_1\right)\right] \tag{3.44}$$

$$\gamma = \frac{1}{G_2 - 1}\left[\left(G_2 - 1\right) - G_1\left(G_2 - G_1\right)\right] \tag{3.45}$$

For that case three kinds of equal limits are considered.

(vii) Logistic of Chaotic Maps

This kind of chaotic maps can be signified by specified eqn. (3.46).

$$X_{K+1} = aX_K\left[1 - X_K\right] \tag{3.46}$$

Where X_K signifies the kth number of the chaotic map then here K represented as the numbers of iterations in that case. Under $X \in [0,1]$ conditions, initially $X_0 \in [0,1]$ then $X_0 \in [0.0, 0.25, 0.75, 0.5, 1.0]$. For this map value of a can be 4.

(viii) Piecewise of Chaotic Maps

This kind of map can be symbolized in the eqn. (3.47);

$$X_{K+1} = \begin{cases} \dfrac{X_K}{G} & 0 \le X_K < G \\ \dfrac{X_K - G}{0.5 - G} & G \le X_K < \dfrac{1}{2} \\ \dfrac{1 - G - X_K}{0.5 - G} & \dfrac{1}{2} \le X_K < 1 - G \\ \dfrac{1 - X_K}{G} & 1 - G \le X_K < 1 \end{cases} \tag{3.47}$$

Where G is well-defined as a control factor for the map that may among 0 and 0.5 as well as $X \in [0,1]$.

(ix) Sine of Chaotic Maps

Unimodal sine functions of chaotic map can be expressed as next eqn. (3.48).

$$X_{K+1} = \frac{a}{4}\sin[\pi X_K] \tag{3.48}$$

Where $0 < a \le 4$ must be sustained.

(x) Singer functions of Chaotic Map

The specific map for equation can be given in eqn. (3.49);

$$X_{K+1} = \nu\left[7.86X_K - 23.31X_K^2 + 28.75X_K^3 - 13.302875X_K^4\right] \tag{3.49}$$

Where, ν can differ among 0.9 to 1.08.

(xi) Sinusoidal types Chaotic Maps

The scientific formulation for the map is specified in the eqn. (3.50);

$$X_{K+1} = aX_K^2 \sin\left[\pi X_K\right] \tag{3.50}$$

Where, a = 2.3 as well as X_0 =0.7, the equations can be shortened in the eqn. (3.51);

$$X_{K+1} = \sin\left[\pi X_K\right] \tag{3.51}$$

(xii) Tent function of Chaotic Maps

This kind of chaotic maps is comparable to logistic function of chaotic maps. That include numerous types of the chaotic effects. This kind of chaotic map can be signified in the eqn. (3.52);

$$X_{K+1} = \begin{cases} \dfrac{X_K}{0.7} & X_K < 0.7 \\ \dfrac{10}{3}(1 - X_K) & X_K \geq 0.7 \end{cases} \tag{3.52}$$

3.3.3 Hybrid Optimizations Methodologies

A hybrid optimization algorithm is one kinds of calculation that solidifies no less than two unique algorithms that deal with a comparable issue, either picking one of that which are relied upon the informational indexes, or trading between them all through the range of the calculation. Hybrid optimizer demonstrate progressively at aggregate stage which the algorithm to apply starting at a bunch of different sorts of calculation that machine the comparative optimization.

Hybridization of algorithms build through heuristic one which is profoundly powerful and apportion with more gainful to use in research field. The benefits of hybridization of algorithms are the quickest speed for union, ability to get arrangement over multidimensional consistent optimization issues and the most grounded looking through capacity. To work on exploratory inquiry and track down the ideal arrangement the mixture mix of some nearby analyzer are joined with worldwide global search arena.

3.3.3.1 Hybrid Chaotic Slime Mould-Sine Cosine Optimization Algorithm

The proposed hybrid algorithm, Chaotic Slime Mould-Sine Cosine Algorithm (hCSMA-SCA) is established to increase the penetrating capability through the entire search region. The alteration with input boundaries with chaotic map is thought about to make the hybridization SMA enhancer with SCA technique which is especially proficient to track down the ideal arrangement over the hunt locale.

This technique is unrivaled as the populace based enhancers are more reasonable to tackle ongoing issue since they can ready to stay away from the caught into nearby optima and investigate the pursuit district just as take advantage of worldwide ideal arrangement more steady than the individual based analyzer. The pseudo code and flow chart for proposed hCSMA-SCA method is presented in **Fig.3.6a and Fig.3.6b.**

INPUTS: Populations extent is taken as N then the nos. of maximum iterations are taken as iter_{MAX}

OUTPUTS: The positions for slime moulds in adding its consequence of the fitness

Initializations of the random populations by singer function of chaotic map with upgrade the positions of search agent.

$$X_{K+1} = v\left[7.86X_K - 23.31X_K^2 + 28.75X_K^3 - 13.302875X_K^4\right]$$

While (iteration $< \text{iter}_{MAX}$)

Compute Slime mould's significances for fitness

Improvement of fitness values by applying approaching foods strategies

$$\overrightarrow{S(\text{iter}_{current}+1)} = \begin{cases} \vec{S_b} + \overrightarrow{ub}.(\vec{Y}.\overrightarrow{S_A(\text{iter}_{current})} - \overrightarrow{S_B(\text{iter}_{current})}); & R_N < P \\ \overrightarrow{uc}.\overrightarrow{S(\text{iter}_{current})}; & R_N \geq P \end{cases}$$

Calculate $$\overrightarrow{Y_{sequence}}(i) = \begin{cases} 1 + R_N .\log\left(\dfrac{Optimal_{FIT} - X(i)}{Optimal_{FIT} - Worst_{FIT}} + 1\right); & R_N < P \\ 1 - R_N .\log\left(\dfrac{Optimal_{FIT} - X(i)}{Optimal_{FIT} - Worst_{FIT}}\right); & R_N \geq P \end{cases}$$

For all search agents upgraded P, $\overrightarrow{ub}$ also $\overrightarrow{uc}$

upgrades current positions by

$$\overrightarrow{S*} = \begin{cases} R_N(Upper_B - Lower_B) + Lower_B; & R_N < e \\ \overrightarrow{S_b(\text{iter}_{current})} + \overrightarrow{ub}.(Y.\overrightarrow{S_A(\text{iter}_{current})} - \overrightarrow{S_B(\text{iter}_{current})}); & R_N < P \\ \overrightarrow{uc}.\overrightarrow{S(\text{iter}_{current})}; & R_N \geq P \end{cases}$$

End For

Do $\text{iter}_{current} = \text{iter}_{current} + 1$

End While **Returns** best value of fitness from calculate $\overrightarrow{S_b}$

Initializations of $\overrightarrow{S*}$ for search agents through final locations achieved by way of slime moulds optimizer

Do Estimated all search agent through their objective functions

Upgraded the best values of fitness attained so far

Upgraded the randomness by r_1, r_2, r_3 & r_4

if $r_4 < 0.5$ ***Upgraded*** the locations of search agent through

$$\overrightarrow{S*}(\text{iter}+1) = \overrightarrow{S_b}(\text{iter}) + r_1 \times \sin(r_2) \times \left|r_3 \times D_m(\text{iter}) - \overrightarrow{S_b}(\text{iter})\right|$$

else ***Upgraded*** the locations of search agent through

$$\overrightarrow{S*}(\text{iter}+1) = \overrightarrow{S_b}(\text{iter}) + r_1 \times \cos(r_2) \times \left|r_3 \times D_m(\text{iter}) - \overrightarrow{S_b}(\text{iter})\right|$$

End **While** ($iter < iter_{MAX}$)

Returns the best significance of optimal solutions. Saved the significant value of standard deviations and worst, mean fitness, best and recorded overall optimal assessment create over consecutive trial run.

Fig.3.6a: PSUDO code for hCSMA-SCA algorithm

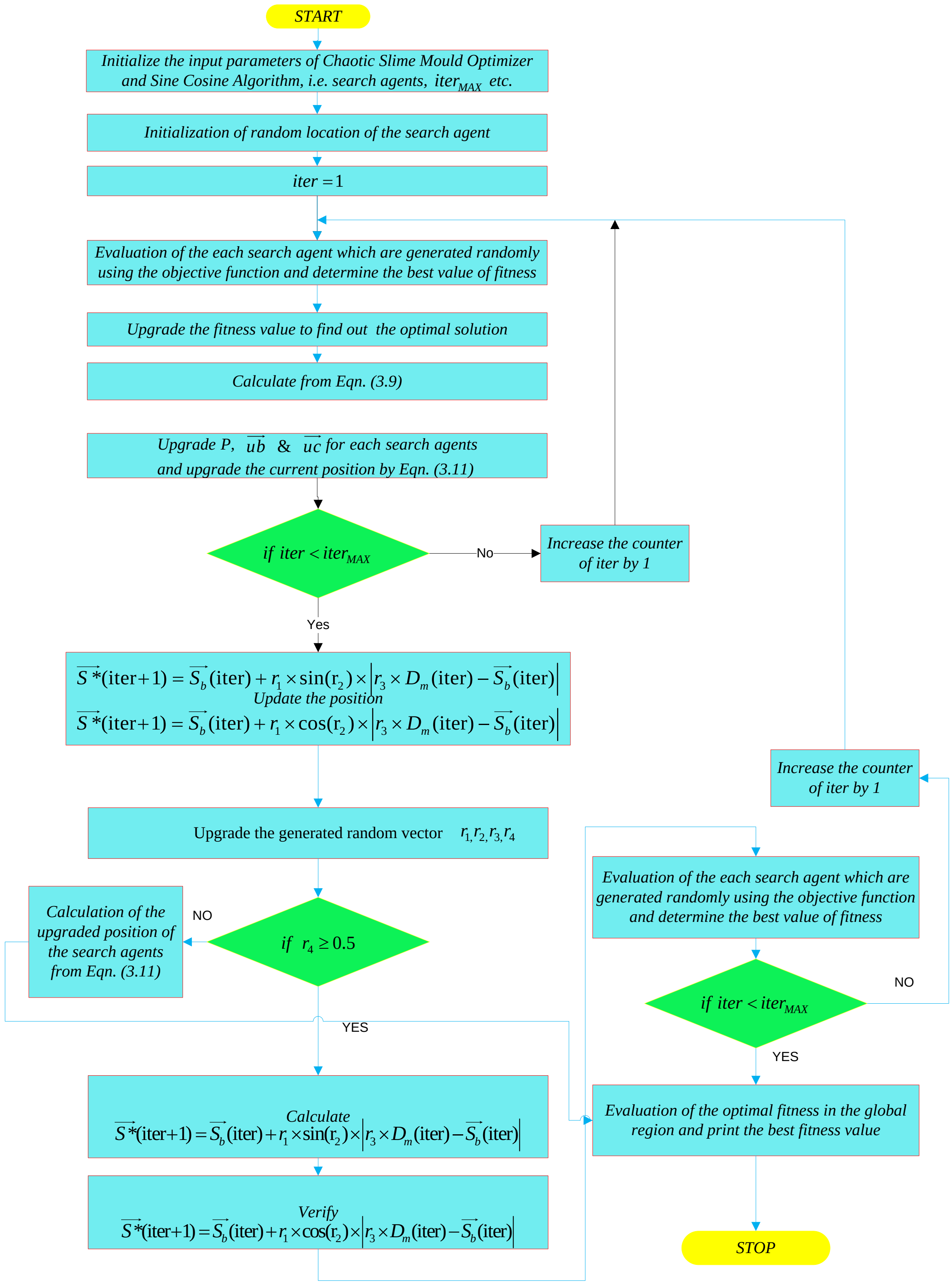


Fig.3.6b: New proposed hybrid CSMA-SCA search algorithm

hCSMA-SCA Algorithm

Step I: Initialize of input parameter as well as maximum no. of iteration.

Step II: Initialize of locations for Slime moulds.

Step III: Initialize of the populations in random manners using singer function of the chaotic map.

Step IV: Upgrade positions of search agents by singer function of chaotic maps, i.e.

$$X_{K+1} = \nu\left[7.86X_K - 23.31X_K^2 + 28.75X_K^3 - 13.302875X_K^4\right]$$

Step V: Checked whether current iterations are less than total iterations.

Step VI: Compute value of the fitness of Slime moulds.

Step VII: Advancement of the fitness values for find $\overrightarrow{S_b}$, optimal solutions.

Step VIII: Compute $\vec{Y}$ using the eqn. (3.9).

Step IX: Advancement of the value P, $\overrightarrow{ub}$ then $\overrightarrow{uc}$ for all search agent and upgrading current positions through eqn. (3.11).

Step X: Intensification of current iteration number through 1.

Step XI: Find the best value for fitness by calculate $\overrightarrow{S_b}$.

Step XII: Stated algorithm parameter and identifies input parameter that are defined through eqn. (3.1) as well as eqn. (3.2). The optimizer improve and create random numbers of sets of solution for specified problems, so that this has an essentially benefit over large explorations.

Step XIII: Initialize of search agent, i.e. numbers of solution ($\overrightarrow{S*}$).

Step XIV: Calculate those values for search agents over objective functions.

Step XV: Upgrade the best solutions.

Step XVI: Upgrade the values of r_1, r_2, r_3, r_4.

Step XVII: Upgrade position of search agents through eqn. (3.3).

Step XVIII: If, $iter_{Current} < iter_{MAX}$, then best solutions can find as the global optimal solutions.

3.3.3.2. Hybrid Chaotic Harris Hawks-Sine Cosine Optimization Algorithm

A new important hybrid algorithm is established by relating chaotic maps with the HHO as well as the SCA method i.e. hCHHO-SCA**,** include exploratory as well as exploitative phase that is stimulated by surprise attacks, the natures of explorations of prey and various strategies are based upon aggressive attacked phenomenon of the harris hawks birds. This is one of the gradient-free with consideration of inhabitants based calculations for the new optimization strategy, which will be helpful to detail on any kinds of optimization issues. The optimizer hCHHO-SCA have certain major performances in the phases of explorations. Not only this, but also had major approach in adaptation from phases of explorations to the phases of exploitations.

A mind boggling social nature has been followed by the harris hawks to track and hop on their prey. Searching for the prey, surprising leap, and different assaulting procedures play out the explorative and that times of this technique. Hybrid combinations of the hCHHO-SCA method is revealed in **Fig.3.7** and novel hybrid optimization process can scientifically described in eqn. (3.53) to the eqn. (3.56);

$$X_m(\text{iter}+1) = X_m(\text{iter}) + r_1 \times \sin(r_2) \times \left| r_3 \times D_m(\text{iter}) - X_m(\text{iter}) \right| \quad (3.53)$$

$$X_m(\text{iter}+1) = X_m(\text{iter}) + r_1 \times \cos(r_2) \times \left| r_3 \times D_m(\text{iter}) - X_m(\text{iter}) \right| \quad (3.54)$$

$$X_m(\text{iter}+1) = \begin{cases} X_m(\text{iter}) + r_1 \times \sin(r_2) \times \left| r_3 \times D_m(\text{iter}) - X_m(\text{iter}) \right|; & if \quad r_4 < 0.5 \\ X_m(\text{iter}) + r_1 \times \cos(r_2) \times \left| r_3 \times D_m(\text{iter}) - X_m(\text{iter}) \right|; & if \quad r_4 \geq 0.5 \end{cases}$$

(3.55)

Where r_4 may be symbolized as the random numbers between [0, 1]. The method created on suggested procedure may be balanced the exploitations through explorations towards get an auspicious solution in zone of search area and finally meets towards find global optimum solution using the eqn. (3.55). **Fig.3.8a and Fig.3.8b** display the pseudo code and flow chart of proposed method.

$$r_1 = \left(2 - iter \times \frac{2}{iter_{MAX}} \right) \tag{3.56}$$

hCHHO-SCA Algorithm

Step I: Initialize of input parameter and maximized no. of iteration.

Step II: Initialize of location of Harris Hawks.

Step III: Initialize the random populations by singer function of chaotic maps.

Step IV: Updated the positions of the search agents through singer function of chaotic maps.

$$X_{K+1} = \nu \left[7.86 X_K - 23.31 X_K^2 + 28.75 X_K^3 - 13.302875 X_K^4 \right]$$

Step V: Checked whether current iterations are less than total no. of iterations.

Step VI: Compute value of the fitness for all Harris hawks.

Step VII: Upgrade fitness value to find the optimum solutions by the eqn. (3.12).

Step VIII: Compute $X_m(\text{iter})$ from the eqn. (3.14).

Step IX: Upgrade r_1, r_2, r_3, r_4 & b for all search agent.

Step X: Rise the current iterations through 1.

Step XI: Find best fitness from eqn. (3.14).

Step XII: State parameters then identify input parameter that well-defined by the eqn. (3.1) as well as eqn. (3.2). Step-XIII: Initialization of search agents, i.e. number of solutions (X_m).

Step XIV: Calculate these search agents through the objective functions.

Step XV: Upgrade best solutions.

Step XVI: Upgrade value of randomness r_1, r_2, r_3, r_4.

Step XVII: Upgrade position of the search agents through eqn. (3.3).

Step XVIII: If, $iter_{Current} < iter_{MAX}$, best solutions can find as the global optimal.

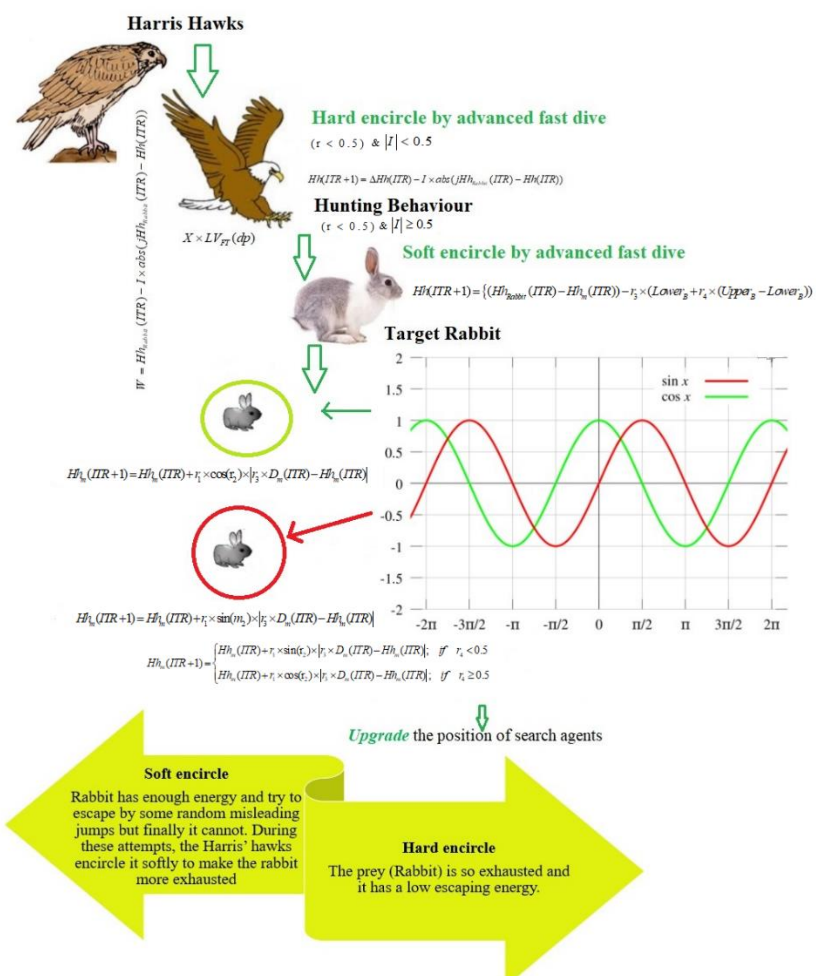


Fig.3.7: New hybrid CHHO-SCA search algorithm

INPUTS: The population sizes are N and the nos. of maximum iterations are $iter_{MAX}$

OUTPUTS: The positions of the prey (rabbits) in adding its implication of the fitness by singer function of chaotic maps

Initializations of random populations by $X_{K+1} = v\left[7.86X_K - 23.31X_K^2 + 28.75X_K^3 - 13.302875X_K^4\right]$

While (iterations < $iter_{MAX}$)

Compute Harris hawks' significances of the fitness

Static the factor X_{Rabbit} for greatest locations of rabbits (prey)

for (all Harris hawks (X_m)) , **Do** Updated energies at preliminary conditions EN_O

if $|EN| \geq 1$ **then** Positions vectors update using $EN = 2\times EN_0 \times\left(1-\frac{iter}{iter_{MAX}}\right)$ → **Phases of the Exploration**

else if $b \geq 0.5$ **then** $\text{X(iter+1)} = \{X_{Hawks}^{RND}(\text{iter}) - r_1 \times abs(X_{Hawks}^{RND}(\text{iter}) - 2\times r_2 \times X(\text{iter}))$

else if $b < 0.5$ **then** $\text{X(iter+1)} = \{(\text{X}_{Rabbit}(\text{iter}) - X_a(\text{iter})) - r_3 \times (Lower_B + r_4 \times (Upper_B - Lower_B))$

if $|EN| < 1$ **then** → **Phases of the Exploitation**

$\text{X(iter+1)} = \Delta X(\text{iter}) - EN \times abs(jX_{Rabbit}(\text{iter}) - X(\text{iter}))$

if $(\text{r} \geq 0.5)$ & $|EN| \geq 0.5$ **then** → **Soft circles**

Location vectors restructured by $\Delta X(\text{iter}) = (X_{Rabbit}(\text{iter}) - X(\text{iter}))$

else if $(\text{r} \geq 0.5)$ & $|EN| < 0.5$ **then** → **Hard circles**

Location vectors restructured by $\text{X(iter+1)} = X_{Rabbit}(\text{iter}) - EN \times abs(\Delta X(\text{iter}))$

else if $(\text{r} < 0.5)$ & $|EN| \geq 0.5$ **then** → **Soft circles by advanced fastest dive**

Location vectors restructured by $V = X_{Rabbit}(iter) - EN \times abs(jX_{Rabbit}(iter) - X(iter))$

else if $(\text{r} < 0.5)$ & $|EN| < 0.5$ **then** → **Hard circles by advanced fastest dive**

Location vectors restructured by $\text{X(iter+1)} = \Delta X(\text{iter}) - EN \times abs(jX_{Rabbit}(\text{iter}) - X(\text{iter}))$

end

end

end

end

Initializations of X_m for search agents by final locations achieved through Harris Hawks

Do Estimated every search agent by objective functions

Upgraded the best values of fitness accomplished so far

Upgraded random numbers by r_1, r_2, r_3 & r_4

if $r_4 < 0.5$ ***Upgraded*** locations of search agent through

$$X_m(\text{iter+1}) = X_m(\text{iter}) + r_1 \times \sin(\text{r}_2) \times |r_3 \times D_m(\text{iter}) - X_m(\text{iter})|$$

else ***Upgrades*** the locations of search agent through

$$X_m(\text{iter+1}) = X_m(\text{iter}) + r_1 \times \cos(\text{r}_2) \times |r_3 \times D_m(\text{iter}) - X_m(\text{iter})|$$

End **While** **(** $iter < iter_{MAX}$ **)**

Returns best value of optimum solutions. Saved the values of mean fitness, standard deviations and best, worst and recorded the all optimal assessments found over sequential trial run.

Fig.3.8a: PSEUDO code for proposed hCHHO-SCA algorithm

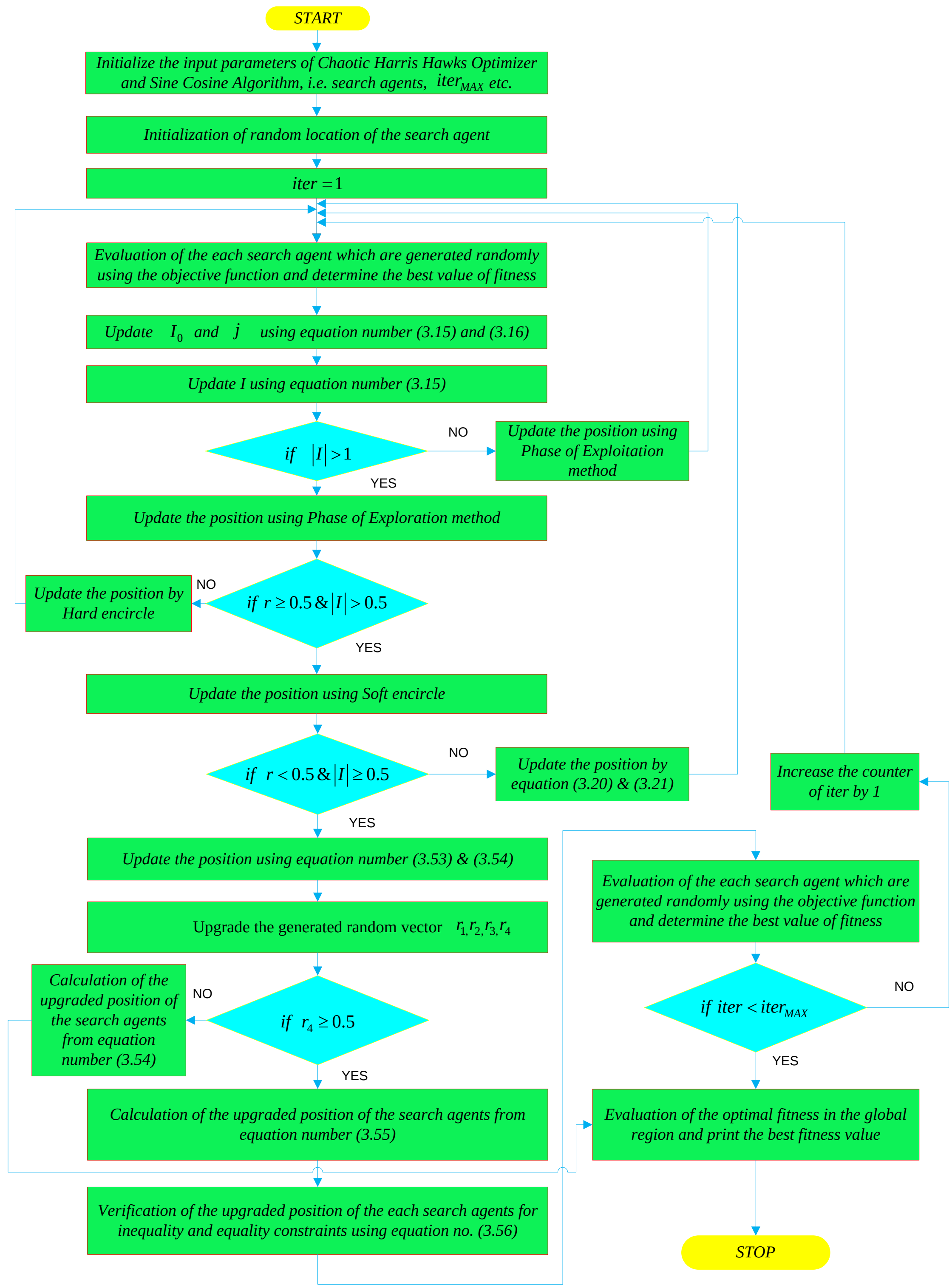


Fig. 3.8b: The flow chart of proposed hCHHO-SCA algorithm

3.4 HYPOTHESIS TESTING

There are two major types of hypothesis testing known as null and alternative hypothesis, which are mostly used by researches. The statistical testing consist of parametric and non-parametric test, shown in **Fig.3.9.** In the research work, hypothesis is mostly in a specific way that can testable to predict what kind of expectations can happen in research that based upon a theory. Hypothesis helps to introduce several questions related to research and helps to find out the expected outcomes of the specific problems. It is a part of scientific methods which form a basis of some scientific experiments. In this research work wilcoxon rank sum test and t-test have been taken into consideration to check the efficiency of the proposed methods to solve PBUCP.

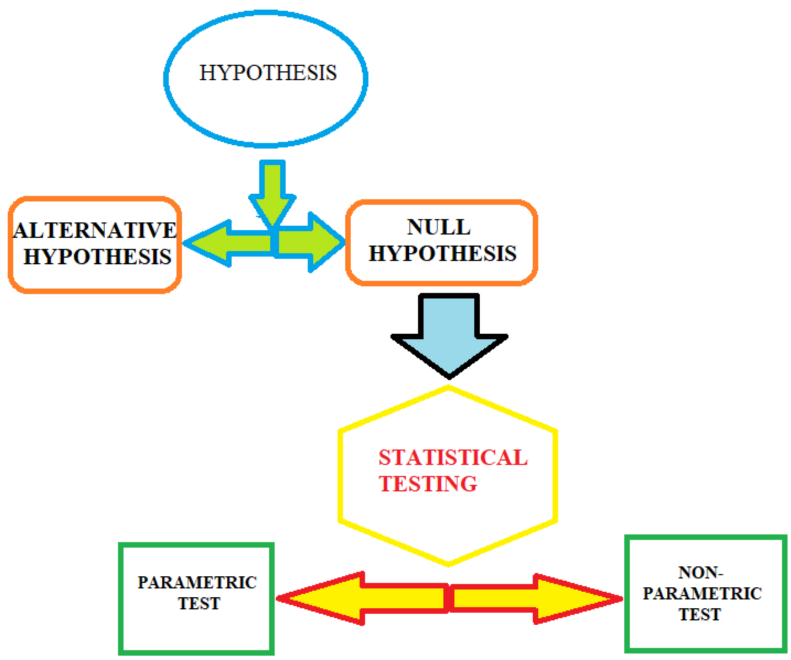


Fig.3.9: Types of hypothesis test

There are several types of hypothesis used in modern research work, such as, simple, complex, directional, non-directional, associative hypothesis, null and alternative hypothesis. To solve PBUCP by using proposed optimizer. The following hypothesis testing techniques are used.

3.4.1 Wilcoxon Rank Sum Test

The wilcoxon rank sum test is one type of nonparametric statistical test, which is used to make comparison between two groups in a paired. This test was created by an American scientist and statistician Frank Wilcoxon in 1945. This test is essential to calculate difference between the sets and analyze those difference to establishment the statistically significant to know that how these two sets differs from another pair. This test of hypothesis test for non-parametric statistics are applied for the population data, which can only rank but does not give any numerical value. In case of nonparametric distribution, it does not consists of parameters. This hypothesis test may be used for testing the null hypothesis of two populations that have continuous type of distributions.

3.4.2 t-Test

The t-test is one type of an inferential statistical test that is used to verify if there are any significant differences in between the mean of the two groups that are related with certain number of features. The mathematical expressions for t-test is discussed in eqn. (3.57).

$$t_{test} = \frac{Mean_1 - Mean_2}{\frac{std}{\sqrt{ss}}} \tag{3.57}$$

Here, t_{test} is defined as the t-value, $Mean_1$ and $Mean_2$ represents the average value of the two group of sets. std represents standard deviations of the two groups of sets and ss represents the sample sizes.

3.5 CONCLUSION

In this chapter the new methodologies are developed based on the hunting natures of harris hawk birds, food searching strategies as well as wrapping behaviors of slime moulds, functions of sine and cosine waves, chaotic maps and adaptive searches technique. Further, three new variants of algorithms has been proposed in this chapter.

The mathematical formulation has done to improve the phase of exploitation and exploration of the existing SMA, HHO and SCA optimizers. Pseudo code and steps of algorithms are explored in depth.

In the upcoming chapters, these proposed algorithm will be utilized to test the benchmark problems and PBUCP problem with impact of PEVs and RES.

CHAPTER-4

TESTING AND VALIDATION OF HYBRID OPTIMIZERS

4.1 INTRODUCTION

Today the electric power is important in our daily life and it play a major role for improvement of Indian economy. The development of various power sectors is growing day by day. Thus, the economy is mostly depend upon the electrical power. Moreover the invention of new technologies are affected our modern life. Rapidly developing the software technologies are modified the working environment for engineers and manufacturers those who are associated with power sectors. Using the modern software technology, the equipment of power system are modified. Thus the facilities and system reliability have been increased. To solve optimization problem, the computational methodologies are take into consideration. In computations the evolutionary optimizer is used as one of the most important system which are inspired by nature. Mostly the natural selection processes are considered in optimization for design and implementation. The multi objective optimization issues are difficult to solve due to its high dimensions. So, the computational methods are useful to solve the multi objective optimization problems.

4.2 OPTIMIZATION PROBLEM

The feasibility of any optimizer can be verified by using test systems. The standard test systems are made by some benchmark functions through which the ability of the optimizer are tested. These benchmark functions are taken as test functions. The general performance, convergence rate, precision and robustness of optimization algorithms are useful to estimate the characteristics of the optimization methods. In the field of optimization, some problems are related with single objective problems and some of are related with multi objective problems. So, in the various type of difficult situations the optimizer have to cope with those problems.

In this research work 23 standard benchmark functions have been taken into consideration. The first test function is named as unimodal test function which is taken as F1 to F7 out of 23 test functions. The second one is multi modal test functions which is taken as F8 to F12 and the third function is known as fixed dimension benchmark functions which is taken as F13 to F23. Each functions have specific dimensions and characteristics. The proposed hybrid optimization methods have been tested on unimodal, muntimodal and fixed dimension benchmark functions. The 30 run and 500 iterations are taken to check the feasibility of the proposed optimizer.

The optimum value or the best fitness value have been found through optimizations. The optimizations related problem includes minimize the undesired factor and maximize the desired factor using scalar objective as well as multi-objective optimization problems.

The metaheuristics optimization algorithms have been used as major techniques to obtain the optimum solutions in the field of real multidisciplinary engineering design problems. These techniques are mostly useful from the stochastic operators which can make them different from the deterministic approaches. For the given problems, the deterministic optimizer can reliable to determine same answer by including the same initial starting point. Though this nature of the optimizer, the local optimum solutions are entrapped, that can consider as disadvantage for the deterministic optimizer algorithms. The local optimal solutions are trapped into the local search region as well as accordingly failure to find the optimum solution in the global search region. So that, in the field of optimization, it have exceptionally large number of solutions in local search region whereas the deterministic optimization algorithms are not reliable to find the optimal solutions throughout the global search region. In general, to solve the optimization problem it requires solution of the set of non-linear or linear equations which are subjected to different types of inequality and equality constraints. The mathematical formula of optimization problem is given below in eqn. (4.1) to eqn. (4.5).

Minimize, $F(X, \mathrm{Y})$ (4.1)

Subjected to, $g_i(X, \mathrm{Y}) \geq 0 \quad (i = 1, 2, ...q)$ (4.2)

$h_j(X, \mathrm{Y}) = 0 \quad (\mathrm{j} = 1, 2, ...\mathrm{p})$ (4.3)

$$x_i^{\min} \le x_i \le x_i^{\max} \qquad (i = 1, 2, ..., n) \tag{4.4}$$

$$y_j^{\min} \le y_j \le y_j^{\max} \qquad (\mathrm{j} = 1, 2, ..., \mathrm{m}) \tag{4.5}$$

Where, $g_i(X, \mathrm{Y})$ represents inequality constraints sets for vector measurements. $h_j(X, \mathrm{Y})$ represents the non-linear equality constraints set. Y is the vector dependent variables $[\mathrm{y}_{1,} \; y_{2,......,} y_m]^T$. X is denoted as vector control variable $[\mathrm{x}_{1,} \; x_{2,......,} x_m]^T$. $x_i^{\min}$ and $x_i^{\max}$ are represented as upper and lower bound of control variables x_i . $y_j^{\min}$ and $y_j^{\max}$ are represented as lower and upper bound dependent on variable y_j . In modern years, some major new optimization methods have been useful to power sectors.

4.3 STANDARD BENCHMARK PROBLEMS

In the present study, the performances of the proposed hybrid optimizers have been tested for uni-modal, multi-modal, fixed dimension and multidisciplinary engineering design problems. As per research objectives the 23rd standard benchmark functions are taken into considerations. The scientific formulation of unimodal, multi-modal and fixed dimension benchmarks is presented in Table-4.1, Table-4.2 and Table-4.3 respectively. The 3D view of unimodal and multi-modal with fixed dimension benchmark functions are shown in **Fig.4.1**, **Fig.4.2** and **Fig.4.3** respectively.

Table 4.1: Unimodal benchmark functions

Function	Dim	Range	$f_{\min}$
$f_1(x) = \sum_{i=1}^{n} x_i^2$	30	[-100 , 100]	0
$f_2(x) = \sum_{i=1}^{n} \lvert x_i \rvert + \prod_{i=1}^{n} \lvert x_i \rvert$	30	[-10 ,10]	0
$f_3(x) = \sum_{i=1}^{n} (\sum_{j-1}^{i} x_j)^2$	30	[-100 , 100]	0
$f_4(x) = \max_i \{\lvert x_i \rvert, 1 \le i \le n\}$	30	[-100 , 100]	0
$f_5(x) = \sum_{i=1}^{n-1} [100(x_{i+1} - x_i^2)^2 + (x_i - 1)^2]$	30	[-30 ,30]	0
$f_6(x) = \sum_{i=1}^{n} ([x_i + 0.5])^2$	30	[-100 , 100]	0
$f_7(x) = \sum_{i=1}^{n} i x_i^4 + random[0,1]$	30	[-1.28, 1.28]	0

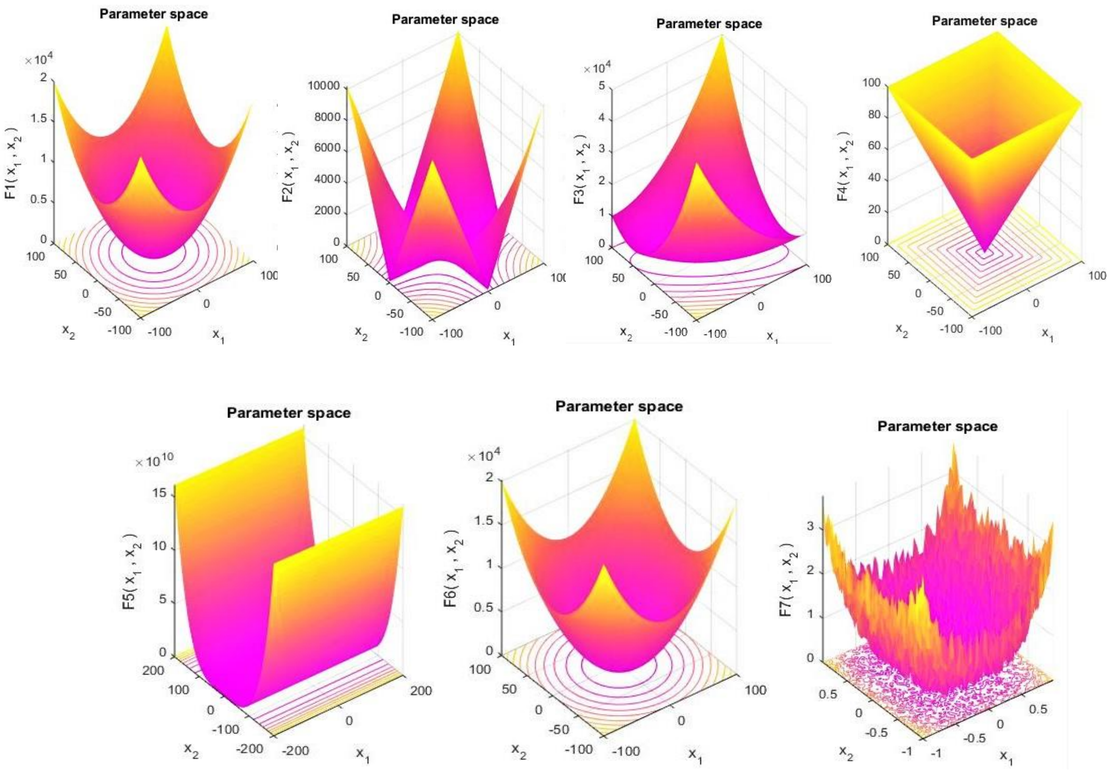


Fig.4.1: 3D-view of unimodal benchmark functions

Table-4.2: Multi-modal benchmark functions

Function	Dim	Range	$f_{\min}$
$F_8(x)=\sum_{i=1}^{n}-x_i\sin(\sqrt{\lvert x_i\rvert})$	30	[-500, 500]	-418.98295
$F_9(x)=\sum_{i=1}^{n}[x_i^2-10\cos(2\pi x_i)+10]$	30	[-5.12, 5.12]	0
$F_{10}(x)=-20\exp(-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{n}x_i^2})-\exp(\frac{1}{n}\sum_{i=1}^{n}\cos(2\pi x_i)+20+c$	30	[-32, 32]	0
$f_{11}(x)=1+\sum_{i=1}^{n}\frac{x_i^2}{4000}-\prod_{i=1}^{n}\cos\frac{(x_i)}{\sqrt{i}}$	30	[-600, 600]	0
$F_{12}(x)=\frac{\pi}{n}\left\{10\sin(\pi y_1)+\sum_{i=1}^{n-1}(y_i-1)^2[1+10\sin^2(\pi y_{i+1})]+(y_n-1)^2\right\}+\sum_{i=1}^{n}u(x_i,10,100,4)$ $y_i=1+\frac{x_i+1}{4}$ $u(x_i,a,k,m)=\begin{cases}k(x_i-a)^m & x_i>a\\ 0 & -a<x_i<a\\ k(-x_i-a)^m & x_i<-a\end{cases}$	30	[-50,50]	0
$F_{13}(x)=0.1\left\{\sin^2(3\pi x_1)+\sum_{i=1}^{n}\begin{bmatrix}(x_i-1)^2\left[1+\sin^2(3\pi x_i+1)\right]\\ +(x_n-1)^2\left[1+\sin^2(2\pi x_n)\right]\end{bmatrix}\right\}+\sum_{i=1}^{n}u(x_i,5,100,4)$	30	[-50,50]	0

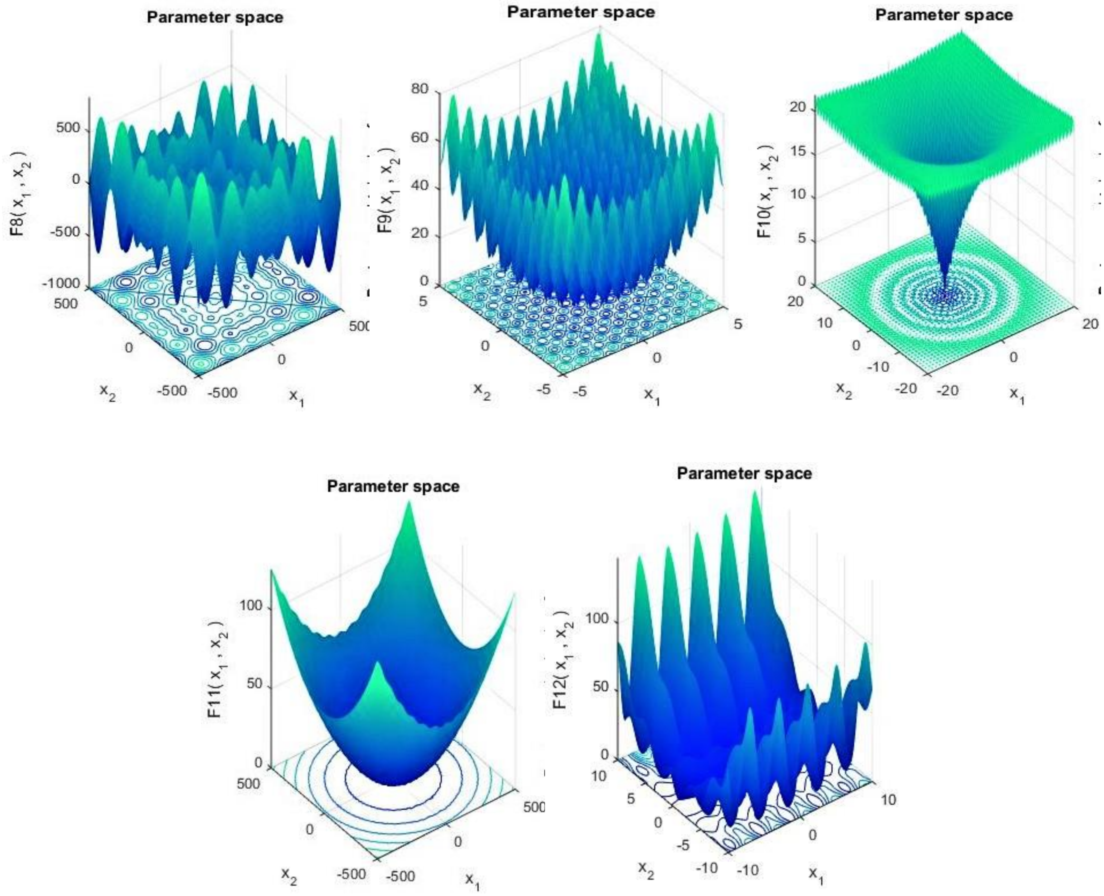
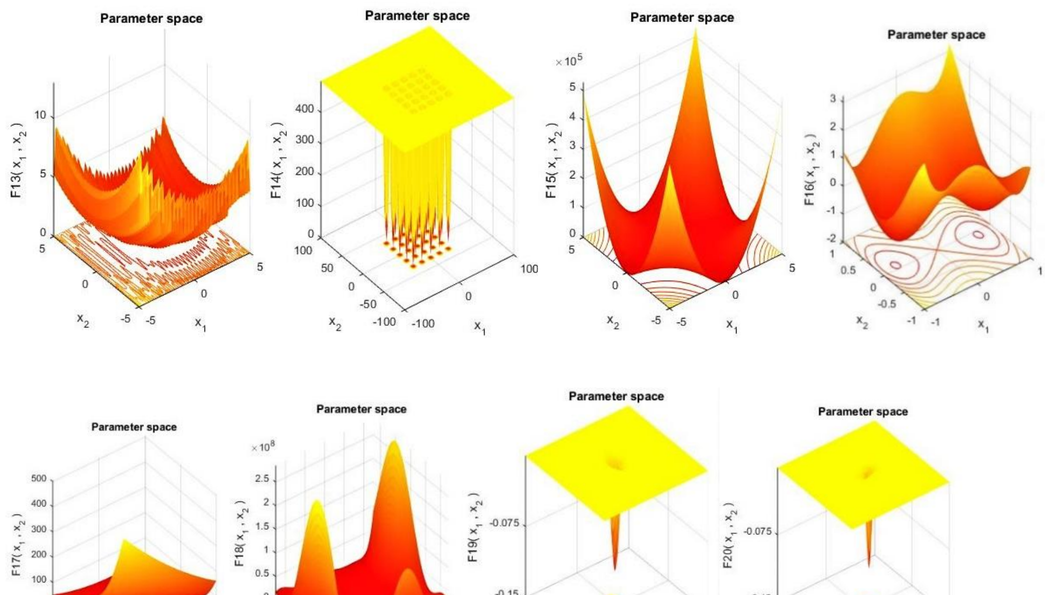


Fig.4.2: 3D-view of multimodal benchmark functions



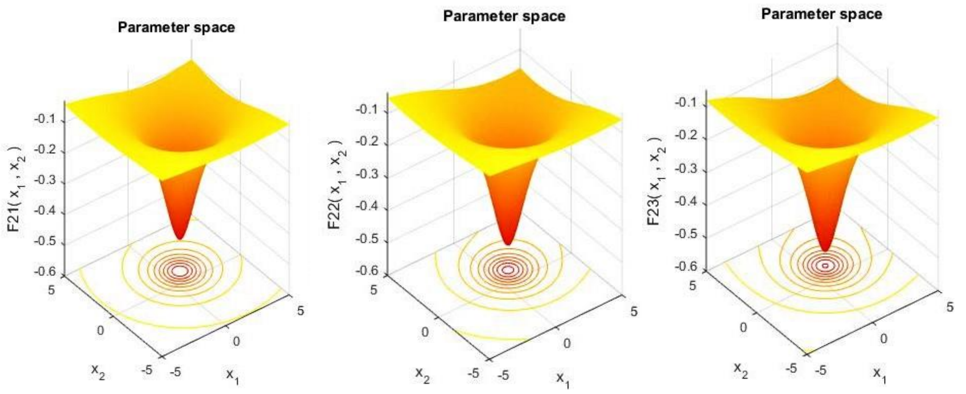


Fig.4.3: 3D-view of fixed dimension benchmark functions

Table 4.3: Fixed dimension benchmark functions

Function	Dim	Range	$f_{\min}$
$f_{14}(x)=\left[\frac{1}{500}+\sum_{j=1}^{2}5\frac{1}{j+\sum_{i=1}^{n}(x_i-a_{ij})^6}\right]^{-1}$	2	[-65.536, 65.536]	1
$F_{15}(x)=\sum_{i=11}^{11}\left[a_i-\frac{x_1\left(b_i^2+b_ix_2\right)}{b_i^2+b_ix_3+x_4}\right]^2$	4	[-5, 5]	0.00030
$F_{16}(x)=4x_1^2-2.1x_1^4+\frac{1}{3}x_1^6+x_1x_2-4x_2^2+4x_2^4$	2	[-5, 5]	-1.0316
$F_{17}(x)=\left(x_2-\frac{5.1}{4\pi^2}x_1^2+\frac{5}{\pi}x_1-6\right)^2+10\left(1-\frac{1}{8\pi}\right)\cos x_1+10$	2	[-5, 5]	0.398
$F_{18}(x)=\left[1+(x_1+x_2+1)^2\left(19-14x_1+3x_1^2-14x_2+6x_1x_2+3x_2^2\right)\right]$ $\times\left[30+\left(2x_1-3x_2\right)^2\times\left(18-32x_1+12x_1^2+48x_2-36x_1x_2+27x_2^2\right)\right]$	2	[-2,2]	3
$f_{19}(x)=-\sum_{i=1}^{4}c_i\exp\left(-\sum_{j=1}^{3}a_{ij}(x_j-p_{ij})^2\right)$	3	[1, 3]	-3.32
$f_{20}(x)=-\sum_{i=1}^{4}c_i\exp\left(-\sum_{j=1}^{6}a_{ij}(x_j-p_{ij})^2\right)$	6	[0, 1]	-3.32
$f_{21}(x)=-\sum_{i=1}^{5}\left[(x-a_i)\ (x-a_i)^T+c_i\right]^{-1}$	4	[0,10]	-10.1532
$f_{22}(x)=-\sum_{i=1}^{7}\left[(x-a_i)\ (x-a_i)^T+c_i\right]^{-1}$	4	[0, 10]	-10.4028
$f_{23}(x)=-\sum_{i=1}^{10}\left[(x-a_i)\ (x-a_i)^T+c_i\right]^{-1}$	4	[0, 10]	-10.5363

4.4 ENGINEERING BENCHMARK PROBLEMS

As per research objectives, one of the objectives is to validate the performances of proposed algorithms in the arena of multidisciplinary engineering design optimizations problems. Thus, the standard eleven types of engineering design problems have been taken into considerations. Such as, Pressure vessel problem, Three-bar truss problem, welded beam problem, Cantilever Beam Design problem, Tension/compression spring design problem, Gear Train Design problem, Speed reducer, Belleville spring, coil compression and multidisc clutch are included. The complete description of those types of engineering design problems have been stated in the following section.

4.4.1 Three-Bar Truss Problem

Three-Bar Truss Problem is a mechanical design issue taken from [206]. The main objective for this type of design issues are to minimize the weight. This weight contains three kinds of constraints, such as, buckling, deflection and stress constraint. The scientific modal of Three Bar Truss issues are shown in eqn. (4.14) through eqn. (4.15c) and **Fig.4.4**.

Consider $\vec{x} = [x_1, x_2] = [A_1, A_2]$ (4.14)

Minimize, $f(\vec{x}) = \left(2\sqrt{2}x_1 + x_2\right) * l$ (4.15)

Subject to:

$$g_1(\vec{x}) = \frac{\sqrt{2}x_1 + x_2}{\sqrt{2}x_1^2 + 2x_1x_2} P - \sigma \leq 0 \quad (4.15a)$$

$$g_2(\vec{x}) = \frac{x_2}{\sqrt{2}x_1^2 + 2x_1x_2} P - \sigma \leq 0 \quad (4.15b)$$

$$g_3(\vec{x}) = \frac{1}{\sqrt{2}x_2 + x_1} P - \sigma \leq 0 \quad (4.15c)$$

Variable ranges are: $0 \leq x_1$, $x_2 \leq 1$

Where l = 100 cm, P = 2KN/ cm^2 , σ = 2 KN/ cm^2

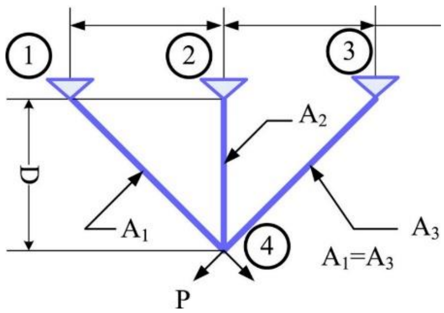


Fig.4.4: Three-bar truss problem

4.4.2 Pressure Vessel Problem

The second multidisciplinary design problem is taken as Pressure Vessel Design issue [206] shown in **Fig.4.5**. The main objective functions of this special problem is to decrease or minimization of total cost including the materials cost, welding as well as forming of the vessel which is in cylindrical form. There are four different types of variables used to design the pressure vessel problem, i.e. head thickness (T_h), shell thickness (T_s), without considering head, the length of cylindrical unit (L). The both ends of the pressure vessel has covered and head of the pressure vessel has taken as shape like hemisphere. The mentioned problem is subjected to four types of constraints and the scientific construction of the pressure vessel design problems are shown in eqn. (4.16) through eqn. (4.17d).

Consider, $\vec{x} = [x_1 x_2 x_3 x_4] = [T_s T_h R L]$ (4.16)

Minimize, $f(\vec{x}) = 0.6224 x_1 x_3 x_4 + 1.7781 x_2 x_3^2 + 3.1661 x_1^2 x_4 + 19.84 x_1^2 x_3$ (4.17)

Subjected to:

$g_1(\vec{x}) = -x_1 + 0.0193 x_3 \leq 0$ (4.17a)

$g_2(\vec{x}) = x_3 + 0.00954 x_3 \leq 0$ (4.17b)

$g_3(\vec{x}) = -\pi x_3^2 x_4 - \frac{4}{3}\pi x_3^3 + 1296000 \leq 0$ (4.17c)

$g_4(\vec{x}) = x_4 - 240 \leq 0$ (4.17d)

Variable ranges are: $0 \le x_1 \le 99$; $0 \le x_2 \le 99$; $10 \le x_3 \le 200$; $10 \le x_4 \le 200$.

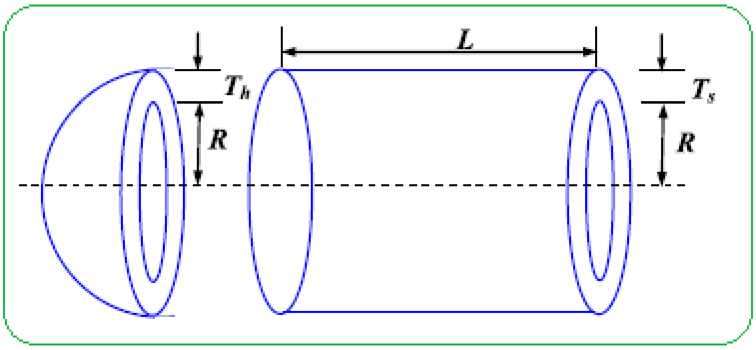


Fig.4.5: Pressure vessel problem

4.4.3 Spring Design Problem

This Problem is the part of multidisciplinary engineering optimizations problem shown in **Fig.4.6**, that is one of the engineering issues related with mechanical parts [206]. The actual objective of this kind of special problem is to decreases the weight of spring. So, the three kinds of designs variables are mostly needed as solution of this issues. These variables are diameter mean coil (D), active coils number (N) and wire diameter (d). The special problem is mainly subjected with constraints that depending upon the surge frequencies, constraint based upon shear stresses and minimum number of deflections. The scientific model for the special problem has been shown in eqn. (4.18) through eqn. (4.19e).

Consider $\vec{x} = [x_1 x_2 x_3] = [dDN]$ (4.18)

Minimize, $f(\vec{x}) = (x_3 + 2) x_2 x_1^2$ (4.19)

Subjected to: $g_1(\vec{x}) = 1 - \frac{x_2^3 x_3}{71785 x_1^4} \le 0$ (4.19a)

$$g_2(\vec{x}) = \frac{4x_2^2 - x_1 x_2}{12566(x_2 x_1^3 - x_1^4)} + \frac{1}{5108 x_1^2} \le 0 \quad (4.19b)$$

$$g_2(\vec{x}) = \frac{4x_2^2 - x_1 x_2}{12566(x_2 x_1^3 - x_1^4)} + \frac{1}{5108 x_1^2} \le 0 \quad (4.19c)$$

$$g_3(\vec{x}) = 1 - \frac{140.45x_1}{x_2^2 x_3} \leq 0 \quad (4.19d)$$

$$g_4(\vec{x}) = \frac{x_1 + x_2}{1.5} - 1 \leq 0 \quad (4.19e)$$

Variable ranges are: $0.005 \leq x_1 \leq 2.00$; $0.25 \leq x_2 \leq 1.30$; $2.00 \leq x_3 \leq 15.0$

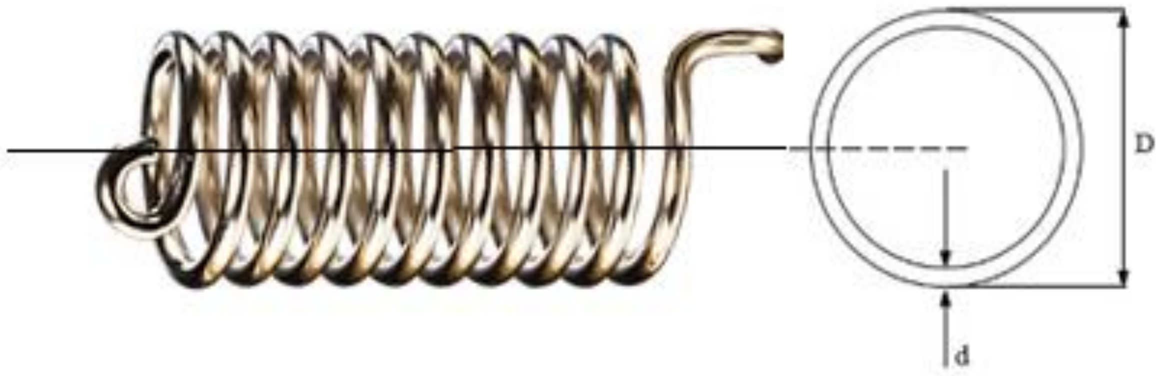


Fig.4.6: Spring design problem

4.4.4 Welded Beam Design Problem

This issues is the another most important design issue shown in **Fig 4.7**, which is taken from [206]. The leading objective of this types of problem is to decrease or minimization of the cost of the fabrication of welded beam which consist of four types of variable, such as, thickness of bar (b), length of the bar including attached part (l), thickness of weld (h) as well as the height of the bar (h). This problem is specially subjected to four types of constraints including Side constraints, Buckling constraints of bar (Pc), Bending stress of the beam (h), End deflection of beam (d) and stress of shear (s). The mathematical description of above mentioned engineering problem is discussed in the following eqn. (4.20) through eqn. (4.22f).

Consider $\vec{x} = [x_1 x_2 x_3 x_4] = [hltb]$ (4.20)

Minimize, $f(\vec{x}) = 1.10471x_1^2 x_2 + 0.04811x_3 x_4 (14.0 + x_2)$ (4.21)

Subject to:

$$g_1(\vec{x}) = \tau(\vec{x}) - \tau_{\max} \le 0, \quad (4.21a)$$

$$g_2(\vec{x}) = \sigma(\vec{x}) - \sigma_{\max} \le 0 \quad (4.21b)$$

$$g_3(\vec{x}) = \delta(\vec{x}) - \delta_{\max} \le 0 \quad (4.21c)$$

$$g_4(\vec{x}) = x_1 - x_4 \le 0 \quad (4.21d)$$

$$g_5(\vec{x}) = P - P_c(\vec{x}) \le 0 \quad (4.21e)$$

$$g_6(\vec{x}) = 0.125 - x_1 \le 0 \quad (4.21f)$$

$$g_7(\vec{x}) = 1.10471x_1^2 + 0.04811x_3x_4(14.0 + x_2) - 5.0 \le 0 \quad (4.21g)$$

Variable ranges are: $0.1 \le x_1 \le 2$; $0.1 \le x_2 \le 10$; $0.1 \le x_3 \le 10$; $0.1 \le x_4 \le 2$

Where $\tau(\vec{x}) = \sqrt{(\tau^{/})^2 + 2\tau^{/}\tau^{//}\frac{x_2}{2R} + (\tau^{//})^2},$ (4.22a)

$$\tau^{/} = \frac{P}{\sqrt{2}x_1x_2}, \tau^{//} = \frac{MR}{J}, M = P\left(L + \frac{x_2}{2}\right), \quad (4.22b)$$

$$R = \sqrt{\frac{x_2^2}{4} + \left(\frac{x_1 + x_3}{2}\right)^2}, \quad (4.22c)$$

$$J = 2\left\{\sqrt{2}x_1x_2\left[\frac{x_2^2}{4} + \left(\frac{x_1 + x_3}{2}\right)^2\right]\right\} \quad (4.22d)$$

$$\sigma(\vec{x}) = \frac{6PL}{x_4x_3^2}, \delta(\vec{x}) = \frac{6PL^3}{Ex_2^2x_4} \quad (4.22e)$$

$$P_c(\vec{x}) = \frac{4.013E\frac{\sqrt{x_3^2x_4^6}}{36}}{L^2}\left(1 - \frac{x_3}{2L}\sqrt{\frac{E}{4G}}\right) \quad (4.22f)$$

$P = 6000lb, L = 14in, \delta_{\max} = 0.25in, E = 30 \times 1^6\ psi,$
$G = 12 \times 10^6\ psi, \tau_{\max} = 13600\ psi, \sigma_{\max} = 3000\ psi$

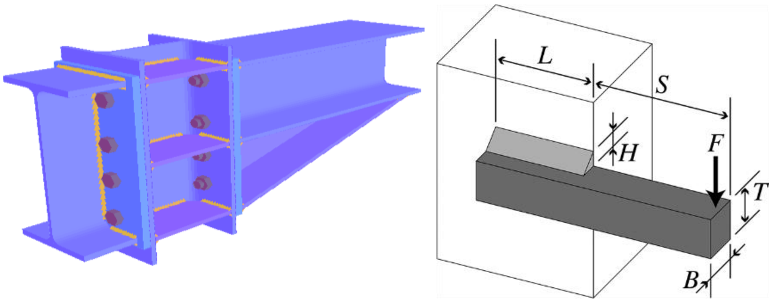


Fig.4.7: Welded beam design problem

4.4.5 Cantilever Beam Design Problem

This problem is one of the most important issues related with civil engineering that is specified as Cantilever Bream Design problem given in **Fig 4.8**. The problem consist of five kinds of the hollow types elements that include squared shape cross sections [206]. The actual objective for this kind of optimizer is to reduce weight of beams. This types of designing issues consist of five kinds of parameters depend upon structure. The thickness of the beam is remained as constant. The scientific formulations of the problem are given from eqn. (4.23) to eqn. (4.24).

The problem formulation is as follows:

Consider $\vec{x} = [x_1 x_2 x_3 x_4 x_5]$

Minimize, $f(\vec{x}) = 0.6224(x_1 + x_2 + x_3 + x_4 + x_5),$ (4.23)

Subject to:

$$g(\vec{x}) = \frac{61}{x_1^3} + \frac{37}{x_2^3} + \frac{19}{x_3^3} + \frac{7}{x_4^3} + \frac{1}{x_5^3} \le 1 \quad (4.24)$$

Variable ranges are: $0.01 \le x_1, x_2, x_3, x_4, x_5 \le 100$

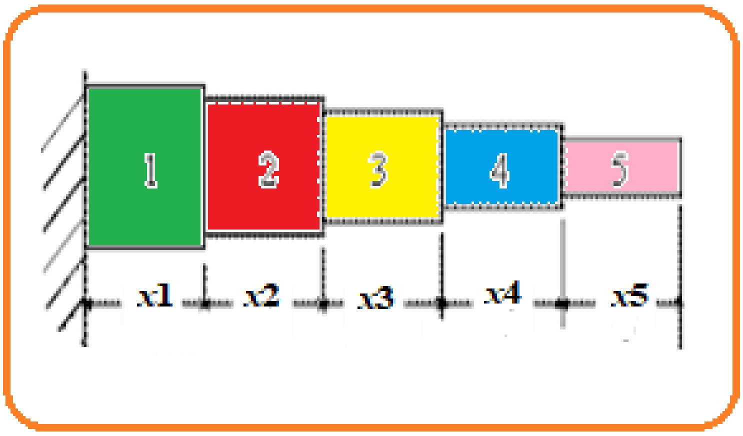


Fig.4.8: Cantilever beam design problem

4.4.6 Gear Train Problem

This optimization issue is known as Gear Train Design problem that contains four kinds of important parameters which are shown in **Fig.4.9** [206]. The actual objective of this type of design problem is to minimization of the scalar values as well as the teeth ratios of gear. Thus, decision variables are included by the numbers of the teeth upon every gear. The scientific model is specified in Eqn. (4.25) to Eqn. (4.26).

Considering $\vec{g} = [g_1 g_2 g_3 g_4] = [M_A M_B M_C M_D]$ (4.25)

Minimizing; $f(\vec{g}) = \left(\frac{1}{6.931} - \frac{g_3 g_4}{g_1 g_4}\right)^2$ (4.26)

Subjected to; $12 \le g_1, g_2, g_3, g_4 \le 60$

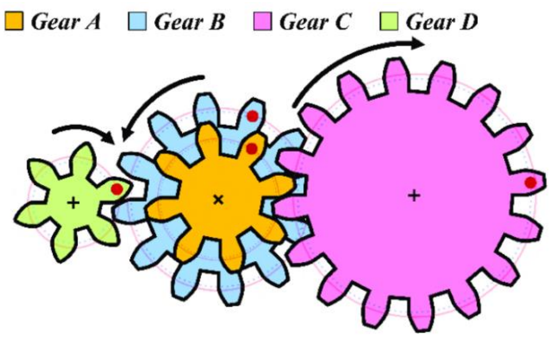


Fig.4.9: Gear train problem

4.4.7 Speed Reducer Problem

The another important special problem is speed reducer shown in **Fig.4.10** [206]. Speed reducer consists of the width of the face s_1, teeth element s_2, numbers of the pinion teeth is denoted as s_3, bearings of the first shaft length is denoted as s_4, the bearings of the second shaft length is denoted as s_5, the first shaft diameter is s_6 and second shaft diameter is s_7; all types of variables can continuous by nature except one variable s_3, which is an integer. The main objective is to reduce the weight of speed reducer which is subjected to some constraints those depended on surface stress and bending stress of the teeth of the gear, shaft's transverse movement or deflection and stress on the shaft. The mathematical model is given from eqn. (4.27) to eqn. (4.28j).

Minimizing; $$f(\vec{s}) = 0.7854 s_1 s_2 (3.3333 s_3^2 + 14.9334 s_3 - 43.0934) - 1.508 s_1 (s_6^2 + s_7^2) + 7.4777 (s_6^3 + s_7^3) + 0.7854 (s_4 s_6^2 + s_5 s_7^2)$$

Subjected to: $$g_1(\vec{s}) = \frac{27}{s_1 s_2^2 s_3} - 1 \le 0 \qquad (4.27)$$

$$g_2(\vec{s}) = \frac{397.5}{s_1 s_2^2 s_3^2} - 1 \le 0 \qquad (4.28a)$$

$$g_3(\vec{s}) = \frac{1.93 s_4^3}{s_2 s_3 s_6^4} - 1 \le 0 \qquad (4.28b)$$

$$g_4(\vec{s}) = \frac{1.93 s_5^3}{s_2 s_3 s_7^4} - 1 \le 0 \qquad (4.28c)$$

$$g_5(\vec{s}) = \frac{1}{110 s_6^3} \sqrt{\left(\frac{745.0 s_4}{s_2 s_3}\right)^2 + 16.9 \times 10^6} - 1 \le 0 \qquad (4.28d)$$

$$g_6(\vec{s}) = \frac{1}{85 s_7^3} \sqrt{\left(\frac{745.0 s_5}{s_2 s_3}\right)^2 + 157.5 \times 10^6} - 1 \le 0 \qquad (4.28e)$$

$$g_7(\vec{s}) = \frac{s_2 s_3}{40} - 1 \le 0 \qquad (4.28f)$$

$$g_8(\vec{s}) = \frac{5s_2}{s_1} - 1 \le 0 \quad (4.28g)$$

$$g_9(\vec{s}) = \frac{s_1}{12s_2} - 1 \le 0 \quad (4.28h)$$

$$g_{10}(\vec{s}) = \frac{1.5s_6 + 1.9}{12s_2} - 1 \le 0 \quad (4.28i)$$

$$g_{11}(\vec{s}) = \frac{1.1s_7 + 1.9}{s_5} - 1 \le 0 \quad (4.28j)$$

Where $2.6 \le s_1 \le 3.6, 0.7 \le s_2 \le 0.8, 17 \le s_3 \le 28, 7.3 \le s_4 \le 8.3,$
$7.8 \le s_5 \le 8.3, 2.9 \le s_6 \le 3.9 and 5 \le s_7 \le 5.5$

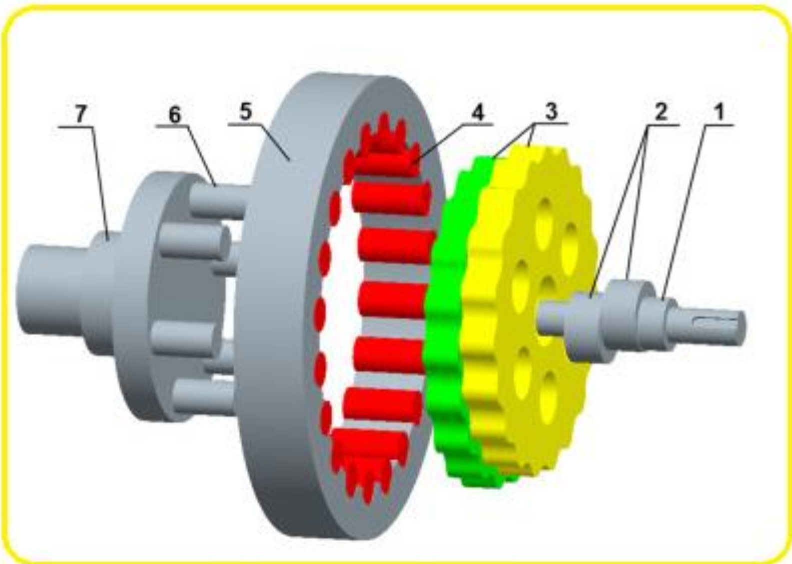


Fig.4.10: Speed reducer problem

4.4.8 Belleville Spring Design Problem

Another types of engineering problem is design of Belleville spring problem shown in **Fig.4.11** [206]. The main objective is to design the spring which taking the least weight and it should satisfy numbers of constraint. This type of designed problems have four kinds of designed variable, i.e. the diameter of internal part of Belleville spring (DIM_I), diameter of external part of the Belleville spring (DIM_E), Spring height (S_H) and The thickness of the Belleville spring (S_T). The subjected constraints are the deflection, compressive type of stresses, deflection height, diameter of outer and inner portion and the slope. The mathematical expressions are given from eqn. (4.29) to eqn. (4.30f).

Minimizing; $f(x) = 0.07075\pi(DIM_E^2 - DIM_I^2)t$ (4.29)

Subjected to:

$$b_1(x) = G - \frac{4P\lambda_{\max}}{(1-\delta^2)\alpha DIM_E}\left[\delta(S_H - \frac{\lambda \max}{2}) + \mu t\right] \geq 0 \quad (4.30)$$

$$b_2(x) = (\frac{4P\lambda_{\max}}{(1-\delta^2)\alpha DIM_E}\left[(S_H - \frac{\lambda}{2})(S_H - \lambda)t + t^3\right])_{\lambda_{\max}} - P_{MAX} \geq 0 \quad (4.30a)$$

$$b_3(x) = \lambda_1 - \lambda_{\max} \geq 0 \quad (4.30b)$$

$$b_4(x) = H - S_H - t \geq 0 \quad (4.30c)$$

$$b_5(x) = DIM_{MAX} - DIM_E \geq 0 \quad (36d)$$

$$b_6(x) = DIM_E - DIM_I \geq 0 \quad (4.30e)$$

$$b_7(x) = 0.3 - \frac{S_H}{DIM_E - DIM_I} \geq 0 \quad (4.30f)$$

Where, $\alpha = \frac{6}{\pi \ln J}(\frac{J-1}{J})^2$

$$\delta = \frac{6}{\pi \ln J}(\frac{J-1}{\ln J} - 1)$$

$$\mu = \frac{6}{\pi \ln J}(\frac{J-1}{2})$$

$$P_{MAX} = 5400 lb$$

$P = 30e6\,psi, \lambda_{\max} = 0.2in, \delta = 0.3, G = 200Kpsi, H = 2in,$
$DIM_{MAX} = 12.01in, J = \frac{DIM_E}{DIM_I}, \lambda_1 = f(a)a, a = \frac{S_H}{t}$

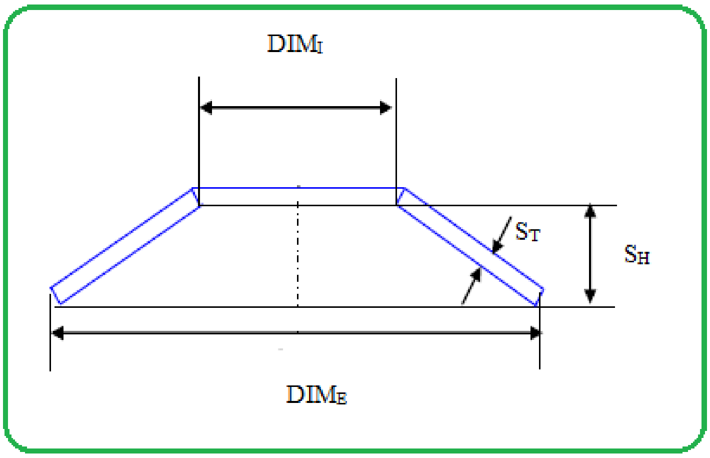


Fig.4.11: Belleville spring design problem

4.4.9 Rolling Element Bearing Problem

This problem is named as rolling element bearing design issue shown in **Fig.4.12** [206]. The actual objectives for this type of problems are to maximize the capacity of load carry considering the dynamic nature of bearing of rolling elements. This special problem consists of several numbers of variables like, diameters of ball (DIM_B), diameters of pitch (DIM_P), coefficients of curvature raceway for outside and internal parts (R_I plus R_O) and ball number (N) etc. The five types of variables appear as constraint as well as indirectly affect the internal part of geometry. Design variables contains few numbers of rolling balls (N) which have discrete behaviour and the remaining design variables are with continuous behaviour. This kind of special problem is executed and based upon kinematic as well as manufacturing condition. The scientific model is discussed below from eqn. (4.31) to eqn. (4.32i).

Maximizing; $C_D = f_c N^{2/3} DIM_B^{1.8}$ if $DIM \le 25.4mm$ (4.31a)

$C_D = 3.647 f_C N^{2/3} DIM_B^{1.4}$ if $DIM \ge 25.4mm$ (4.31b)

Subjected to: $$r_1(x) = \frac{\theta_0}{2\sin^{-1}\left(\frac{DIM_B}{DIM_{MAX}}\right)} - N + 1 \geq 0 \quad (4.32)$$

$$r_2(x) = 2DIM_B - K_{DIM_{MIN}}(DIM - \text{dim}) \geq 0 \quad (4.32a)$$

$$r_3(x) = K_{DIM_{MAX}}(DIM - \text{dim}) \geq 0 \quad (4.32b)$$

$$r_4(x) = \beta B_W - DIM_B \leq 0 \quad (4.32c)$$

$$r_4(x) = DIM_{MAX} - 0.5(DIM + \text{dim}) \geq 0 \quad (4.32d)$$

$$r_5(x) = DIM_{MAX} - 0.5(DIM + \text{dim}) \geq 0 \quad (4.32e)$$

$$r_6(x) = (0.5 + re)(DIM + \text{dim}) \geq 0 \quad (4.32f)$$

$$r_7(x) = 0.5(DIM - DIM_{MAX} - DIM_B) - \alpha DIM_B \geq 0 \quad (4.32g)$$

$$r_8(x) = f_I \geq 0.515 \quad (4.32h)$$

$$r_9(x) = f_0 \geq 0.515 \quad (4.32i)$$

Where, $$f_c = 37.91\left[1 + \left\{1.04\left(\frac{1-\varepsilon}{1+\varepsilon}\right)^{1.72}\left(\frac{f_I(2f_0-1)}{f_0(2f_I-1)}\right)^{0.41}\right\}^{10/3}\right]^{-0.3} \times \left[\frac{\varepsilon^{0.3}(1-\varepsilon)^{1.39}}{(1+\varepsilon)^{1/3}}\right]\left[\frac{2f_I}{2f_I-1}\right]^{0.41}$$

$$\theta_0 = 2\pi - 2\cos^{-1}\left(\frac{\left[\{(DIM - \text{dim})/2 - 3(t/4)\}^2 + (DIM/2 - t/4 - DIM_B)^2 - \{\text{dim}/2 + t/4\}^2\right]}{2\{(DIM - \text{dim})/2 - 3(t/4)\}\{D/2 - t/4 - DIM_B\}}\right)$$

$$\varepsilon = \frac{DIM_B}{DIM_{MAX}}, \ f_I = \frac{R_I}{DIM_B}, \ f_0 = \frac{R_0}{DIM_B}, t = DIM - \text{dim} - 2DIM_B$$

$$DIM = 160, \text{dim} = 90, B_W = 30, R_I = R_0 = 11.033$$

$$0.5(DIM + \text{dim}) \leq DIM_{MAX} \leq 0.6(DIM + \text{dim}),$$
$$0.15(DIM - \text{dim}) \leq DIM_B \leq 0.45(DIM - \text{dim}), 4 \leq N \leq 50 \quad 0.515 \leq f_I \text{ and } f_0 \leq 0.6$$

$$0.4 \leq K_{DIM_{MIN}} \leq 0.5, 0.6 \leq K_{DIM_{MAX}} \leq 0.7, 0.3 \leq re \leq 0.1, 0.02 \leq re \leq 0.1, 0.6 \leq \beta \leq 0.85$$

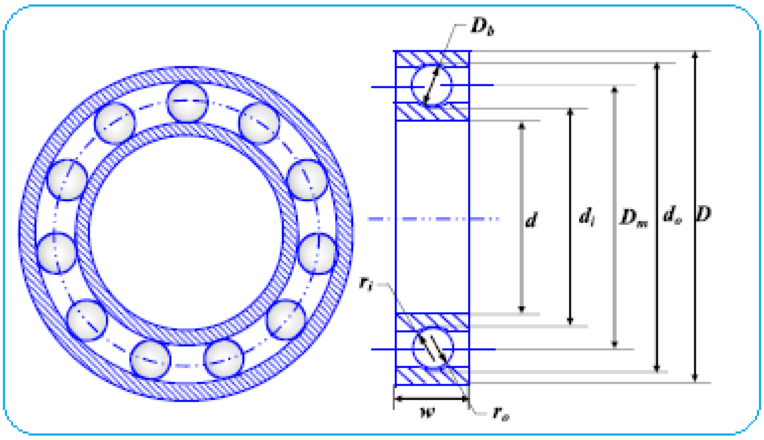


Fig.4.12: Rolling element bearing problem

4.4.10 Multiple Disk Clutch Brake Problem

Another important special problem is Multidisc clutch brake problem which is shown in **Fig. 4.13** [283]. The main object of this kind of optimization issue is to minimize or decrease weight and it consists of five numbers of discrete variables, such as, inner radius surface (R_{in}), outer radius surface (R_o), disc's thicknesses (Th), actuating type of force (F_{ac}) and number of the surface of friction (S_f). The mathematical formulation for this engineering optimization problem is given from eqn. (4.33) to eqn. (4.34g).

Minimizing, $f\left(R_{in}, R_O, S_f, Th\right) = \pi Th\gamma\left(R_0^2 - R_{in}^2\right)\left(S_f + 1\right)$ (4.33)

Where, $R_{in} \in 60, 61, 62....80; R_o \in 90, 91, ...110; Th \in 1, 1.5, 2, 2.5, 3;$
$F_{ac} \in 600, 610, 620, 1000; S_f \in 2, 3, 4, 5, 6, 7, 8, 9$

Subjected to, $m_1 = R_0 - R_{in} - \Delta R \geq 0$ (4.34)

$m_2 = L_{MAX} - (S_f + 1)(Th + \alpha) \geq 0$ (4.34a)

$m_3 = PM_{MAX} - PM_{\pi} \geq 0$ (4.34b)

$m_4 = PM_{MAX} Y_{MAX} + PM_{\pi} Y_{SR} \geq 0$ (4.34c)

$m_5 = Y_{SR_{MAX}} - Y_{SR} \geq 0$ (4.34d)

$$m_6 = t_{MAX} - t \geq 0 \tag{4.34e}$$

$$m_7 = DC_h - DC_f \geq 0 \tag{4.34f}$$

$$m_8 = t \geq 0 \tag{4.34g}$$

Where, $PM_{\pi} = \dfrac{F_{ac}}{\Pi\left(R_0^2 - R_{in}^2\right)}$

$$Y_{SR} = \frac{2\pi n\left(R_0^3 - R_{in}^3\right)}{90\left(R_0^2 - R_{in}^2\right)}$$

$$t = \frac{i_x \pi n}{30\left(DC_h + DC_f\right)}$$

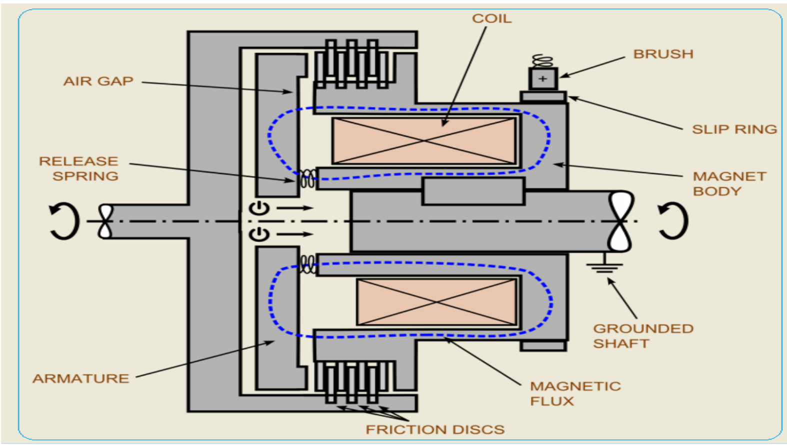


Fig.4.13: Multiple disk clutch brake design

4.4.11 I Beam Design Problem

This problem is known as I-Beam design problem shown in **Fig.4.14**. This is consists of two types of flanges and a web, that is subjected to bend in this plane of the web as well as restrained beside buckling out from that plane. There are two kinds of symmetrical axis like XX and YY. The two types of flanges of that beam assume with little thickness which are comparing with the depth of the I-beam. It consists of one single parameter A_f, that is defined as chord's cross-sectional region. The single web can be defined as two types of parameters, such as, thickness (i.e. Δ) and depth is taken as $\Im$. The web depth is the main distance in-between the flanges and centroids as well as the beam depths are defined as in equal with another. The scientific formulation is given from eqn. (4.35a) to eqn. (4.35c).

$$A = 2.A_f + \Delta.\Im \tag{4.35a}$$

$$I = \frac{\Im^2}{4}.\left(2.A_f + \frac{\Delta\Im}{3}\right) \tag{4.35b}$$

$$W = \frac{\Im}{2}.\left(2.A_f + \frac{\Delta\Im}{3}\right) \tag{4.35c}$$

Where, A is defined as the cross sectional region, I denoted as inertia moment of the cross section of xx axis and W is represented as module of cross section.

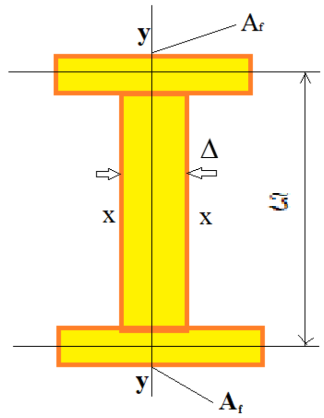


Fig.4.14: I-Beam design problem

4.5 RESULTS AND DISCUSSION

In order to validate the results, 30 trial runs have been taken into consideration to overawed the stochastic environment of proposed optimization algorithms and each of the objective functions have been estimated for index, average values, standard deviation, best value, worst value and median values are shown in tables given below. The Wilcoxon rank-sum test and t-test are taken into considered to measure the p-value and h-value for standard benchmarks considering unimodal, multimodal and fixed dimension functions using proposed optimizers. The minimum fitness value, number of trails, maximum fitness value, mean fitness, median fitness, 1^{st} quartile, i.e. 25^{th} percentile, 2^{nd} quartile, i.e. 50^{th} percentile as well as 3^{rd} quartile, i.e. 75^{th} percentile, semi interquartile deviation, numbers of outliers and standard deviations are shown in tables.

Table-4.4a: Test results of benchmark functions using sigmoid chaotic variant-HHO and tent chaotic variant-HHO methods

Methods	Benchmark functions	Index	Mean Value	Standard Deviation	Best Value	Worst Value	Median Value
sigmoid chaotic variant-HHO	F_1	22	1.78E-105	9.65E-105	5.47E-130	5.29E-104	8.86E-114
	F_2	10	4.77E-53	2.43E-52	6.08E-67	1.33E-51	1.01E-57
	F_3	10	2.86E-88	1.03E-87	4.60E-113	4.68E-87	3.50E-98
	F_4	15	6.27E-56	2.30E-55	8.62E-63	1.03E-54	1.25E-58
	F_5	29	0.0094009	0.0149072	5.20E-06	0.0546977	0.0028663
	F_6	14	0.0001435	0.0001918	2.15E-07	0.0007693	5.42E-05
	F_7	11	0.00014	0.000129	1.75E-05	0.000614	0.00011
	F_8	9	-12569.2	0.297933	-12569.5	-12568.4	-12569.2
	F_9	1	0	0	0	0	0
	F_{10}	1	8.88E-16	0	8.88E-16	8.88E-16	8.88E-16
	F_{11}	1	0	0	0	0	0
	F_{12}	10	4.26E-06	6.77E-06	8.95E-10	2.94E-05	1.33E-06
	F_{13}	16	8.48E-05	0.000156	2.39E-09	0.000756	1.84E-05
	F_{14}	22	1.394305	0.956253	0.998004	5.928845	0.998004
	F_{15}	10	0.000323	1.31E-05	0.000308	0.000358	0.000323
	F_{16}	23	-1.03163	7.82E-09	-1.03163	-1.03163	-1.03163
	F_{17}	23	0.397889	2.82E-06	0.397887	0.397901	0.397887
	F_{18}	17	10.20001	12.14398	3	30.00017	3.000001
	F_{19}	25	-3.83732	0.04127	-3.86278	-3.71175	-3.86087
	F_{20}	7	-3.28229	0.06948	-3.32183	-3.06709	-3.32117
	F_{21}	2	-5.05508	0.000106	-5.05517	-5.05459	-5.0551
	F_{22}	17	-5.61619	1.613069	-10.4023	-5.08732	-5.08759
	F_{23}	30	-5.30861	0.987257	-10.5358	-5.12806	-5.1284
tent chaotic variant-HHO	F_1	11	1.90E-93	7.66E-93	4.26E-113	3.81E-92	2.84E-101
	F_2	10	1.61E-48	8.64E-48	2.71E-58	4.74E-47	8.13E-54
	F_3	20	6.29E-58	3.45E-57	2.33E-96	1.89E-56	5.38E-83
	F_4	21	2.53E-47	9.09E-47	3.81E-57	4.04E-46	1.70E-52
	F_5	7	0.0141706	0.0165762	6.52E-06	0.0659621	0.0084633
	F_6	10	0.0001314	0.0002198	5.37E-08	0.0010337	3.50E-05
	F_7	13	0.000142	0.000133	5.10E-06	0.000546	0.000106
	F_8	14	-12568.8	0.741372	-12569.5	-12567.2	-12569.1
	F_9	1	0	0	0	0	0
	F_{10}	1	8.88E-16	0	8.88E-16	8.88E-16	8.88E-16
	F_{11}	1	0	0	0	0	0
	F_{12}	4	1.15E-05	1.58E-05	2.43E-12	6.26E-05	5.23E-06
	F_{13}	11	4.83E-05	8.32E-05	1.97E-07	0.000454	2.37E-05
	F_{14}	22	1.492398	1.262647	0.998004	5.928845	0.998004
	F_{15}	22	0.000351	2.92E-05	0.000311	0.000407	0.000349
	F_{16}	12	-1.03163	2.59E-09	-1.03163	-1.03163	-1.03163
	F_{17}	3	0.397899	2.85E-05	0.397887	0.398028	0.397887
	F_{18}	13	3	1.14E-06	3	3.000006	3
	F_{19}	22	-3.86036	0.002853	-3.86277	-3.85399	-3.86192
	F_{20}	26	-3.11878	0.097761	-3.28749	-2.86416	-3.10928
	F_{21}	16	-5.21953	0.919241	-10.0866	-5.03976	-5.05297
	F_{22}	26	-5.08202	0.006573	-5.0876	-5.06019	-5.08422
	F_{23}	3	-5.18762	1.181623	-10.4787	-1.66876	-5.12587

Table-4.4b: Test results of benchmark functions using CSCA and CSMA methods

Methods	Benchmark functions	Index	Mean Value	Standard Deviation	Best Value	Worst Value	Median Value
CSCA	F_1	6	14.924102	32.234052	0.0126823	150.96222	3.3275452
	F_2	15	0.0308807	0.0681456	5.61E-05	0.338269	0.0090707
	F_3	22	7312.0527	4472.7626	888.81139	17459.641	6768.0351
	F_4	20	34.067024	12.303361	8.5723653	56.149767	35.5722
	F_5	25	30785.706	51612.245	55.748013	193231.83	6243.1935
	F_6	18	21.67592	17.905493	3.8014928	80.47601	14.401448
	F_7	30	0.063687	0.056811	0.003208	0.273373	0.048301
	F_8	2	-3760.65	235.9351	-4164.57	-3340.13	-3798.33
	F_9	3	38.88475	34.19933	0.386263	124.6243	37.09739
	F_{10}	28	13.46625	9.179928	0.068041	20.31943	20.1836
	F_{11}	30	0.926611	0.350491	0.001721	1.75701	0.979517
	F_{12}	12	201583.3	486409.6	1.2165	1753896	12.45208
	F_{13}	5	430067.1	2178707	4.242706	11951328	67.14688
	F_{14}	22	2.122433	0.999879	0.998004	2.982105	2.982105
	F_{15}	7	0.0010485	0.0003626	0.0003445	0.0016001	0.0009054
	F_{16}	21	-1.03157	5.43E-05	-1.03163	-1.03141	-1.03159
	F_{17}	12	0.400424	0.002417	0.397921	0.406789	0.399671
	F_{18}	10	3.000055	4.76E-05	3.000002	3.000159	3.000042
	F_{19}	13	-3.85392	0.002069	-3.86128	-3.85001	-3.85436
	F_{20}	13	-2.92704	0.272363	-3.17629	-1.90979	-3.00493
	F_{21}	19	-2.2713	1.843985	-4.93159	-0.35065	-0.88064
	F_{22}	13	-3.4056	2.064134	-9.35948	-0.90629	-3.40587
	F_{23}	24	-4.03031	1.573079	-9.49138	-0.94108	-4.10111
CSMA	F_1	1	2.48E-296	0	0	7.43E-295	0
	F_2	16	7.43E-122	4.07E-121	6.23E-239	2.23E-120	1.96E-178
	F_3	2	5.28E-294	0	0	1.58E-292	0
	F_4	26	1.94E-128	1.06E-127	5.00E-276	5.82E-127	2.27E-188
	F_5	6	5.034157	9.3744495	0.0055729	28.24224	0.9543281
	F_6	16	0.0062209	0.0029861	0.0007766	0.0129432	0.0057947
	F_7	29	0.000134	9.13E-05	1.40E-05	0.000354	0.000118
	F_8	21	-12568.9	0.416875	-12569.5	-12567.7	-12568.9
	F_9	1	0	0	0	0	0
	F_{10}	1	8.88E-16	0	8.88E-16	8.88E-16	8.88E-16
	F_{11}	1	0	0	0	0	0
	F_{12}	22	0.007442	0.008958	5.38E-05	0.033799	0.003023
	F_{13}	8	0.012679	0.016749	2.62E-05	0.065159	0.00534
	F_{14}	5	0.998004	8.26E-13	0.998004	0.998004	0.998004
	F_{15}	12	0.000634	0.000344	0.000308	0.001516	0.000531
	F_{16}	7	-1.03163	1.53E-09	-1.03163	-1.03163	-1.03163
	F_{17}	1	0.397887	3.95E-08	0.397887	0.397888	0.397887
	F_{18}	26	3	4.83E-10	3	3	3
	F_{19}	29	-3.86277	8.60E-05	-3.86278	-3.86231	-3.86278
	F_{20}	13	-3.2423	0.057317	-3.32199	-3.19744	-3.20309
	F_{21}	8	-10.1527	0.000354	-10.1532	-10.1517	-10.1528
	F_{22}	26	-10.4023	0.000542	-10.4028	-10.4004	-10.4025
	F_{23}	20	-10.5358	0.000489	-10.5363	-10.5341	-10.536

Table-4.4c: Test results of benchmark functions using hCHHO-SCA and hCSMA-SCA methods

Methods	Benchmark functions	Index	Mean Value	Standard Deviation	Best Value	Worst Value	Median Value
hCHHO-SCA	F_1	22	0	0	0	0	0
	F_2	10	0	0	0	0	0
	F_3	10	0	0	0	0	0
	F_4	15	0	0	0	0	0
	F_5	29	2.6362e-08	4.4868e-08	3.8629e-10	7.8172e-08	5.2851e-10
	F_6	14	8.9762e-11	1.3955e-10	7.8969e-17	2.5053e-10	1.8754e-11
	F_7	11	7.9572e-05	7.596e-05	3.4922e-05	0.00016728	3.6515e-05
	F_8	9	-12569.4866	6.6155e-09	-12569.4866	-12569.4866	-12569.4866
	F_9	1	0	0	0	0	0
	F_{10}	1	8.8818e-16	0	8.8818e-16	8.8818e-16	8.8818e-16
	F_{11}	1	0	0	0	0	0
	F_{12}	10	1.5322e-11	2.63e-11	6.9242e-14	4.569e-11	2.0756e-13
	F_{13}	16	1.0904e-09	1.8775e-09	1.045e-13	3.2584e-09	1.2787e-11
	F_{14}	22	0.998	1.3597e-16	0.998	0.998	0.998
	F_{15}	10	0.00030749	1.3887e-17	0.00030749	0.00030749	0.00030749
	F_{16}	23	-1.0316	0	-1.0316	-1.0316	-1.0316
	F_{17}	23	0.39789	0	0.39789	0.39789	0.39789
	F_{18}	17	3	0	3	3	3
	F_{19}	25	-3.8628	7.0217e-16	-3.8628	-3.8628	-3.8628
	F_{20}	7	-3.2824	0.068643	-3.322	-3.2031	-3.322
	F_{21}	2	-10.1532	1.9404e-11	-10.1532	-10.1532	-10.1532
	F_{22}	17	-10.4029	1.4709e-11	-10.4029	-10.4029	-10.4029
	F_{23}	30	-10.5364	4.3308e-12	-10.5364	-10.5364	-10.5364
hCSMA-SCA	F_1	1	0	0	0	0	0
	F_2	16	0	0	0	0	0
	F_3	2	0	0	0	0	0
	F_4	26	0	0	0	0	0
	F_5	6	0.28096	0.41472	0.023283	0.75936	0.060232
	F_6	16	0.35973	0.60387	0.0040544	1.057	0.018163
	F_7	29	0.0028796	0.0016594	0.0011439	0.0044505	0.0030444
	F_8	21	-12557.6044	10.656	-12569.0252	-12547.9287	-12555.8595
	F_9	1	0	0	0	0	0
	F_{10}	1	8.8818e-16	0	8.8818e-16	8.8818e-16	8.8818e-16
	F_{11}	1	0	0	0	0	0
	F_{12}	22	0.0039826	0.0061706	6.8577e-05	0.011096	0.0007834
	F_{13}	8	0.3524	0.42634	0.10287	0.84467	0.10965
	F_{14}	5	0.998	2.6626e-12	0.998	0.998	0.998
	F_{15}	12	0.00030772	1.6886e-07	0.00030753	0.00030782	0.00030782
	F_{16}	7	8.9243e-10	-1.0316	-1.0316	-1.0316	-1.0316
	F_{17}	1	0.39789	1.6857e-08	0.39789	0.39789	0.39789
	F_{18}	26	3	2.3378e-13	3	3	3
	F_{19}	29	-3.8575	0.0045471	-3.8628	-3.8549	-3.8549
	F_{20}	13	-2.9959	0.14759	-3.1326	-2.8394	-3.0156
	F_{21}	8	-10.031	0.084338	-10.0856	-9.9339	-10.0736
	F_{22}	26	-10.3556	0.074037	-10.4027	-10.2702	-10.3938
	F_{23}	20	-10.5327	0.0056605	-10.5362	-10.5262	-10.5357

To examine the effectiveness of the proposed sigmoid chaotic variant-HHO, tent chaotic variant-HHO, CSCA, CSMA, hCHHO-SCA and hCSMA-SCA optimization techniques, a well-studied set of various benchmark functions are taken [274] [197] [69]. Table-4.4a represents the results of 23rd standard benchmark functions using proposed sigmoid and tent chaotic function with HHO, i.e. CHHO optimizer. The mean value, best value, standard deviation, worst value, median value and index and given for unimodal, multimodal and fixed dimension benchmark functions.

Table-4.4b represents the results of 23rd standard benchmark functions using proposed CSCA and CSMA optimization algorithms. The chaotic functions are used to increase the exploitation capability of the proposed optimizer. The mean value, best value, standard deviation, worst value, median value and index are given for unimodal, multimodal and fixed dimension benchmark functions.

Table-4.5a: Hypothesis testing for benchmark functions using sigmoid chaotic variant-HHO method

Methods	**Sigmoid chaotic variant-HHO**			
Benchmark functions	**Wilcoxon rank-sum test**		**t-test**	
	p-Value	**h-Value**	**p-Value**	**h-Value**
F_1	8.10E-10	1	0	0.18425282
F_2	4.12E-06	1	0	0.3153962
F_3	2.03E-07	1	0	0.32558199
F_4	9.92E-11	1	0	0.13806894
F_5	0.1296702	0	0	0.27971766
F_6	0.5493268	0	0	0.83732162
F_7	0.982307	0	0	0.928964
F_8	0.455297	0	1	0.026586
F_9	-	0	-	-
F_{10}	-	0	-	-
F_{11}	-	0	-	-
F_{12}	0.011228	1	1	0.034485
F_{13}	0.994102	0	0	0.260701
F_{14}	0.510598	0	0	0.749488
F_{15}	0.000132	1	1	4.64E-05
F_{16}	0.043581	1	0	0.263967
F_{17}	0.717185	0	0	0.059318
F_{18}	3.37E-05	1	1	0.002939
F_{19}	0.510598	0	1	0.004392
F_{20}	3.35E-08	1	1	4.27E-09
F_{21}	1.56E-08	1	0	0.335259
F_{22}	5.07E-10	1	0	0.080288
F_{23}	1.70E-08	1	0	0.671887

Table-4.4c represents the results of 23rd standard benchmark functions using proposed hCHHO-SCA and hCSMA-SCA optimization algorithms. The exploration and exploitation capability have been increased by using those hybrid variants. Further, these hybrid algorithms are helped to avoid the local optima and approached toward global optima.

Table-4.5a represents the hypothesis testing results of CHHO, where chaotic sigmoid functions are used for uni-modal, multi-modal and fixed dimension standard benchmarks. For statistical analysis wilcoxon rank-sum test and t-test have been taken into consideration. In case of hypothesis test, the statistical sample is taken as input data. The main goal of this test is to provide the evidence of null hypothesis.

Table-4.5b: Hypothesis testing for benchmark functions using CSCA and CSMA method

Methods	CSCA				CSMA			
Benchmark functions	Wilcoxon rank-sum test		t-test		Wilcoxon rank-sum test		t-test	
	p-Value	h-Value	p-Value	h-Value	p-Value	h-Value	p-Value	h-Value
F_1	3.02E-11	1	1	0.0168616	3.16E-12	1	0	0.1842528
F_2	3.02E-11	1	1	0.0191001	3.02E-11	1	0	0.3153816
F_3	3.02E-11	1	1	7.60E-10	4.11E-12	1	0	0.325582
F_4	3.02E-11	1	1	2.53E-15	3.02E-11	1	0	0.1380689
F_5	3.02E-11	1	1	0.0027943	2.61E-10	1	1	0.0065072
F_6	3.02E-11	1	1	2.87E-07	3.34E-11	1	1	3.50E-12
F_7	3.02E-11	1	1	1.13E-06	0.684323	0	0	0.807225
F_8	3.02E-11	1	1	2.28E-47	0.371077	0	0	0.717503
F_9	1.21E-12	1	1	8.55E-07	-	0	-	-
F_{10}	1.21E-12	1	1	7.34E-09	-	0	-	-
F_{11}	1.21E-12	1	1	8.31E-15	-	0	-	-
F_{12}	3.02E-11	1	1	0.030823	3.34E-11	1	1	8.96E-05
F_{13}	3.02E-11	1	0	0.288526	3.47E-10	1	1	0.000278
F_{14}	1.61E-06	1	1	0.020639	2.87E-10	1	1	0.040493
F_{15}	1.46E-10	1	1	2.76E-11	0.000117	1	1	9.52E-05
F_{16}	3.02E-11	1	1	7.57E-06	0.077268	0	0	0.900873
F_{17}	5.49E-11	1	1	3.44E-06	0.133449	0	1	0.034728
F_{18}	4.50E-11	1	1	8.62E-07	8.89E-10	1	0	0.112301
F_{19}	2.23E-09	1	1	5.59E-11	7.39E-11	1	1	6.82E-05
F_{20}	0.000158	1	1	0.000508	2.78E-07	1	1	5.14E-06
F_{21}	3.02E-11	1	1	3.52E-08	3.02E-11	1	1	3.92E-23
F_{22}	1.07E-07	1	1	0.000117	3.02E-11	1	1	6.31E-86
F_{23}	6.53E-08	1	1	0.001395	3.02E-11	1	1	4.54E-21

Table-4.5c: Hypothesis testing for benchmark functions using hCHHO-SCA and hCSMA-SCA method

Methods	hCHHO-SCA				hCSMA-SCA			
Benchmark functions	Wilcoxon rank-sum test		t-test		Wilcoxon rank-sum test		t-test	
	p-Value	h-Value	p-Value	h-Value	p-Value	h-Value	p-Value	h-Value
F_1	0.1	0.326305864	0	0	0.1	0.326305864	0	0
F_2	0.1	0.326305864	0	0	0.1	0.326305864	0	0
F_3	0.1	0	0	0.422649724	0.1	0	0	0.422649724
F_4	0.1	0	0	0.405834471	0.1	0	0	0.405834471
F_5	0.1	0	0	0.281388529	0.1	0	0	0.369656628
F_6	0.1	0	0	0.363600369	0.1	0	0	0.410609526
F_7	0.1	0	0	0.07617809	0.1	0	0	0.09709188
F_8	0.4	0	0	0.359352354	0.2	0	0	0.359352354
F_9	0.1	0	0	0.359352354	0.1	0	0	0.359352354
F_{10}	1	0	0	NA	1	0	0	NA
F_{11}	1	0	0	0	1	0	0	0
F_{12}	0.7	0	0	0.240972852	0.1	0	0	0.380623419
F_{13}	0.2	0	0	0.423374074	0.1	0	0	0.288659162
F_{14}	0.1	0	0	0.183503419	0.7	0	0	0.183503419
F_{15}	0.1	0	0	0.135694639	0.1	0	0	0.137709731
F_{16}	1	0	0	0.961023302	0.7	0	0	0.672958617
F_{17}	0.2	0	0	0.195648734	0.1	0	0	0.191358353
F_{18}	0.1	0	0	0.409981	0.1	0	0	0.409981
F_{19}	0.7	0	0	0.225040814	0.4	0	0	0.226532495
F_{20}	0.1	0	0	0.056100528	0.1	0	0	0.110900202
F_{21}	0.1	0	0	2.59E-05	0.1	0	0	9.58E-05
F_{22}	0.1	0	0	2.83E-02	0.1	0	0	2.59E-02
F_{23}	0.1	0	0	1.50E-05	0.1	0	0	3.63E-07

Table-4.5b represents the results of hypothesis test by using CSCA and CSMA optimizer. The random samples from the population sets have been examined and analyzed by using t-test and Wilcoxon rank-sum test. The p-Value and h-Value have been measured for 23rd standard benchmark functions using CSCA and CSMA optimization algorithms. Table-4.5c shows the hypothesis test results of uni-modal, multi-modal and fixed dimension benchmark functions.

Table-4.6a represents the statistical analysis of 23rd standard benchmark functions by using CHHO-Sigmoid optimization method. The 30 trail runs are taken into consideration. Out of the 30 trail runs, the minimum fitness, maximum fitness, mean fitness, median fitness and first quartile have been measured.

Table-4.6a: Statistical analysis of benchmark functions for CHHO-Sigmoid method

Method	Benchmark Functions	No. of trial	Minimum fitness	Maximum fitness	Mean fitness	Median fitness	First quartile (25th Percentile)
CHHO-Sigmoid	F_1	30	5.47E-130	5.29E-104	1.78E-105	8.86E-114	2.85E-117
	F_2	30	6.08E-67	1.33E-51	4.77E-53	1.01E-57	3.92E-60
	F_3	30	4.60E-113	4.68E-87	2.86E-88	3.50E-98	7.78E-102
	F_4	30	8.62E-63	1.03E-54	6.27E-56	1.25E-58	1.97E-60
	F_5	30	5.20E-06	0.0546977	0.0094009	0.0028663	0.0009499
	F_6	30	2.15E-07	0.0007693	0.0001435	5.42E-05	1.04E-05
	F_7	30	1.75E-05	0.000614	0.00014	0.00011	5.10E-05
	F_8	30	-12569.5	-12568.4	-12569.2	-12569.2	-12569.4
	F_9	30	0	0	0	0	-
	F_{10}	30	8.88E-16	8.88E-16	8.88E-16	8.88E-16	-
	F_{11}	30	0	0	0	0	30
	F_{12}	30	8.95E-10	2.94E-05	4.26E-06	1.33E-06	4.10E-07
	F_{13}	30	2.39E-09	0.000756	8.48E-05	1.84E-05	2.00E-06
	F_{14}	30	0.998004	5.928845	1.394305	0.998004	0.998004
	F_{15}	30	0.000308	0.000358	0.000323	0.000323	0.000311
	F_{16}	30	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163
	F_{17}	30	0.397887	0.397901	0.397889	0.397887	0.397887
	F_{18}	30	3	30.00017	10.20001	3.000001	3
	F_{19}	30	-3.86278	-3.71175	-3.83732	-3.86087	-3.86265
	F_{20}	30	-3.32183	-3.06709	-3.28229	-3.32117	-3.32161
	F_{21}	30	-5.05517	-5.05459	-5.05508	-5.0551	-5.05513
	F_{22}	30	-10.4023	-5.08732	-5.61619	-5.08759	-5.08761
	F_{23}	30	-10.5358	-5.12806	-5.30861	-5.1284	-5.12845

Table-4.6b: Statistical analysis of benchmark functions for CHHO-Sigmoid method

Method	Benchmark Functions	Second quartile (50th Percentile)	Third quartile (75th Percentile)	Semi Interquartile Deviation	Number of outliers	Standard Deviation
CHHO-sigmoid	F_1	8.86E-114	4.65E-111	2.32E-111	6	9.65E-105
	F_2	1.01E-57	2.83E-55	1.42E-55	6	2.43E-52
	F_3	3.50E-98	5.10E-92	2.55E-92	6	1.03E-87
	F_4	1.25E-58	4.31E-57	2.15E-57	4	2.30E-55
	F_5	0.0028663	0.0085606	0.0038054	5	0.0149072
	F_6	5.42E-05	0.0002344	0.000112	1	0.0001918
	F_7	0.00011	0.000185	6.71E-05	1	0.000129
	F_8	-12569.2	-12569	0.20875	0	0.297933
	F_9	0	-	-	0	0
	F_{10}	8.88E-16	-	-	0	0
	F_{11}	0	-	-	0	0
	F_{12}	1.33E-06	3.74E-06	1.66E-06	4	6.77E-06
	F_{13}	1.84E-05	8.86E-05	4.33E-05	2	0.000156
	F_{14}	0.998004	1.992031	0.497014	1	0.956253
	F_{15}	0.000323	0.00033	9.71E-06	0	1.31E-05
	F_{16}	-1.03163	-1.03163	9.56E-10	3	7.82E-09
	F_{17}	0.397887	0.397888	3.03E-07	5	2.82E-06
	F_{18}	3.000001	30	13.5	0	12.14398
	F_{19}	-3.86087	-3.82497	0.018837	2	0.04127
	F_{20}	-3.32117	-3.20227	0.05967	0	0.06948
	F_{21}	-5.0551	-5.05505	3.92E-05	1	0.000106
	F_{22}	-5.08759	-5.08753	4.15E-05	4	1.613069
	F_{23}	-5.1284	-5.12833	5.99E-05	2	0.987257

Table-4.6b shows the statistical analysis of uni-modal, multi-modal and fixed dimension benchmark functions by using CHHO-Sigmoid optimizer. In this case, the second quartile, third quartile, semi interquartile deviation, numbers of outliers and standard deviation have been taken into consideration as statistical analysis.

The statistical analysis helps to investigate the patterns and trends of the sets of samples. Further, from this analysis, the relations between the quantitative data can be measured. It is one of the important tool for research which is used by scientists and researchers. Table-4.7a represents the analysis of minimum fitness, maximum fitness, mean fitness, median fitness and first quartile using CHHO-Tent optimization algorithm.

Table-4.7a: Statistical analysis of benchmark functions using CHHO-Tent method

Method	Benchmark Functions	No. of trial	Minimum fitness	Maximum fitness	Mean fitness	Median fitness	First quartile (25th Percentile)
CHHO-Tent	F_1	30	4.26E-113	3.81E-92	1.90E-93	2.84E-101	3.37E-105
	F_2	30	2.71E-58	4.74E-47	1.61E-48	8.13E-54	8.90E-56
	F_3	30	2.33E-96	1.89E-56	6.29E-58	5.38E-83	1.75E-92
	F_4	30	3.81E-57	4.04E-46	2.53E-47	1.70E-52	1.25E-53
	F_5	30	6.52E-06	0.0659621	0.0141706	0.0084633	0.0014947
	F_6	30	5.37E-08	0.0010337	0.0001314	3.50E-05	2.57E-06
	F_7	30	5.10E-06	0.000546	0.000142	0.000106	3.43E-05
	F_8	30	-12569.5	-12567.2	-12568.8	-12569.1	-12569.5
	F_9	30	0	0	0	0	-
	F_{10}	30	8.88E-16	8.88E-16	8.88E-16	8.88E-16	-
	F_{11}	30	0	0	0	0	-
	F_{12}	30	2.43E-12	6.26E-05	1.15E-05	5.23E-06	1.48E-06
	F_{13}	30	1.97E-07	0.000454	4.83E-05	2.37E-05	6.38E-06
	F_{14}	30	0.998004	5.928845	1.492398	0.998004	0.998004
	F_{15}	30	0.000311	0.000407	0.000351	0.000349	0.000324
	F_{16}	30	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163
	F_{17}	30	0.397887	0.398028	0.397899	0.397887	0.397887
	F_{18}	30	3	3.000006	3	3	3
	F_{19}	30	-3.86277	-3.85399	-3.86036	-3.86192	-3.86252
	F_{20}	30	-3.28749	-2.86416	-3.11878	-3.10928	-3.19476
	F_{21}	30	-10.0866	-5.03976	-5.21953	-5.05297	-5.05407
	F_{22}	30	-5.0876	-5.06019	-5.08202	-5.08422	-5.08668
	F_{23}	30	-10.4787	-1.66876	-5.18762	-5.12587	-5.12765

Table-4.7b shows the statistical analysis of 23rd standard benchmarks by using CHHO-Tent optimizer. The second quartile, third quartile, semi interquartile deviation, standard deviation and the number of outliers are taken into consideration. This analysis is the process through which the irregular observations have been measured in the data set. Many optimization algorithms are used to decrease the effects of outlier. Some of the modern optimizers are used to eliminate the effects of outlier.

Table-4.7b: Statistical analysis of benchmark functions using CHHO-Tent method

Method	Benchmark Functions	Second quartile (50th Percentile)	Third quartile (75th Percentile)	Semi Interquartile Deviation	Number of outliers	Standard Deviation
CHHO-Tent	**F_1**	2.84E-101	9.29E-99	4.65E-99	7	7.66E-93
	F_2	8.13E-54	1.78E-51	8.92E-52	7	8.64E-48
	F_3	5.38E-83	2.04E-80	1.02E-80	5	3.45E-57
	F_4	1.70E-52	1.65E-50	8.23E-51	6	9.09E-47
	F_5	0.0084633	0.019806	0.0091556	1	0.01657616
	F_6	3.50E-05	0.0001348	6.61E-05	3	0.000219756
	F_7	0.000106	0.000193	7.94E-05	1	0.000133
	F_8	-12569.1	-12568.2	0.611975	0	0.741372
	F_9	0	-	-	0	0
	F_{10}	8.88E-16	-	-	0	0
	F_{11}	0	-	-	0	0
	F_{12}	5.23E-06	1.41E-05	6.29E-06	3	1.58E-05
	F_{13}	2.37E-05	6.26E-05	2.81E-05	1	8.32E-05
	F_{14}	0.998004	0.998004	3.36E-10	7	1.262647
	F_{15}	0.000349	0.000375	2.56E-05	0	2.92E-05
	F_{16}	-1.03163	-1.03163	2.65E-10	3	2.59E-09
	F_{17}	0.397887	0.397898	5.10E-06	2	2.85E-05
	F_{18}	3	3	4.51E-08	5	1.14E-06
	F_{19}	-3.86192	-3.85863	0.001941	0	0.002853
	F_{20}	-3.10928	-3.06099	0.066885	0	0.097761
	F_{21}	-5.05297	-5.05102	0.001523	3	0.919241
	F_{22}	-5.08422	-5.07991	0.003389	2	0.006573
	F_{23}	-5.12587	-5.12093	0.003362	2	1.181623

Table-4.8a represents the statistical analysis of uni-modal, multi-modal and fixed dimension benchmark functions using CSCA optimization algorithm. In this table, the minimum fitness, maximum fitness, mean fitness, median fitness and first quartile have been taken into consideration.

Table-4.8a: Statistical analysis of benchmark functions using CSCA method

Method	Benchmark Functions	No. of trial	Minimum fitness	Maximum fitness	Mean fitness	Median fitness	First quartile (25th Percentile)
CSCA	**F_1**	30	0.0126823	150.962217	14.9241019	3.32754519	0.45880173
	F_2	30	5.61E-05	0.33826899	0.03088071	0.00907073	0.00270342
	F_3	30	888.811393	17459.641	7312.05273	6768.03506	3324.72525
	F_4	30	8.57236527	56.1497669	34.0670238	35.5722004	23.8047818
	F_5	30	55.7480132	193231.826	30785.7062	6243.19348	1021.34689
	F_6	30	3.80149279	80.4760098	21.67592	14.4014476	7.3764213
	F_7	30	0.003208	0.273373	0.063687	0.048301	0.025428
	F_8	30	-4164.57	-3340.13	-3760.65	-3798.33	-3949.21
	F_9	30	0.386263	124.6243	38.88475	37.09739	11.97815
	F_{10}	30	0.068041	20.31943	13.46625	20.1836	1.669122
	F_{11}	30	0.001721	1.75701	0.926611	0.979517	0.676949
	F_{12}	30	1.2165	1753896	201583.3	12.45208	3.08448
	F_{13}	30	4.242706	11951328	430067.1	67.14688	16.40445
	F_{14}	30	0.998004	2.982105	2.122433	2.982105	0.998017
	F_{15}	30	0.000344	0.0016	0.001048	0.000905	0.00079
	F_{16}	30	-1.03163	-1.03141	-1.03157	-1.03159	-1.03161
	F_{17}	30	0.397921	0.406789	0.400424	0.399671	0.398587
	F_{18}	30	3.000002	3.000159	3.000055	3.000042	3.000017
	F_{19}	30	-3.86128	-3.85001	-3.85392	-3.85436	-3.85479
	F_{20}	30	-3.17629	-1.90979	-2.92704	-3.00493	-3.08467
	F_{21}	30	-4.93159	-0.35065	-2.2713	-0.88064	-4.61652
	F_{22}	30	-9.35948	-0.90629	-3.4056	-3.40587	-4.76423
	F_{23}	30	-9.49138	-0.94108	-4.03031	-4.10111	-4.82367

Table-4.8b shows the statistical analysis of 23rd standard benchmarks by using CSCA optimizer. For statistical analysis, the second quartile, third quartile, semi interquartile deviation, standard deviation and the number of outliers are taken into consideration. In statistical measurements, the quartile divides the numbers of data sets into four portions. Those four quarters can be more or less than their equal sizes.

Table-4.8b: Statistical analysis of benchmark functions using CSCA method

Method	Benchmark Functions	Second quartile (50th Percentile)	Third quartile (75th Percentile)	Semi Interquartile Deviation	Number of outliers	Standard Deviation
CSCA	F_1	3.327545	13.42188	6.48154	3	32.23405
	F_2	0.00907073	0.02609298	0.01169478	3	6.81E-02
	F_3	6768.03506	10341.9592	3508.61699	0	4472.762602
	F_4	35.5722004	44.6045082	10.3998632	0	12.30336069
	F_5	6243.19348	40306.9516	19642.8024	3	51612.24475
	F_6	14.4014476	34.4746371	13.5491079	0	17.90549312
	F_7	0.048301	0.097094	0.035833	1	0.056811
	F_8	-3798.33	-3566.88	191.1673	0	235.9351
	F_9	37.09739	51.30532	19.66359	0	34.19933
	F_{10}	20.1836	20.23746	9.284171	0	9.179928
	F_{11}	0.979517	1.11134	0.217195	0	0.350491
	F_{12}	12.45208	42259.02	21127.97	5	486409.6
	F_{13}	67.14688	7039.714	3511.655	6	2178707
	F_{14}	2.982105	2.982105	0.992044	0	0.999879
	F_{15}	0.000905	0.001412	0.000311	0	0.000363
	F_{16}	-1.03159	-1.03154	3.69E-05	0	5.43E-05
	F_{17}	0.399671	0.401601	0.001507	0	0.002417
	F_{18}	3.000042	3.000068	2.55E-05	0	4.76E-05
	F_{19}	-3.85436	-3.85294	0.000925	1	0.002069
	F_{20}	-3.00493	-2.9572	0.063739	5	0.272363
	F_{21}	-0.88064	-0.87942	1.868549	0	1.843985
	F_{22}	-3.40587	-0.91082	1.926704	0	2.064134
	F_{23}	-4.10111	-3.27456	0.774552	1	1.573079

Table-4.9a: Statistical analysis of benchmark functions using CSMA method

Method	Benchmark Functions	No. of trial	Minimum fitness	Maximum fitness	Mean fitness	Median fitness	First quartile (25th Percentile)
CSMA	**F_1**	30	0	7.43E-295	2.48E-296	0	
	F_2	30	6.23E-239	2.23E-120	7.43E-122	1.96E-178	6.56E-210
	F_3	30	0	1.58E-292	5.28E-294	0	
	F_4	30	5.00E-276	5.82E-127	1.94E-128	2.27E-188	4.29E-194
	F_5	30	0.00557291	28.2422401	5.03415701	0.95432807	0.47468183
	F_6	30	0.0007766	0.01294323	0.00622091	0.00579468	0.00451544
	F_7	30	1.40E-05	0.000354	0.000134	0.000118	6.96E-05
	F_8	30	-12569.5	-12567.7	-12568.9	-12568.9	-12569.2
	F_9	30	0	0	0	0	
	F_{10}	30	8.88E-16	8.88E-16	8.88E-16	8.88E-16	
	F_{11}	30	0	0	0	0	
	F_{12}	30	5.38E-05	0.033799	0.007442	0.003023	0.000862
	F_{13}	30	2.62E-05	0.065159	0.012679	0.00534	0.001905
	F_{14}	30	0.998004	0.998004	0.998004	0.998004	0.998004
	F_{15}	30	0.000308	0.001516	0.000634	0.000531	0.00034
	F_{16}	30	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163
	F_{17}	30	0.397887	0.397888	0.397887	0.397887	0.397887
	F_{18}	30	3	3	3	3	3
	F_{19}	30	-3.86278	-3.86231	-3.86277	-3.86278	-3.86278
	F_{20}	30	-3.32199	-3.19744	-3.2423	-3.20309	-3.32197
	F_{21}	30	-10.1532	-10.1517	-10.1527	-10.1528	-10.1529
	F_{22}	30	-10.4028	-10.4004	-10.4023	-10.4025	-10.4027
	F_{23}	30	-10.5363	-10.5341	-10.5358	-10.536	-10.5362

Table-4.9a and Table-4.9b represent the statistical analysis of benchmark functions using hCHHO-SCA optimization algorithm. The 30 trail runs are taken into consideration. The minimum, maximum, mean and median fitness are measured. The first, second and third quartiles are taken into consideration. The first quartile define as 25% of the dataset. It is also defined as middle value between median and smallest value of the dataset. The second quartile is the median value of the dataset. The second quartile define as 50% of the dataset. The third quartile is the middle value between the highest value and median value. The third quartile define as 75% of the dataset.

Table-4.9b: Statistical analysis of benchmark functions using CSMA method

Method	Benchmark Functions	Second quartile (50th Percentile)	Third quartile (75th Percentile)	Semi Interquartile Deviation	Number of outliers	Standard Deviation
CSMA	**F_1**	0	1.49E-297		0	0.00E+00
	F_2	1.96E-178	1.41E-154	7.03E-155	7	4.07E-121
	F_3	0	0		0	0
	F_4	2.27E-188	1.76E-171	8.82E-172	7	1.06E-127
	F_5	0.95432807	2.97249316	1.24890567	5	9.374449507
	F_6	0.00579468	0.0080493	0.00176693	0	0.00298608
	F_7	0.000118	0.000167	4.88E-05	0	9.13E-05
	F_8	-12568.9	-12568.6	0.321297	0	0.416875
	F_9	0	-	-	0	0
	F_{10}	8.88E-16	-	-	0	0
	F_{11}	0	-	-	0	0
	F_{12}	0.003023	0.013083	0.006111	0	0.008958
	F_{13}	0.00534	0.019299	0.008697	1	0.016749
	F_{14}	0.998004	0.998004	3.33E-13	1	8.26E-13
	F_{15}	0.000531	0.00077	0.000215	0	0.000344
	F_{16}	-1.03163	-1.03163	5.15E-10	2	1.53E-09
	F_{17}	0.397887	0.397887	2.07E-08	2	3.95E-08
	F_{18}	3	3	8.66E-11	4	4.83E-10
	F_{19}	-3.86278	-3.86278	1.06E-07	3	8.60E-05
	F_{20}	-3.20309	-3.20303	0.059471	0	0.057317
	F_{21}	-10.1528	-10.1526	0.000187	1	0.000354
	F_{22}	-10.4025	-10.4021	0.000283	1	0.000542
	F_{23}	-10.536	-10.5355	0.000342	1	0.000489

Table-4.10a and Table-4.10b represents the statistical analysis of standard benchmarks using hCHHO-SCA optimization algorithm. The proposed hCHHO-SCA optimizer was run for 30 times. In this optimizer the minimum, maximum, mean, median and first quartile are obtained. Further, the second and third quartile, semi interquartile and standard deviation are taken into consideration.

Table-4.10a: Statistical analysis of benchmark functions using hCHHO-SCA method

Method	Benchmark Functions	No. of trial	Minimum fitness	Maximum fitness	Mean fitness	Median fitness	First quartile (25th Percentile)
hCHHO-SCA	**F_1**	30	0	0	0	0	NaN
	F_2	30	0	0	0	0	NaN
	F_3	30	0	0	0	0	NaN
	F_4	30	0	0	0	0	NaN
	F_5	30	3.8629e-10	7.8172e-08	2.6362e-08	5.2851e-10	3.8629e-10
	F_6	30	7.8969e-17	2.5053e-10	8.9762e-11	1.8754e-11	7.8969e-17
	F_7	30	3.4922e-05	0.00016728	7.9572e-05	3.6515e-05	3.4922e-05
	F_8	30	-12569.4866	-12569.4866	-12569.4866	-12569.4866	-12569.4866
	F_9	30	0	0	0	0	NAN
	F_{10}	30	8.8818e-16	8.8818e-16	8.8818e-16	8.8818e-16	NAN
	F_{11}	30	0	0	0	0	NAN
	F_{12}	30	6.9242e-14	4.569e-11	1.5322e-11	2.0756e-13	6.9242e-14
	F_{13}	30	1.045e-13	3.2584e-09	1.0904e-09	1.2787e-11	1.045e-13
	F_{14}	30	0.998	0.998	0.998	0.998	NAN
	F_{15}	30	0.00030749	0.00030749	0.00030749	0.00030749	0.00030749
	F_{16}	30	-1.0316	-1.0316	-1.0316	-1.0316	NAN
	F_{17}	30	0.39789	0.39789	0.39789	0.39789	NAN
	F_{18}	30	3	3	3	3	NAN
	F_{19}	30	-3.8628	-3.8628	-3.8628	-3.8628	-3.8628
	F_{20}	30	-3.322	-3.2031	-3.2824	-3.322	-3.322
	F_{21}	30	-10.1532	-10.1532	-10.1532	-10.1532	-10.1532
	F_{22}	30	-10.4029	-10.4029	-10.4029	-10.4029	-10.4029
	F_{23}	30	-10.5364	-10.5364	-10.5364	-10.5364	-10.5364

Table-4.10b: Statistical analysis of benchmark functions using hCHHO-SCA method

Method	Benchmark Functions	Second quartile (50th Percentile)	Third quartile (75th Percentile)	Semi Interquartile Deviation	Number of outliers	Standard Deviation
hCHHO-SCA	**F_1**	0	NaN	NaN	0	0
	F_2	0	NaN	NaN	0	0
	F_3	0	NaN	NaN	0	0
	F_4	0	NaN	NaN	0	0
	F_5	5.2851e-10	7.8172e-08	3.8893e-08	0	4.4868e-08
	F_6	1.8754e-11	2.5053e-10	1.2527e-10	0	1.3955e-10
	F_7	3.6515e-05	0.00016728	6.6178e-05	0	7.596e-05
	F_8	-12569.4866	-12569.4866	6.3201e-09	0	6.6155e-09
	F_9	0	NAN	NAN	0	0
	F_{10}	8.8818e-16	NAN	NAN	0	0
	F_{11}	0	NAN	NAN	0	0
	F_{12}	2.0756e-13	4.569e-11	2.2811e-11	0	2.63e-11
	F_{13}	1.2787e-11	3.2584e-09	1.6291e-09	0	1.8775e-09
	F_{14}	0.998	NAN	NAN	0	1.3597e-16
	F_{15}	0.00030749	0.00030749	1.3796e-17	0	1.3887e-17
	F_{16}	-1.0316	NAN	NAN	0	0
	F_{17}	0.39789	NAN	NAN	0	0
	F_{18}	3	NAN	NAN	0	0
	F_{19}	-3.8628	-3.8628	4.4409e-16	0	7.0217e-16
	F_{20}	-3.322	-3.2031	0.059447	0	0.068643
	F_{21}	-10.1532	-10.1532	1.8326e-11	0	1.9404e-11
	F_{22}	-10.4029	-10.4029	1.2973e-11	0	1.4709e-11
	F_{23}	-10.5364	-10.5364	4.3299e-12	0	4.3308e-12

Table-4.11a and Table-4.11b shows the statistical analysis of 23rd standard benchmarks by using hCSMA-SCA optimization algorithm. The minimum, maximum, mean and median fitness are measured. The first quartile, the second quartile, third quartile, semi interquartile deviation, standard deviation and the number of outliers are taken into consideration. This analysis is the process through which the irregular observations have been measured in the data set. Many optimization algorithms are used to decrease the effects of outlier.

Table-4.11a: Statistical analysis of benchmark functions using hCSMA-SCA method

Method	Benchmark Functions	No. of trial	Minimum fitness	Maximum fitness	Mean fitness	Median fitness	First quartile (25th Percentile)
hCSMA-SCA	**F_1**	30	0	0	0	0	NAN
	F_2	30	0	0	0	0	NAN
	F_3	30	0	0	0	0	NAN
	F_4	30	0	0	0	0	NAN
	F_5	30	0.023283	0.75936	0.28096	0.060232	0.023283
	F_6	30	0.0040544	1.057	0.35973	0.018163	0.0040544
	F_7	30	0.0011439	0.0044505	0.0028796	0.0030444	0.0011439
	F_8	30	-12569.025	-12547.928	12557.6044	-12555.85	-12569.0252
	F_9	30	0	0	0	0	NAN
	F_{10}	30	8.8818e-16	8.8818e-16	8.8818e-16	8.8818e-16	NAN
	F_{11}	30	0	0	0	0	NAN
	F_{12}	30	6.8577e-05	0.011096	0.0039826	0.0007834	6.8577e-05
	F_{13}	30	0.10287	0.84467	0.3524	0.10965	0.10287
	F_{14}	30	0.998	0.998	0.998	0.998	0.998
	F_{15}	30	0.00030753	0.00030782	0.00030772	0.00030782	0.00030753
	F_{16}	30	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316
	F_{17}	30	0.39789	0.39789	0.39789	0.39789	0.39789
	F_{18}	30	3	3	3	3	3
	F_{19}	30	-3.8628	-3.8549	-3.8575	-3.8549	-3.8628
	F_{20}	30	-3.1326	-2.8394	-2.9959	-3.0156	-3.1326
	F_{21}	30	-10.0856	-9.9339	-10.031	-10.0736	-10.0856
	F_{22}	30	-10.4027	-10.2702	-10.3556	-10.3938	-10.4027
	F_{23}	30	-10.5362	-10.5262	-10.5327	-10.5357	-10.5362

Table-4.11b: Statistical analysis of benchmark functions using hCSMA-SCA method

Method	Benchmark Functions	Second quartile (50th Percentile)	Third quartile (75th Percentile)	Semi Interquartile Deviation	Number of outliers	Standard Deviation
hCSMA-SCA	F_1	0	NAN	NAN	0	0
	F_2	0	0	0	0	NAN
	F_3	0	0	0	0	NAN
	F_4	0	0	0	0	NAN
	F_5	0.060232	0.75936	0.36804	0	0.41472
	F_6	0.018163	1.057	0.52646	0	0.60387
	F_7	0.0030444	0.0044505	0.0016533	0	0.0016594
	F_8	-12555.8595	-12547.9287	10.5483	0	10.656
	F_9	0	NAN	NAN	0	0
	F_{10}	8.8818e-16	NAN	NAN	0	0
	F_{11}	0	NAN	NAN	0	0
	F_{12}	0.0007834	0.011096	0.0055136	0	0.0061706
	F_{13}	0.10965	0.84467	0.3709	0	0.42634
	F_{14}	0.998	0.998	2.5583e-12	0	2.6626e-12
	F_{15}	0.00030782	0.00030782	1.473e-07	0	1.6886e-07
	F_{16}	-1.0316	-1.0316	8.4466e-10	0	8.9243e-10
	F_{17}	0.39789	0.39789	1.6569e-08	0	1.6857e-08
	F_{18}	3	3	2.3159e-13	0	2.3378e-13
	F_{19}	-3.8549	-3.8549	0.0039379	0	0.0045471
	F_{20}	-3.0156	-2.8394	0.1466	0	0.14759
	F_{21}	-10.0736	-9.9339	0.075843	0	0.084338
	F_{22}	-10.3938	-10.2702	0.066219	0	0.074037
	F_{23}	-10.5357	-10.5262	0.005028	0	0.0056605

The time span are required to perform the optimization algorithms is known as computational time or simulation time. The computational time is also considered as running time of proposed optimizers. Table-4.12a shows the computational time of 23^{rd} standard benchmark functions using CHHO-sigmoid and CHHO-Tent optimization methods. The best, average and the worst values are taken in consideration.

Table-4.12a: Computational time of unimodal, multimodal and fixed dimension benchmark functions using CHHO-sigmoid and CHHO-Tent methods

Methods	**CHHO-Sigmoid**			**CHHO-Tent**		
Benchmark Functions	**Best Value**	**Average Value**	**Worst Value**	**Best Value**	**Average Value**	**Worst Value**
F_1	0.046875	0.0822917	0.265625	0.0625	0.0984375	0.328125
F_2	0.046875	0.0776042	0.1875	0.0625	0.0864583	0.21875
F_3	0.21875	0.2442708	0.296875	0.359375	0.3791667	0.484375
F_4	0.046875	0.0598958	0.125	0.078125	0.09375	0.109375
F_5	0.0625	0.0817708	0.109375	0.125	0.1473958	0.25
F_6	0.046875	0.0614583	0.09375	0.09375	0.109375	0.21875
F_7	0.125	0.158333	0.265625	0.21875	0.235938	0.25
F_8	0.0625	0.083854	0.109375	0.140625	0.15625	0.265625
F_9	0.046875	0.068229	0.09375	0.109375	0.120833	0.171875
F_{10}	0.0625	0.077083	0.21875	0.109375	0.126563	0.234375
F_{11}	0.078125	0.088021	0.109375	0.140625	0.146875	0.21875
F_{12}	0.28125	0.308854	0.5	0.484375	0.5125	0.640625
F_{13}	0.28125	0.319271	0.4375	0.484375	0.499479	0.546875
F_{14}	0.5	0.542188	0.625	0.84375	0.881771	1.03125
F_{15}	0.046875	0.056771	0.140625	0.078125	0.108333	0.28125
F_{16}	0.046875	0.055729	0.078125	0.078125	0.086979	0.21875
F_{17}	0.03125	0.065104	0.1875	0.0625	0.097917	0.234375
F_{18}	0.03125	0.052083	0.09375	0.0625	0.071354	0.140625
F_{19}	0.046875	0.060417	0.078125	0.09375	0.107813	0.234375
F_{20}	0.046875	0.064583	0.09375	0.09375	0.107813	0.21875
F_{21}	0.0625	0.071354	0.09375	0.109375	0.124479	0.296875
F_{22}	0.0625	0.083854	0.109375	0.125	0.139063	0.296875
F_{23}	0.078125	0.097396	0.125	0.140625	0.159896	0.296875

Table-4.12b shows the computational time of 23^{rd} standard benchmark functions using CSCA and CSMA optimization methods. The best, average and the worst values have been measured. Table-4.12c represents the computational time for uni-modal, multimodal and fixed dimension benchmark functions using proposed hybrid optimizers, i.e. hCHHO-SCA and hCSMA-SCA.

Table-4.12c represents the computational time of uni-modal, multi-modal and fixed dimension benchmark functions using hCHHO-SCA and hCSMA-SCA optimizers. The best, average and the worst values are taken into consideration.

Table.4.12b: Computational time of unimodal, multimodal and fixed dimension benchmark functions using CSCA and CSMA methods

Methods	CSCA			CSMA		
Benchmark Functions	Best Value	Average Value	Worst Value	Best Value	Average Value	Worst Value
F_1	0.171875	0.20729167	0.515625	0.96875	1.18645833	2.359375
F_2	0.171875	0.19947917	0.5	0.984375	1.07604167	1.71875
F_3	0.28125	0.296875	0.328125	1.109375	1.1328125	1.296875
F_4	0.171875	0.18020833	0.203125	0.96875	1.01666667	1.25
F_5	0.1875	0.19270833	0.21875	0.984375	1.01822917	1.109375
F_6	0.171875	0.17604167	0.1875	0.96875	1.015625	1.234375
F_7	0.234375	0.24375	0.265625	1.03125	1.085938	1.171875
F_8	0.1875	0.196354	0.328125	0.96875	1.001563	1.0625
F_9	0.171875	0.179688	0.203125	0.953125	0.975	1.015625
F_{10}	0.171875	0.188021	0.21875	0.953125	0.976042	1.0625
F_{11}	0.1875	0.19375	0.203125	0.953125	0.98125	1.046875
F_{12}	0.328125	0.339583	0.359375	1.109375	1.136458	1.171875
F_{13}	0.328125	0.339583	0.359375	1.109375	1.136979	1.171875
F_{14}	0.328125	0.345313	0.40625	0.46875	0.506771	0.609375
F_{15}	0.03125	0.04479167	0.046875	0.234375	0.252083	0.328125
F_{16}	0.03125	0.031771	0.046875	0.171875	0.189583	0.234375
F_{17}	0.015625	0.036458	0.09375	0.1875	0.251042	0.671875
F_{18}	0.015625	0.030208	0.03125	0.171875	0.180729	0.234375
F_{19}	0.03125	0.044271	0.046875	0.21875	0.226042	0.265625
F_{20}	0.046875	0.060938	0.0625	0.296875	0.309375	0.328125
F_{21}	0.046875	0.053646	0.0625	0.25	0.2625	0.28125
F_{22}	0.046875	0.061458	0.078125	0.25	0.264063	0.28125
F_{23}	0.0625	0.067188	0.078125	0.265625	0.277083	0.296875

Table-4.12c: Computational time of unimodal, multimodal and fixed dimension benchmark functions using hCHHO-SCA and hCSMA-SCA methods

Methods	**hCHHO-SCA**			**hCSMA-SCA**		
Benchmark Functions	**Best Value**	**Average Value**	**Worst Value**	**Best Value**	**Average Value**	**Worst Value**
F_1	0.046875	0.0822917	0.265625	0.171875	0.20729167	0.515625
F_2	0.046875	0.0776042	0.1875	0.171875	0.19947917	0.5
F_3	0.21875	0.2442708	0.296875	0.28125	0.296875	0.328125
F_4	0.046875	0.0598958	0.125	0.171875	0.18020833	0.203125
F_5	0.0625	0.0817708	0.109375	0.1875	0.19270833	0.21875
F_6	0.046875	0.0614583	0.09375	0.171875	0.17604167	0.1875
F_7	0.125	0.158333	0.265625	0.234375	0.24375	0.265625
F_8	0.0625	0.083854	0.109375	0.1875	0.196354	0.328125
F_9	0.046875	0.068229	0.09375	0.171875	0.179688	0.203125
F_{10}	0.0625	0.077083	0.21875	0.171875	0.188021	0.21875
F_{11}	0.078125	0.088021	0.109375	0.1875	0.19375	0.203125
F_{12}	0.28125	0.308854	0.5	0.328125	0.339583	0.359375
F_{13}	0.28125	0.319271	0.4375	0.328125	0.339583	0.359375
F_{14}	0.5	0.542188	0.625	0.328125	0.345313	0.40625
F_{15}	0.046875	0.056771	0.140625	0.03125	0.04479167	0.046875
F_{16}	0.046875	0.055729	0.078125	0.03125	0.031771	0.046875
F_{17}	0.03125	0.065104	0.1875	0.015625	0.036458	0.09375
F_{18}	0.03125	0.052083	0.09375	0.015625	0.030208	0.03125
F_{19}	0.046875	0.060417	0.078125	0.03125	0.044271	0.046875
F_{20}	0.046875	0.064583	0.09375	0.09375	0.107813	0.21875
F_{21}	0.0625	0.071354	0.09375	0.109375	0.124479	0.296875
F_{22}	0.0625	0.083854	0.109375	0.125	0.139063	0.296875
F_{23}	0.078125	0.097396	0.125	0.140625	0.159896	0.296875

The convergence curve for unimodal, multimodal and fixed dimension benchmark functions are taken into consideration. The acceptability of the measured quantity can be analyzed by using convergence graphs. **Fig.4.15, Fig.4.16** and **Fig.4.17** shows the convergence graph of standard uni-modal benchmark functions for CHHO-sigmoid, CHHO-Tent, CSCA, CSMA, hCHHO-SCA and hCSMA-SCA with other existing optimization algorithms.

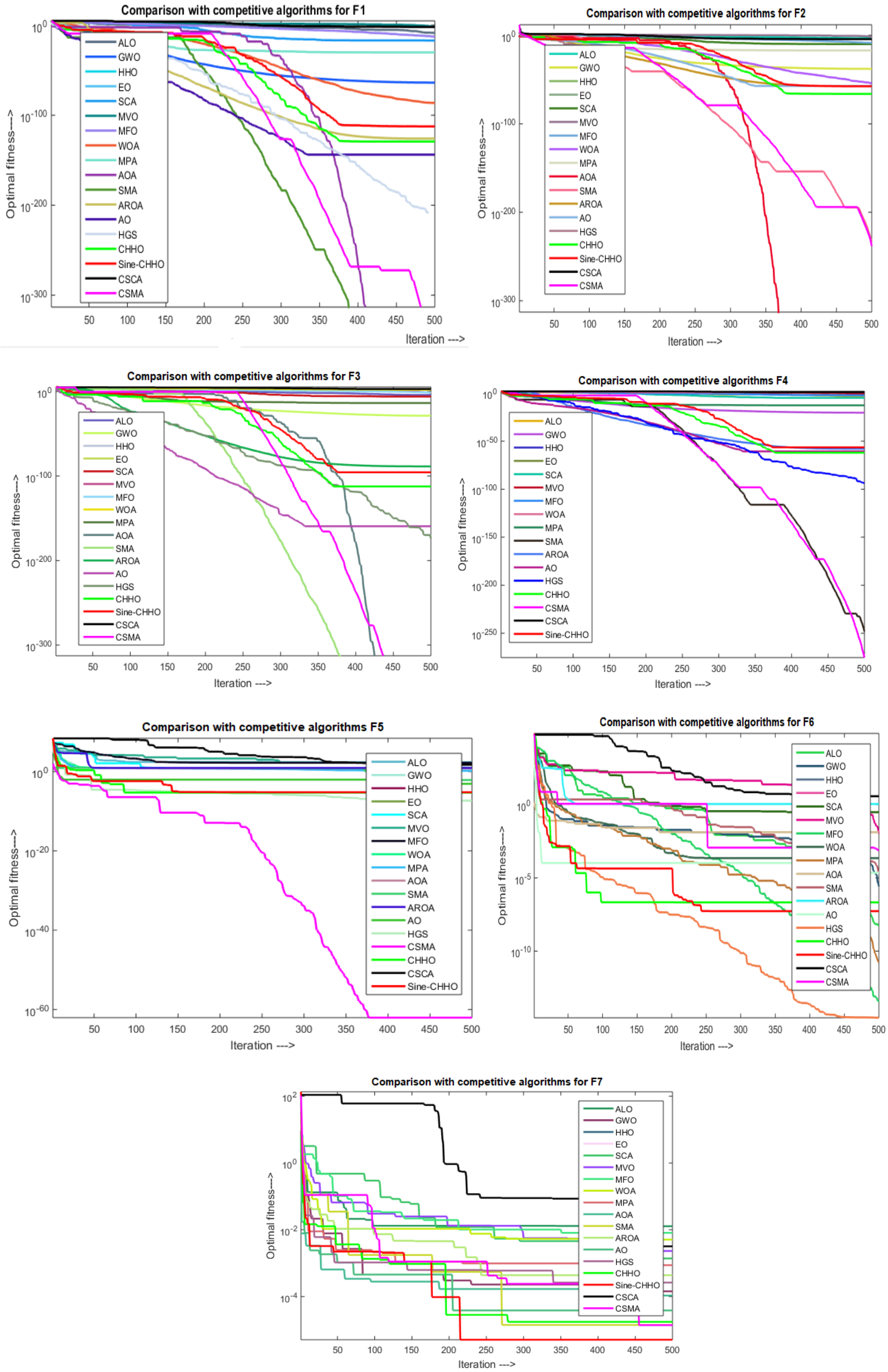


Fig.4.15: Convergence graph of standard unimodal benchmark functions for CHHO-sigmoid, CHHO-Tent, CSCA, CSMA with other existing methods

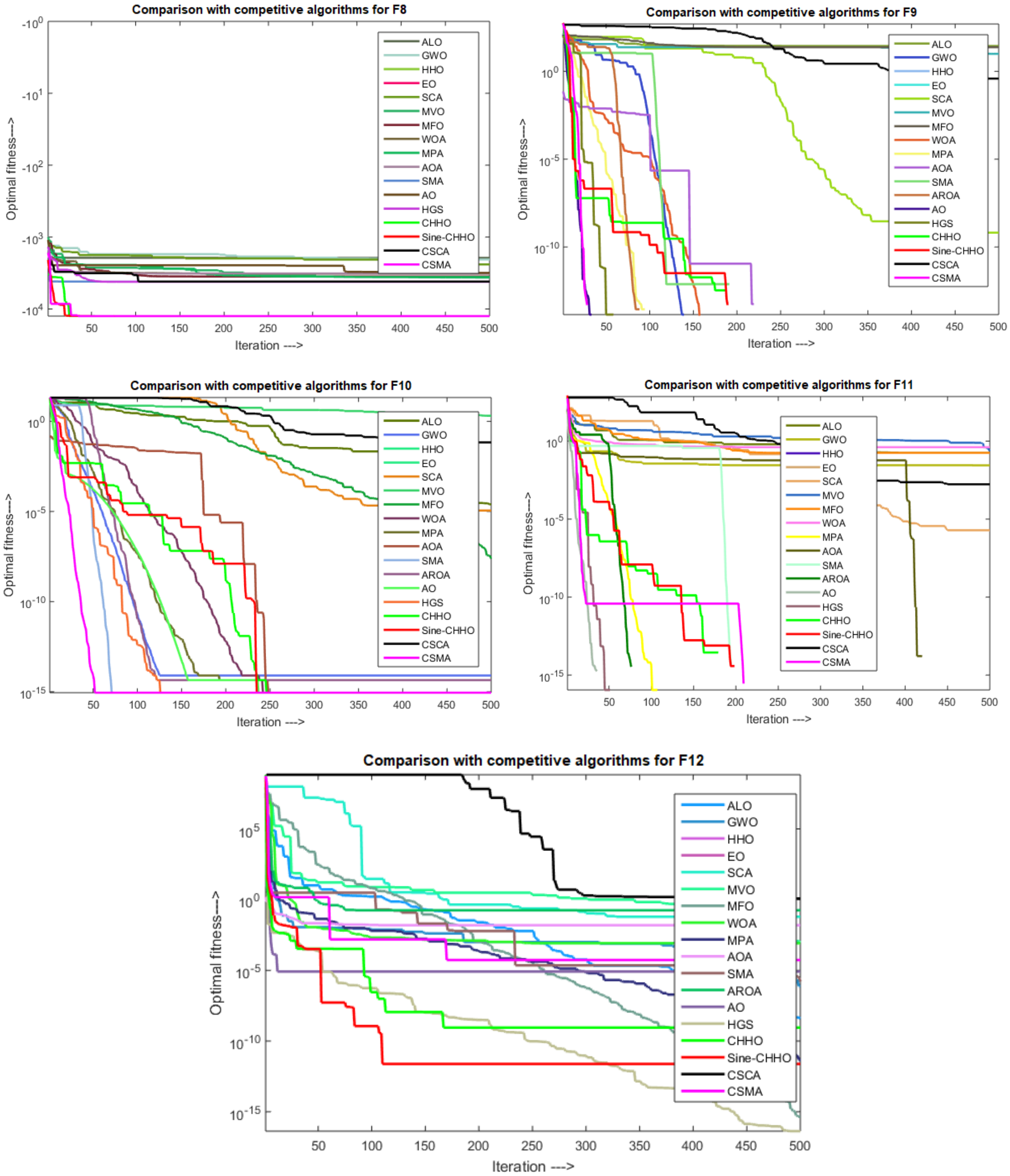
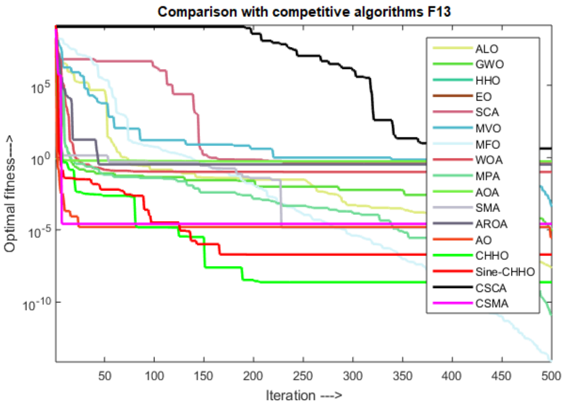
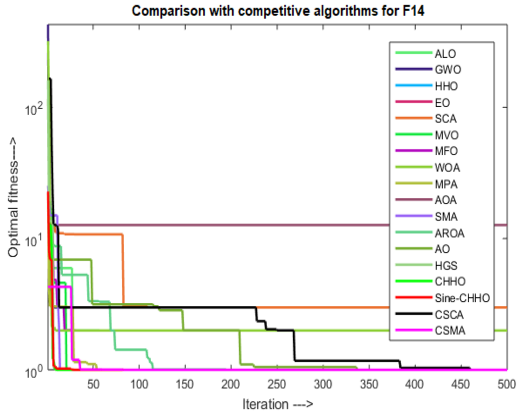
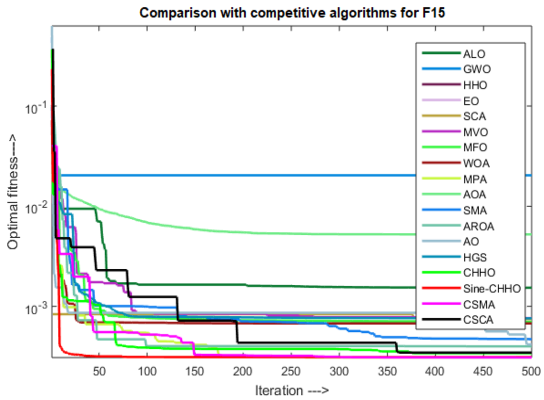
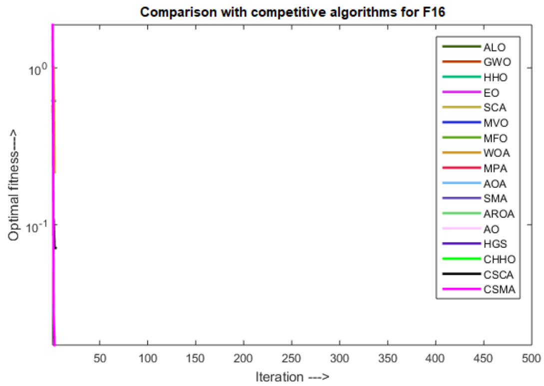


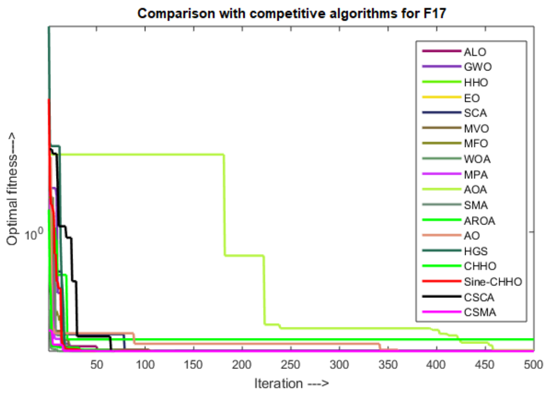
Fig.4.16: Convergence graph of standard multimodal benchmark functions for CHHO-Sigmoid, CHHO-Tent, CSCA, CSMA with other existing methods

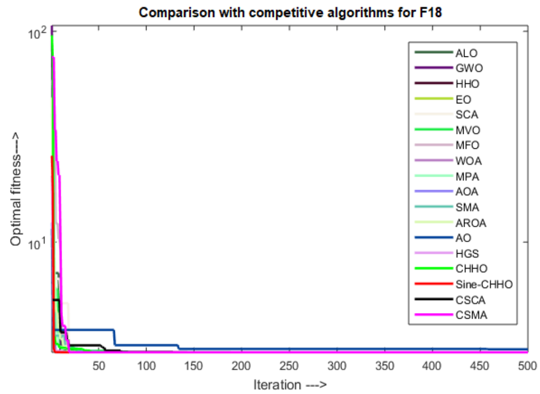

Comparison with competitive algorithms F13
Optimal fitness--->
Iteration --->
ALO
GWO
HHO
EO
SCA
MVO
MFO
WOA
MPA
AOA
SMA
AROA
AO
CHHO
Sine-CHHO
CSCA
CSMA

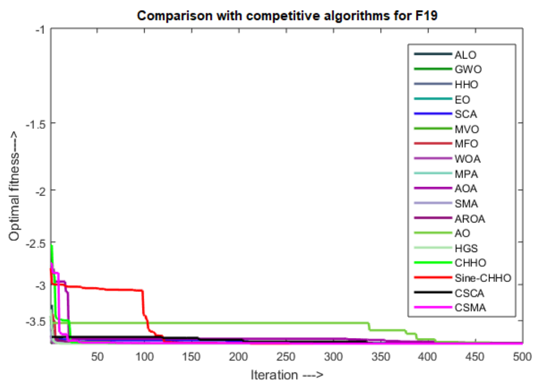

Comparison with competitive algorithms for F14
Optimal fitness--->
Iteration --->
ALO
GWO
HHO
EO
SCA
MVO
MFO
WOA
MPA
AOA
SMA
AROA
AO
HGS
CHHO
Sine-CHHO
CSCA
CSMA

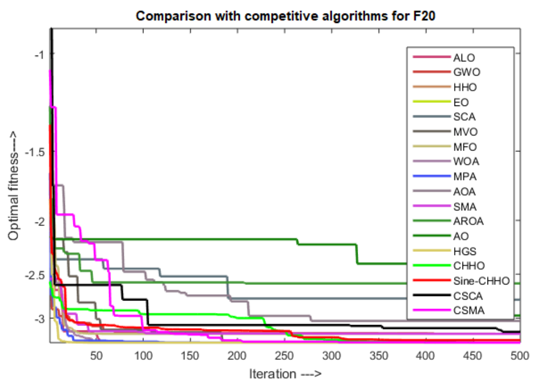

Comparison with competitive algorithms for F15
Optimal fitness--->
Iteration --->
ALO
GWO
HHO
EO
SCA
MVO
MFO
WOA
MPA
AOA
SMA
AROA
AO
HGS
CHHO
Sine-CHHO
CSMA
CSCA


Comparison with competitive algorithms for F16
Optimal fitness--->
Iteration --->
ALO
GWO
HHO
EO
SCA
MVO
MFO
WOA
MPA
AOA
SMA
AROA
AO
HGS
CHHO
CSCA
CSMA


Comparison with competitive algorithms for F17
Optimal fitness--->
Iteration --->
ALO
GWO
HHO
EO
SCA
MVO
MFO
WOA
MPA
AOA
SMA
AROA
AO
HGS
CHHO
Sine-CHHO
CSCA
CSMA


Comparison with competitive algorithms for F18
Optimal fitness--->
Iteration --->
ALO
GWO
HHO
EO
SCA
MVO
MFO
WOA
MPA
AOA
SMA
AROA
AO
HGS
CHHO
Sine-CHHO
CSCA
CSMA


Comparison with competitive algorithms for F19
Optimal fitness--->
Iteration --->
ALO
GWO
HHO
EO
SCA
MVO
MFO
WOA
MPA
AOA
SMA
AROA
AO
HGS
CHHO
Sine-CHHO
CSCA
CSMA


Comparison with competitive algorithms for F20
Optimal fitness--->
Iteration --->
ALO
GWO
HHO
EO
SCA
MVO
MFO
WOA
MPA
AOA
SMA
AROA
AO
HGS
CHHO
Sine-CHHO
CSCA
CSMA

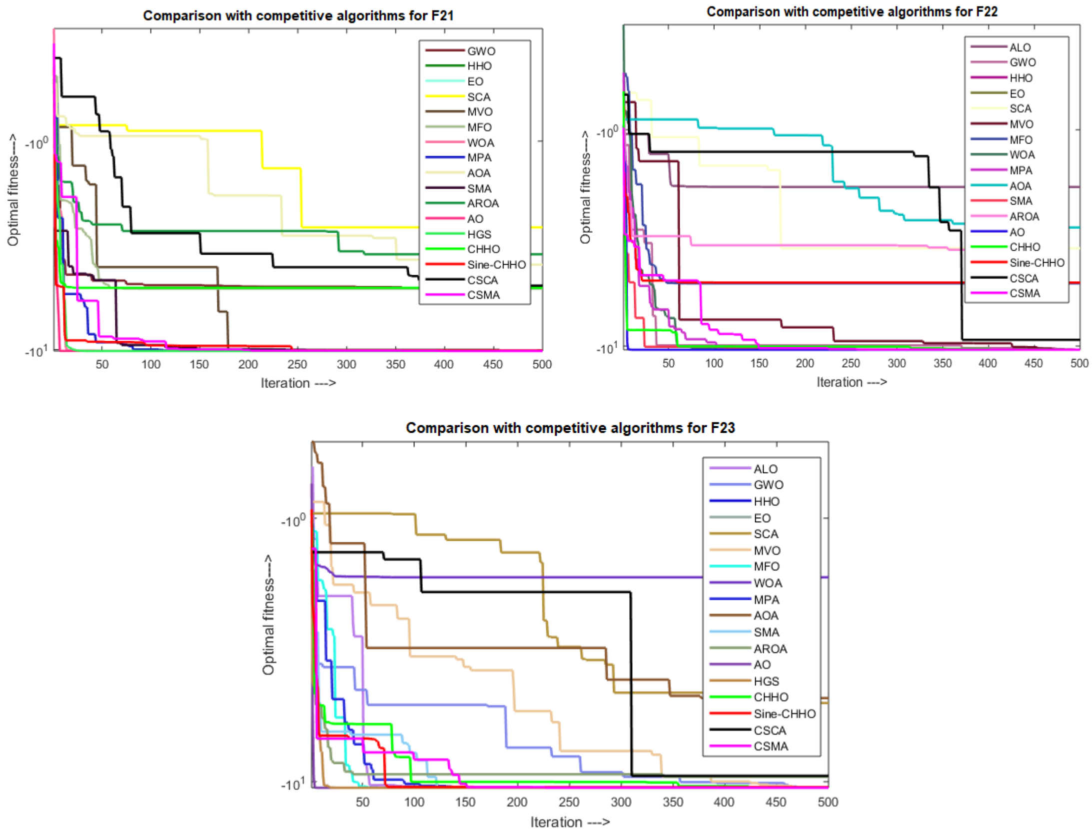


Fig.4.17: Convergence graph of standard fixed dimension benchmark functions for CHHO-Sigmoid, CHHO-Tent, CSCA and CSMA with other existing methods

Multidisciplinary Engineering Design Problem

In this section, the descriptions of each engineering design problems have been explained. Further, the numerical analysis of each multidisciplinary engineering design problems along with their constraints are taken into consideration. Eleven types of engineering design problems are explained in details. These engineering problems are tested over three-bar truss issues, compression design, pressure-vessel design, welded beam, gear train, cantilever beam design, speed reducer, rolling elements, Belleville spring, multidisc clutch brake issues and I-beam design problem [275]. Every design problems are simulated by using proposed optimization methods. Table-4.13a shows the results of engineering design issues by using CHHO-Sigmoid and CHHO-Tent optimizer.

Table-4.13a: Test results of engineering design problem using CHHO-Sigmoid and CHHO-Tent methods

Methods	Engineering Design Problem	Index	Mean Value	Standard Deviation	Best Value	Worst Value	Median Value
CHHO-Sigmoid	ENGG1	20	264.9507	1.633372	263.8959	269.4896	264.1965
	ENGG2	23	4266.717	824.4892	2999.914	5534.588	4386.527
	ENGG3	15	41073.27	35621.11	6776.092	140791.7	33304.17
	ENGG4	26	0.013639	0.000705	0.012782	0.015579	0.013476
	ENGG5	5	2.501823	0.651282	1.755663	4.048809	2.236811
	ENGG6	30	-69716	17281.71	-84614.1	-42057	-80629.6
	ENGG7	27	0.479461	0.070626	0.391696	0.649952	0.466958
	ENGG8	1	0.000308	0.000939	0	0.003105	0
	ENGG9	6	3.00E+22	2.67E+22	1.980551	5.30E+22	5.30E+22
	ENGG10	7	1.460584	0.050024	1.309154	1.517641	1.478089
	ENGG11	1	0.007537	0.002734	0.006626	0.019818	0.006626
CHHO-Tent	ENGG1	7	264.0119	0.177209	263.8959	264.6276	263.9329
	ENGG2	21	3424.007	489.6215	3013.702	5000.387	3212.224
	ENGG3	3	6666.379	396.6526	6028.263	7571.221	6606.421
	ENGG4	26	0.013884	0.001273	0.012692	0.017773	0.013418
	ENGG5	6	1.934821	0.163277	1.761417	2.291372	1.860657
	ENGG6	14	-75839.8	12586.59	-84351.8	-42057	-81897.2
	ENGG7	15	0.44457	0.046902	0.389654	0.571009	0.427836
	ENGG8	1	0	0	0	0	0
	ENGG9	24	1.77E+22	2.54E+22	1.980151	5.30E+22	2.04844
	ENGG10	26	1.306028	0.001485	1.303728	1.309188	1.305793
	ENGG11	1	0.006626	1.97E-18	0.006626	0.006626	0.006626

Table-4.13b represents the results of engineering design problem using proposed CSCA and CSMA optimizer. The 30 runs are taken for each proposed optimization methods. The total 500 iterations are considered for each case. Further the 30 search agents are taken into consideration for each optimizer.

Table-4.13b: Test results of engineering design problem using CSCA and CSMA methods

Methods	Engineering Design Problem	Index	Mean Value	Standard Deviation	Best Value	Worst Value	Median Value
CSCA	**ENGG1**	5	268.416	8.095207	263.9066	282.8427	264.0557
	ENGG2	24	3113.958	35.09274	3056.331	3196.872	3109.471
	ENGG3	3	7117.71	552.986	6168.385	8445.029	7032.918
	ENGG4	28	0.013131	0.000437	0.012868	0.015361	0.013067
	ENGG5	19	1.868309	0.045219	1.782771	1.969818	1.872921
	ENGG6	13	-75292.5	3604.909	-84674.8	-68917.2	-74653.3
	ENGG7	6	0.420596	0.012284	0.400398	0.441619	0.420554
	ENGG8	3	2.84E-10	4.86E-10	2.87E-15	1.84E-09	8.74E-11
	ENGG9	11	2.317083	0.188134	2.074527	2.761535	2.269613
	ENGG10	24	1.355879	0.025619	1.309738	1.412898	1.354886
	ENGG11	12	0.006627	1.24E-06	0.006626	0.006631	0.006627
CSMA	**ENGG1**	1	270.1234	1.900753	264.3061	271.6106	270.9186
	ENGG2	29	2994.474	0.00273	2994.472	2994.483	2994.473
	ENGG3	29	6446.046	554.7171	5885.38	7319.001	6234.395
	ENGG4	17	0.013104	0.000728	0.012687	0.015507	0.012719
	ENGG5	9	1.733205	0.03547	1.724998	1.92035	1.725759
	ENGG6	9	-85538.7	1.686104	-85539.2	-85529.9	-85539.1
	ENGG7	1	0.392736	0.005759	0.389654	0.404658	0.389659
	ENGG8	22	7.86E-12	1.20E-11	7.63E-14	5.47E-11	3.39E-12
	ENGG9	8	4.12E+22	4.22E+22	1.14E+21	1.81E+23	3.27E+22
	ENGG10	2	1.303441	0.000122	1.303277	1.303797	1.303399
	ENGG11	7	0.006626	3.80E-10	0.006626	0.006626	0.006626

Table-4.13c shows the effectiveness of the proposed optimizer, i.e. hCHHO-SCA and hCSMA-SCA by represents the outputs for 11 types of engineering problems. The index, mean, median value, best and worst value, standard deviation are taken into consideration.

Table-4.13c: Test results of engineering design problem using hCHHO-SCA and hCSMA-SCA methods

Methods	Engineering Design Problem	Index	Mean Value	Standard Deviation	Best Value	Worst Value	Median Value
hCHHO-SCA	ENGG1	20	264.9507	1.633372	263.8959	269.4896	264.1965
	ENGG2	23	4266.717	824.4892	2999.914	5534.588	4386.527
	ENGG3	15	41073.27	35621.11	6776.092	140791.7	33304.17
	ENGG4	26	0.013639	0.000705	0.012782	0.015579	0.013476
	ENGG5	5	2.501823	0.651282	1.755663	4.048809	2.236811
	ENGG6	30	-69716	17281.71	-84614.1	-42057	-80629.6
	ENGG7	27	0.479461	0.070626	0.391696	0.649952	0.466958
	ENGG8	1	0.000308	0.000939	0	0.003105	0
	ENGG9	6	3.00E+22	2.67E+22	1.980551	5.30E+22	5.30E+22
	ENGG10	7	1.460584	0.050024	1.309154	1.517641	1.478089
	ENGG11	1	0.007537	0.002734	0.006626	0.019818	0.006626
hCSMA-SCA	ENGG1	5	268.416	8.095207	263.9066	282.8427	264.0557
	ENGG2	24	3113.958	35.09274	3056.331	3196.872	3109.471
	ENGG3	3	7117.71	552.986	6168.385	8445.029	7032.918
	ENGG4	28	0.013131	0.000437	0.012868	0.015361	0.013067
	ENGG5	19	1.868309	0.045219	1.782771	1.969818	1.872921
	ENGG6	13	-75292.5	3604.909	-84674.8	-68917.2	-74653.3
	ENGG7	6	0.420596	0.012284	0.400398	0.441619	0.420554
	ENGG8	3	2.84E-10	4.86E-10	2.87E-15	1.84E-09	8.74E-11
	ENGG9	11	2.317083	0.188134	2.074527	2.761535	2.269613
	ENGG10	24	1.355879	0.025619	1.309738	1.412898	1.354886
	ENGG11	12	0.006627	1.24E-06	0.006626	0.006631	0.006627

The hypothesis testing is required to decide whether the outputs of the research work supports the particular philosophy or not. For null hypothesis, there are no significance different between the specific populations and any difference due to experimental or sampling error. Table-4.14a represents the hypothesis testing results which includes the p-Value and h-Value of Wilcoxon rank sum test and t-test. Table-4.14b represents the hypothesis testing of special problems using CSCA and CSMA methods.

Table-4.14a: Hypothesis testing of special problems using CHHO-Sigmoid methods

Methods	CHHO-Sigmoid			
Engineering Design Problem	Wilcoxon rank-sum test		t-test	
	p-Value	h-Value	p-Value	h-Value
ENGG1	0.001004	1	1	0.003512
ENGG2	7.20E-05	1	1	4.53E-05
ENGG3	6.72E-10	1	1	1.12E-05
ENGG4	0.935192	0	0	0.326655
ENGG5	9.21E-05	1	1	4.35E-05
ENGG6	0.564209	0	0	0.187119
ENGG7	0.085	0	1	0.03462
ENGG8	0.081523	0	0	0.083096
ENGG9	0.365012	0	0	0.069773
ENGG10	3.34E-11	1	1	1.52E-16
ENGG11	0.807271	0	0	0.078347

Table.4.14b: Hypothesis testing of special problems using CSCA and CSMA methods

Methods	CSCA				CSMA			
Engineering Design Problem	Wilcoxon rank-sum test		t-test		Wilcoxon rank-sum test		t-test	
	p-Value	h-Value	p-Value	h-Value	p-Value	h-Value	p-Value	h-Value
ENGG1	0.000804	1	1	0.005651	3.69E-11	1	1	3.81E-17
ENGG2	0.051877	0	1	0.00188	3.02E-11	1	1	4.36E-05
ENGG3	0.00073	1	1	0.000452	0.030317	1	0	0.095079
ENGG4	0.015014	1	1	0.00505	0.00077	1	1	0.0026
ENGG5	0.684323	0	1	0.032128	2.37E-10	1	1	5.92E-08
ENGG6	0.002755	1	0	0.814666	3.02E-11	1	1	0.000219
ENGG7	0.185767	0	1	0.013157	5.00E-09	1	1	1.84E-06
ENGG8	1.21E-12	1	1	0.003331	1.21E-12	1	1	0.001234
ENGG9	0.038936	1	1	0.000672	9.28E-06	1	1	0.016806
ENGG10	3.02E-11	1	1	2.67E-11	3.34E-11	1	1	3.46E-10
ENGG11	6.32E-12	1	1	3.35E-06	6.32E-12	1	1	0.001456

In case of null hypothesis the quantity must be measured as zero (null). In two different situations the measured difference is equals to zero which indicate the null hypothesis.

Table-4.15a: Statistical analysis of engineering design problem using CHHO-Sigmoid method

Method	Engineering Design Problem	No. of trial	Minimum fitness	Max fitness	Mean fitness	Median fitness	First quartile (25th Percentile)
CHHO-Sigmoid	**ENGG1**	30	263.8959	269.4896	264.9507	264.1965	263.9717
	ENGG2	30	2999.914	5534.588	4266.717	4386.527	3543.398
	ENGG3	30	6776.092	140791.7	41073.27	33304.17	8318.445
	ENGG4	30	0.012782	0.015579	0.013639	0.013476	0.013144
	ENGG5	30	1.755663	4.048809	2.501823	2.236811	2.095331
	ENGG6	30	-84614.1	-42057	-69716	-80629.6	-82901.2
	ENGG7	30	0.391696	0.649952	0.479461	0.466958	0.417503
	ENGG8	30	0	0.003105	0.000308	0	
	ENGG9	30	1.980551	5.30E+22	3.00E+22	5.30E+22	2.007652
	ENGG10	30	1.309154	1.517641	1.460584	1.478089	1.440768
	ENGG11	30	0.006626	0.019818	0.007537	0.006626	0.417503

Table-4.15b: Statistical analysis of engineering design problem using CHHO-Sigmoid method

Method	Engineering Design Problem	Second quartile (50th Percentile)	Third quartile (75th Percentile)	Semi Interquartile Deviation	Number of outliers	Standard Deviation
CHHO-Sigmoid	**ENGG1**	264.1965	265.0787	0.553537	4	1.633372
	ENGG2	4386.527	5134.453	795.5276	0	824.4892
	ENGG3	33304.17	68064.15	29872.85	0	35621.11
	ENGG4	0.013476	0.014168	0.000512	0	0.000705
	ENGG5	2.236811	2.910767	0.407718	0	0.651282
	ENGG6	-80629.6	-44979.5	18960.84	0	17281.71
	ENGG7	0.466958	0.558786	0.070642	0	0.070626
	ENGG8	0	0.003101		0	0.000939
	ENGG9	5.30E+22	5.30E+22	2.65E+22	0	2.67E+22
	ENGG10	1.478089	1.492907	0.026069	0	0.050024
	ENGG11	0.006626	0.010936		0	0.002734

Table-4.15a and Table-4.15b shows the statistical analysis of the 11 types of design problems using CHHO-Sigmoid optimizer. The minimum fitness, maximum fitness, mean value, median value, standard deviation are taken into consideration. Further, the first, second and third quartile, number of outliers and semi interquartile are also taken into consideration.

Table-4.16a and Table-4.16b are represented the statistical output of engineering design problem by using CHHO-Tent optimization algorithm. 30 numbers of trail runs are taken into consideration.

Table-4.16a: Statistical analysis of engineering design problem using CHHO-Tent method

Method	Engineering Design Problem	No. of trial	Minimum fitness	Max fitness	Mean fitness	Median fitness	First quartile (25th Percentile)
CHHO-Tent	**ENGG1**	30	263.8959	264.6276	264.0119	263.9329	263.8976
	ENGG2	30	3013.702	5000.387	3424.007	3212.224	3062.555
	ENGG3	30	6028.263	7571.221	6666.379	6606.421	6381.897
	ENGG4	30	0.012692	0.017773	0.013884	0.013418	0.01297
	ENGG5	30	1.761417	2.291372	1.934821	1.860657	1.836569
	ENGG6	30	-84351.8	-42057	-75839.8	-81897.2	-82723.7
	ENGG7	30	0.389654	0.571009	0.44457	0.427836	0.408945
	ENGG8	30	0	0	0	0	0
	ENGG9	30	1.980151	5.30E+22	1.77E+22	2.04844	2.005777
	ENGG10	30	1.303728	1.309188	1.306028	1.305793	1.304952
	ENGG11	30	0.006626	0.006626	0.006626	0.006626	

Table-4.16b: Statistical analysis of engineering design problem using CHHO-Tent method

Method	Engineering Design Problem	Second quartile (50th Percentile)	Third quartile (75th Percentile)	Semi Interquartile Deviation	Number of outliers	Standard Deviation
CHHO-Tent	**ENGG1**	263.9329	264.0802	0.091278	2	0.177209
	ENGG2	3212.224	3597.599	267.5218	1	489.6215
	ENGG3	6606.421	6897.166	257.6346	0	396.6526
	ENGG4	0.013418	0.014352	0.000691	1	0.001273
	ENGG5	1.860657	2.047582	0.105506	0	0.163277
	ENGG6	-81897.2	-79847.8	1437.992	7	12586.59
	ENGG7	0.427836	0.474261	0.032658	0	0.046902
	ENGG8	0			0	0
	ENGG9	2.04844	5.30E+22	2.65E+22	0	2.54E+22
	ENGG10	1.305793	1.307026	0.001037	0	0.001485
	ENGG11	0.006626	0.006626		0	1.97E-18

Table-4.17a and Table-4.17b represents the minimum fitness, maximum fitness, mean value, median value, standard deviation, first, second and third quartile, number of outliers and semi interquartile.

Table-4.17a: Statistical analysis of engineering design problem using CSCA method

Method	Engineering Design Problem	No. of trial	Minimum fitness	Max fitness	Mean fitness	Median fitness	First quartile (25th Percentile)
CSCA	**ENGG1**	30	263.9066	282.8427	268.416	264.0557	263.9776
	ENGG2	30	3056.331	3196.872	3113.958	3109.471	3085.709
	ENGG3	30	6168.385	8445.029	7117.71	7032.918	6663.147
	ENGG4	30	0.012868	0.015361	0.013131	0.013067	0.012948
	ENGG5	30	1.782771	1.969818	1.868309	1.872921	1.842291
	ENGG6	30	-84674.8	-68917.2	-75292.5	-74653.3	-77575.6
	ENGG7	30	0.400398	0.441619	0.420596	0.420554	0.411715
	ENGG8	30	2.87E-15	1.84E-09	2.84E-10	8.74E-11	1.67E-11
	ENGG9	30	2.074527	2.761535	2.317083	2.269613	2.16908
	ENGG10	30	1.309738	1.412898	1.355879	1.354886	1.336299
	ENGG11	30	0.006626	0.006631	0.006627	0.006627	0.006626

Table-4.17b: Statistical analysis of engineering design problem using CSCA method

Method	Engineering Design Problem	Second quartile (50th Percentile)	Third quartile (75th Percentile)	Semi Interquartile Deviation	Number of outliers	Standard Deviation
CSCA	**ENGG1**	264.0557	264.2036	0.113021	7	8.095207
	ENGG2	3109.471	3130.136	22.21347	0	35.09274
	ENGG3	7032.918	7351.738	344.2952	0	552.986
	ENGG4	0.013067	0.013186	0.000119	1	0.000437
	ENGG5	1.872921	1.886737	0.022223	0	0.045219
	ENGG6	-74653.3	-73028.4	2273.603	0	3604.909
	ENGG7	0.420554	0.428116	0.0082	0	0.012284
	ENGG8	8.74E-11	3.12E-10	1.48E-10	3	4.86E-10
	ENGG9	2.269613	2.429668	0.130294	0	0.188134
	ENGG10	1.354886	1.376045	0.019873	0	0.025619
	ENGG11	0.006627	0.006628	6.42E-07	1	1.24E-06

Table-4.18a and Table-4.18b represent the statistical analysis of special design problems using proposed CSMA optimizer. The minimum fitness, maximum fitness, mean value, median value, standard deviation are taken into consideration. Further, the first, second and third quartile, number of outliers and semi interquartile are also taken into consideration.

Table-4.18a: Statistical analysis of engineering design problem using CSMA method

Method	Engineering Design Problem	No. of trial	Minimum fitness	Max fitness	Mean fitness	Median fitness	First quartile (25th Percentile)
CSMA	**ENGG1**	30	264.3061	271.6106	270.1234	270.9186	270.7088
	ENGG2	30	2994.472	2994.483	2994.474	2994.473	2994.472
	ENGG3	30	5885.38	7319.001	6446.046	6234.395	5933.141
	ENGG4	30	0.012687	0.015507	0.013104	0.012719	0.012719
	ENGG5	30	1.724998	1.92035	1.733205	1.725759	1.725349
	ENGG6	30	-85539.2	-85529.9	-85538.7	-85539.1	-85539.2
	ENGG7	30	0.389654	0.404658	0.392736	0.389659	0.389655
	ENGG8	30	7.63E-14	5.47E-11	7.86E-12	3.39E-12	2.10E-13
	ENGG9	30	1.14E+21	1.81E+23	4.12E+22	3.27E+22	6.53E+21
	ENGG10	30	1.303277	1.303797	1.303441	1.303399	1.303347
	ENGG11	30	0.006626	0.006626	0.006626	0.006626	0.006626

Table-4.18b: Statistical analysis of engineering design problem using CSMA method

Method Engineering Design Problem		Second quartile (50th Percentile)	Third quartile (75th Percentile)	Semi Interquartile Deviation	Number of outliers	Standard Deviation
CSMA	**ENGG1**	270.9186	271.0648	0.177977	7	1.900753
	ENGG2	2994.473	2994.474	0.000989	3	0.00273
	ENGG3	6234.395	7155.527	611.1931	0	554.7171
	ENGG4	0.012719	0.01328	0.000281	2	0.000728
	ENGG5	1.725759	1.727284	0.000967	2	0.03547
	ENGG6	-85539.1	-85539	0.092166	4	1.686104
	ENGG7	0.389659	0.390422	0.000383	7	0.005759
	ENGG8	3.39E-12	8.54E-12	4.16E-12	2	1.20E-11
	ENGG9	3.27E+22	6.72E+22	3.04E+22	0	4.22E+22
	ENGG10	1.303399	1.303487	7.04E-05	1	0.000122
	ENGG11	0.006626	0.006626	1.07E-10	3	3.80E-10

The time span are required to perform the optimization algorithms is known as computational time or simulation time. The computational time is also considered as running time of proposed optimizers. Table-4.19a shows the computational time for engineering design problem using CHHO-sigmoid and CHHO-Tent optimization techniques. Table-4.19b shows the computational time for engineering design problem using CSCA and CSMA optimization techniques. The best, average and the worst values are taken in consideration.

Table-4.19a: Computational time of engineering design problem using CHHO-Sigmoid and CHHO-Tent methods

Methods	**CHHO-Sigmoid**			**CHHO-Tent**		
Engineering Design Problem	**Best Value**	**Average Value**	**Worst Value**	**Best Value**	**Average Value**	**Worst Value**
ENGG1	0.09375	0.129688	0.421875	0.15625	0.184375	0.5625
ENGG2	0.140625	0.159896	0.265625	0.234375	0.259896	0.453125
ENGG3	0.09375	0.102083	0.125	0.15625	0.165104	0.265625
ENGG4	0.09375	0.120313	0.21875	0.171875	0.191146	0.296875
ENGG5	0.109375	0.125	0.140625	0.1875	0.204688	0.453125
ENGG6	0.15625	0.194271	0.375	0.296875	0.325521	0.8125
ENGG7	0.109375	0.120833	0.203125	0.1875	0.202604	0.375
ENGG8	0.078125	0.088021	0.15625	0.125	0.142708	0.265625
ENGG9	0.09375	0.116667	0.296875	0.15625	0.202083	0.453125
ENGG10	0.109375	0.125	0.203125	0.171875	0.192188	0.34375
ENGG11	0.09375	0.109896	0.140625	0.15625	0.183854	0.328125

Table-4.19b: Computational time of engineering design problem using CSCA and CSMA

Methods	**CSCA**			**CSMA**		
Engineering Design Problem	**Best Value**	**Average Value**	**Worst Value**	**Best Value**	**Average Value**	**Worst Value**
ENGG1	**0.0625**	**0.071354**	0.234375	0.375	0.444792	1.3125
ENGG2	0.140625	0.153646	0.296875	0.6875	0.732813	1.15625
ENGG3	0.078125	0.090625	0.109375	0.484375	0.501563	0.515625
ENGG4	0.078125	0.089063	0.15625	0.4375	0.456771	0.515625
ENGG5	0.09375	0.104167	0.15625	0.5	0.517708	0.546875
ENGG6	0.171875	0.185417	0.203125	0.859375	0.894271	1.046875
ENGG7	0.109375	0.113021	0.125	0.5625	0.573438	0.609375
ENGG8	0.078125	0.079167	0.09375	0.46875	0.496875	0.609375
ENGG9	0.09375	0.104688	0.15625	0.484375	0.506771	0.59375
ENGG10	0.09375	0.108854	0.140625	0.546875	0.567708	0.59375
ENGG11	0.078125	0.090104	0.09375	0.46875	0.500521	0.546875

The uni-modal, multimodal with fixed dimension benchmark functions are taken into consideration to compare the mean value and standard deviation with other optimization algorithms. Validate the efficacy of the proposed optimization algorithm, i.e. CHHO, CSCA, CSMA, hCHHO-SCA and hCSMA-SCA are compared with existing optimization algorithms, i.e. FA[27], GSA [82], ALO[213], MVO [230], CS[199], FPA[195], BA[253], BPSO[176], BGSA[82], GA[180], SSA[238], MFO[270], BDA[225], SMA, HHO[259] and SCA[231]. The proposed optimization algorithms are performing better than other optimization algorithm with are shown in Table-4.20a for uni-modal and Table-4.20b for multimodal and fixed dimension benchmark functions.

Table-4.20a: Comparisons of uni-modal benchmark functions

Algorithm	unimodal	F-1	F-2	F-3	F-4	F-5	F-6	F-7
FA [198]	**SD**	0.014	0.01	0.01	0.03	1.44	0.01	353
	Mean	0.04	0.05	0.04	0.14	2.17	0.05	-1250
GSA [284]	**SD**	0	0.19	318.95	1.74	62.22	0	493
	Mean	0	0.056	896.535	7.355	67.543	0	-2820
ALO [222]	**SD**	0	0	0	0	0.11	0	314
	Mean	0	0	0	0	0.347	0	-1610
MVO [239]	**SD**	0.649	44.746	177.097	1.583	1479.477	0.631	937
	Mean	2.086	15.925	453.2	3.123	1272.13	2.295	-11700
CS [208]	**SD**	0	0.04	0.021	0	0.007	0	0.008
	Mean	0.007	0.212	0.247	0	0.007	0	-2090
FPA [285]	**SD**	0	0	0	0.002	0.367	0	50.4
	Mean	0	0.001	0	0.004	0.781	0	-1840
BA [286]	**SD**	0.528	3.816	0.766	0.89	0.3	0.674	858
	Mean	0.774	0.335	0.115	0.192	0.334	0.779	-1070
BPSO [287]	**SD**	1.98	0.053	13.7	0.484	65.8	3.85	16.7
	Mean	5.59	0.196	15.5	1.9	86.4	6.98	-989
BGSA [197]	**SD**	49.8	0.228	272	2.21	2930	77.5	80.6
	Mean	83	1.19	456	7.37	3100	107	-861
GA [288]	**SD**	0.126	0.053	0.121	0.862	0.973	0.869	2.47
	Mean	0.119	0.145	0.139	0.158	0.714	0.168	-2090
SSA [247]	**SD**	0	1	0	0.656	0	0	0.809
	Mean	0	0.227	0	0	0	0	0.056

Algorithm	unimodal	F-1	F-2	F-3	F-4	F-5	F-6	F-7
MFO [289]	**SD**	0	0.001	188.528	5.275	120.261	0	726
	Mean	0	0.001	696.731	70.686	139.149	0	-8500
BDA [234]	**SD**	0.418	0.069	22.7	0.331	34.7	0.13	65.7
	Mean	0.282	0.059	14.2	0.248	23.6	0.095	-924
SMA [282]	**SD**	0	0	0	0	4.90297	0.000407	7.16E−05
	Mean	0	4.20E−187	0	8.84E−183	1.27571	0.00088	8.21E−05
HHO [268]	**SD**	1.72E−96	6.98E−51	1.05E−62	5.01E−47	1.87E−02	1.56E−04	1.07E−04
	Mean	3.95E−97	1.56E−51	1.92E−63	1.02E−47	1.32E−02	1.15E−04	1.40E−04
SCA [290]	**SD**	0	0	0.137	0.582	0.002	0	0.004
	Mean	0	0	0.037	0.097	0.001	0	1
CSMA	**SD**	**0**	**4.07E-121**	**0**	**1.06E-127**	**9.3744495**	**0.0029861**	**9.13E-05**
	Mean	**2.48E-296**	**7.43E-122**	**5.28E-294**	**1.94E-128**	**5.034157**	**0.0062209**	**0.000134**
CHHO	**SD**	**9.65E-105**	**2.43E-52**	**1.03E-87**	**2.30E-55**	**0.0149072**	**0.0001918**	**0.000129**
	Mean	**1.78E-105**	**4.77E-53**	**2.86E-88**	**6.27E-56**	**0.0094009**	**0.0001435**	**0.00014**
CSCA	**SD**	**32.23405**	**0.06814**	**4472.76**	**12.3033**	**51612.24**	**17.90549**	**0.05681**
	Mean	**14.9241**	**0.03088**	**7312.05**	**34.06702**	**30785.7**	**21.6759**	**0.06368**
hCHHO-SCA	**SD**	**0**	**0**	**0**	**0**	**4.4868e-08**	**1.3955e-10**	**7.596e-05**
	Mean	**0**	**0**	**0**	**0**	**2.6362e-08**	**8.9762e-11**	**7.9572e-05**
hCSMA-SCA	**SD**	**0**	**0**	**0**	**0**	**0.41472**	**0.60387**	**0.0016594**
	Mean	**0**	**0**	**0**	**0**	**0.28096**	**0.35973**	**0.0028796**

Table-4.20b: Comparisons of multi-modal and fixed dimension benchmark functions

Algorithms	Parameters	Multi modal and Fixed Dimension Benchmark functions															
		F-8	**F-9**	**F-10**	**F-11**	**F-12**	**F-13**	**F-14**	**F-15**	**F-16**	**F-17**	**F-18**	**F-19**	**F-20**	**F-21**	**F-22**	**F-23**
PSO [291]	**SD**	1152.814	11.62938	0.50901	0.007724	0.026301	0.008907	2.56	0.00	0.00	0.00	0.00	0.00	0.06	3.02	3.09	1.78
	Mean	-4841.29	46.70423	0.276015	0.009215	0.006917	0.006675	3.63	0.00	-1.03	0.40	3.00	-3.86	-3.27	-6.87	-8.46	-9.95
DE [292]	**SD**	574.70	38.80	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00	0.00	N/A	N/A	0.00	0.00	0.00
	Mean	-11080.10	69.20	0.00	0.00	0.00	0.00	1.00	0.00	-1.03	0.40	3.00	N/A	N/A	-10.15	-10.40	-10.54
GSA [284]	**SD**	493.04	7.47	0.24	5.04	0.95	7.13	3.83	0.00	0.00	0.00	0.00	0.00	0.02	3.74	2.01	0.00
	Mean	-2821.07	25.97	0.06	27.70	1.80	8.90	5.86	0.00	-1.03	0.40	3.00	-3.86	-3.32	-5.96	-9.68	-10.54
HHO [268]	**SD**	1.47E+02	0.00E+00	4.01E−31	0.00E+00	1.19E−05	2.15E−04	9.23E−01	1.97E−04	6.78E−16	2.54E−06	0.00	2.44E−03	0.137406	0.885673	1.3523	0.927655
	Mean	−1.25E+04	0.00E+00	8.88E−16	0.00E+00	2.08E−06	1.57E−04	9.98E−01	3.10E−04	−1.03E+00	3.98E−01	3.0E+00	−3.86E+00	−3.322	−10.1451	−10.40	−10.5364
SMA [282]	**SD**	0.068790	0.00	0.00	0.00	0.00101	0.00211	N/A	N/A	0.069163	2.915833	0.145401	0.361610	2.46585	0.70239	N/A	N/A
	Mean	−12 569.4	0.00	8.88E−16	0.00	0.00095	0.00135	N/A	N/A	521.0127	619.4282	1300.6589	1400.6565	1510.5477	1611.5995	N/A	N/A
SCA [290]	**SD**	0.0036	0.7303	1	0.0051	0	0	0.1924	0.0676	0.4921	0.1105	0.0134	0.2001	N/A	N/A	N/A	N/A
	Mean	1	0	0.3804	0	0	0	0.3908	0.0230	0.0497	0	0.0129	0	N/A	N/A	N/A	N/A
CHHO	**SD**	**0.297933**	**0**	**0**	**0**	**6.77E-06**	**0.000156**	**0.956253**	**1.31E-05**	**7.82E-09**	**2.82E-06**	**12.14398**	**0.04127**	**0.06948**	**0.000106**	**1.613069**	**0.987257**
	Mean	**-12569.2**	**0**	**8.88E-16**	**0**	**4.26E-06**	**8.48E-05**	**1.394305**	**0.000323**	**-1.03163**	**0.397889**	**10.20001**	**-3.83732**	**-3.28229**	**-5.05508**	**-5.61619**	**-5.30861**
CSCA	**SD**	**235.9351**	**34.19933**	**9.179928**	**0.350491**	**486409.6**	**2178707**	**0.999879**	**0.0003626**	**5.43E-05**	**0.002417**	**4.76E-05**	**0.002069**	**0.272363**	**1.843985**	**2.064134**	**1.573079**
	Mean	**-3760.65**	**38.88475**	**13.46625**	**0.926611**	**201583.3**	**430067.1**	**2.122433**	**0.0010485**	**-1.03157**	**0.400424**	**3.000055**	**-3.85392**	**-2.92704**	**-2.2713**	**-3.4056**	**-4.03031**
CSMA	**SD**	**0.416875**	**0**	**0**	**0**	**0.008958**	**0.016749**	**8.26E-13**	**0.000344**	**1.53E-09**	**3.95E-08**	**4.83E-10**	**8.60E-05**	**0.057317**	**0.000354**	**0.000542**	**0.000489**
	Mean	**-12568.9**	**0**	**8.88E-16**	**0**	**0.007442**	**0.012679**	**0.998004**	**0.000634**	**-1.03163**	**0.397887**	**3**	**-3.86277**	**-3.2423**	**-10.1527**	**-10.4023**	**-10.5358**
hCHHO-SCA	**SD**	**6.6155e-09**	**0**	**0**	**0**	**2.63e-11**	**1.8775e-09**	**1.3597e-16**	**1.3887e-17**	**0**	**0**	**0**	**7.0217e-16**	**0.068643**	**1.9404e-11**	**1.4709e-11**	**4.3308e-12**
	Mean	**-12569.4866**	**0**	**8.8818e-16**	**0**	**1.5322e-11**	**1.0904e-09**	**0.998**	**0.00030749**	**-1.0316**	**0.39789**	**3**	**-3.8628**	**-3.2824**	**-10.1532**	**-10.4029**	**-10.5364**
hCSMA-SCA	**SD**	**10.656**	**0**	**0**	**0**	**0.0061706**	**0.42634**	**2.6626e-12**	**1.6886e-07**	**8.9243e-10**	**1.6857e-08**	**2.3378e-13**	**0.0045471**	**0.14759**	**0.084338**	**0.074037**	**0.0056605**
	Mean	**-12557.6044**	**0**	**8.8818e-16**	**0**	**0.0039826**	**0.3524**	**0.998**	**0.00030772**	**-1.0316**	**0.39789**	**3**	**-3.8575**	**-2.9959**	**-10.031**	**-10.3556**	**-10.5327**

4.6 CONCLUSION

This chapter discuss about the phase of exploitation of existing HHO optimizer has been upgraded successfully using chaotic singer function like CHHO-Sigmoid, CHHO-Tent, CSCA, and CSMA. The phase of explorations are updated by hCHHO-SCA and hCSMA-SCA have been successfully tested for unimodal, multimodal, fixed dimension standard benchmark problems and multidisciplinary engineering design problems. The validation of proposed optimization algorithms, i.e. CHHO, CSCA, CSMA, hCHHO-SCA and hCSMA-SCA are done by comparing those methods with existing other optimization algorithms.

CHAPTER-5

PROFIT BASED UNIT COMMITMENT PROBLEM

5.1 INTRODUCTION

The profit based unit commitment problem is a combinational optimization problem challenged for industries in deregulated power sectors. The PBUCP is one of the most complicated, non-linear and mixed integer optimizing issues which determine the optimum schedule (i.e. OFF/ON status of generating units) and power generation schedule of committed units based on input parameters with forecasted power demand, reserve price and electrical energy prices. The important parameters, like electrical energy prices, market reserve prices, electricity demand and input parameters of power units can be treated as input parameters. Further, the input parameters of generating units comprises the limits of power generations in MW, minimum up-time and minimum down-time in hours, the initial status of units. The cost of hot as well as cold start-up and the coefficients of fuel represents cost functions. The PBUCP is normally different from conventional UCP regarding the main objective function, power demand and the reserve capacity constraints. The electricity demand and the reserve constraint under the deregulated markets are taken into consideration as the soft constraint. Thus, GENCOs can maximize their own profit value without obligation to achieve those two major constraints.

A generation scheduling needs satisfaction to a number of operating constraints for achieving reduction of minimum total production cost. The constraints are restricted for individual generating units, generation limit, capacity limits, minimum up time, minimum down time for the first and last hour as well as spinning reserve constraint, power balance, group constraints and ramp rate etc.

The aim of PBUCP is to determine best profit from the overall generation schedule. In order to calculate the power for the each unit for individual hours, the problem of economic load dispatch is solved. One of the major problem can be solved by unit commitment by proper production of energy scheduling. In order to deal with maximum profit, it is possible to supply power including small amount of fuel consumption and least amount of losses with the help of the optimization technique. The scheduling problem is constructed with two important aspects such as solving the problem of the condition of commitment for available units and its reserve capacity and the allocation of the committed unit within given constraints.

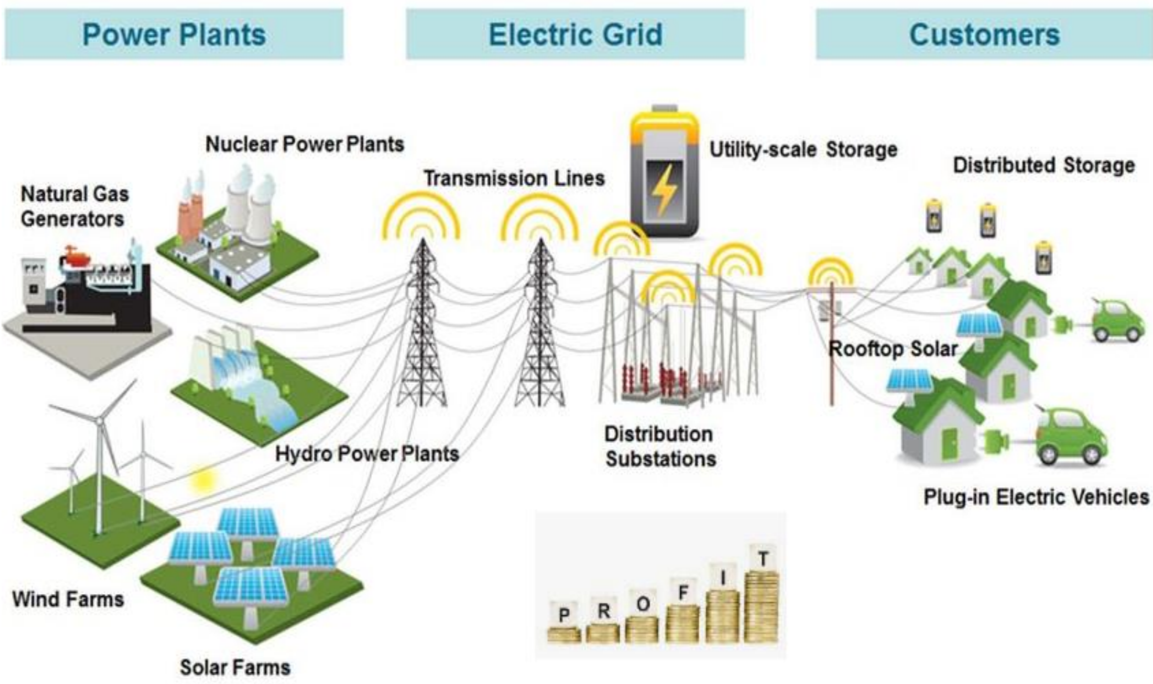


Fig.5.1: Representation of deregulated power system

The simple diagram of PBUCP is shown in **Fig.5.1.** PBUCP is also known as complex problem which increase non- linearity of optimization with associated with several types of constraints. Earlier the many optimization techniques are applied to solve PBUCP.

5.2 PROFIT BASED UNIT COMMITMENT PROBLEM

The main objective for PBUCP is to maximize the profit with minimize the total operational cost and find out the optimum scheduling considering different system constraints. The profit of each generating unit includes revenue and total fuel cost of the generator. The profit can be calculated from the eqn. (5.1).

$$\text{Profit} = (RV - TFC) \tag{5.1}$$

The revenue includes the energy price, power generation from each units and the commitment status of that unit of the generating units that can be measured from eqn. (5.2). Where ∂_h is denoted as energy price of the generating units at h hour, $P_{i,h}$ is denoted as the power if ith unit at h hour and $U_{i,h}$ is denoted as the commitment status of ith generating unit at h hour.

$$RV = \sum_{h=1}^{H}\sum_{i=1}^{NG}\partial_h \times P_{i,h}U_{i,h} \tag{5.2}$$

Total operating cost includes fuel cost, start-up cost and shut-down cost of ith generating unit at hth hour. The operating cost must be minimized to increase the profit. The eqn. (5.3) is used to minimize the total operating cost.

$$\min(TFC) = \sum_{h=1}^{H}\sum_{i=1}^{NG}\left\{F_{\mathrm{cosi,h}}\,(P_{i,h}) + SUC_{i,h} + SDC_{i,h}\right\} \tag{5.3}$$

Where, fuel cost is represented as $F_{\cos i,h}(P_{i,h})$ is in quadratic manner. The start-up cost is denoted as $SUC_{i,h}$ and the shut-down cost is denoted as $SDC_{i,h}$.

It is mathematically a non-smooth, non-convex and quadratic equation of power of the each committed generator at hour hth and after including fuel cost coefficient the modification of eqn. (5.3) can be represented by eqn. (5.4). Where, TFC is associated with total operating cost. A_i B_i and C_i are signified as cost coefficient in $\$/h$ $\$/MWh$ and. $\$/MWh^2$ respectively.

$$TFC = \sum_{h=1}^{H}\sum_{i=1}^{NG}[(A_i P_{i,h}^2 + B_i P_{i,h} + C_i)\times U_{i,h} + SUC_{i,h}(1-U_{i,(h-1)})\times \mathrm{U}_{i,h}] \tag{5.4}$$

5.2.1 Start-up and Shutdown Cost

Start-up cost is the cost that occurs when the thermal generating units are bringing online. This is expressed as in terms of hours for which generating unit has been shut-down. The eqn. (5.5) represents the mathematical expression of shut down cost.

$$SUC_{i,h} == \begin{cases} HSU_i; & for \quad T_i^{DW} \le T_i^{OFF} \le (T_i^{DW} + T_i^{COLD}) \\ CSU_i; & for \quad T_i^{OFF} > (T_i^{DW} + T_i^{COLD}) \end{cases} \quad C_i \ (i \in NU \quad ; \quad h = 1,2,3,...,H) \tag{5.5}$$

Where, $SUC_{i,h}$ is represented as start-up cost of i^th^ generating unit at h^th^ hour. This cost is associated with hot start cost and cold start cost. HSU_i is denoted as hot start cost of i^th^ unit and CSU_i is cold start cost of i^th^ unit. T_i^{DW} is represented as minimum down time of i^th^ generating unit. T_i^{OFF} is denoted as the OFF time duration of i^th^ generating unit throughout the h^th^ hour. T_i^{COLD} is represented as cold start hour of i^th^ generating unit. The down time of the each generator is one of the important parameter for start-up cost. If the sum of down time and cold start hour is higher, then the cold start cost is taken into consideration. Otherwise, if the down time for i^th^ generating unit is less, then the hot-start cost is in taken into consideration.

The shut-down cost can be measure from eqn. (5.6), where K is represented as incremental cost of the i^th^ generating unit at h^th^ hour.

$$SDC_{ih} = KP_{ih} \tag{5.6}$$

5.3 CONSTRAINTS

PBUCP needs to provide optimum solution within certain constraints. In PBUCP, various constraints are need be satisfied to get profit. In power system, reliability council and power pool may be imposed various rule on scheduling of generating units, depends on power generation and characteristics of load curve. The major constraints involved for this problem are discussed below:

5.3.1 Power Balance Constraints

The power generation of total numbers of committed generating units at h^th^ hours must be greater than or equals to power demand for that particular hours. This constraints can be measured from eqn. (5.7), i.e. the total power generated by i^th^ unit at time h^th^ hours must be meet the power demand.

$$\sum_{i=1}^{NU} P_{i,h} \times U_{i,h} = PD_h \tag{5.7}$$

5.3.2 Spinning Reserve Constraints

Considering the reliability of the units, there is always provision for extra capacity of power generation that may be required instantly to withstand with sudden failure of the running unit or sudden rise of power demand. The failure can be occurred by sudden tripping of the power generators. Some addition of the auxiliary generating unit is required to cope up with the shortfall and meet the sudden increase of power demand. The additional power generation capacity is known as spinning reserve. The spinning reserve can be calculated from the eqn. (5.8).

$$\sum_{i=1}^{NU} P_{i(\max),h} \times U_{i,h} \geq PD_h + R_h. \tag{5.8}$$

The total power generated by i[th] unit at h[th] hours must be meet the power demand. Further there must be some extra generation of power which is required to withstand with any sudden faults of generator that may use as reserve purpose for that particular hour h.

5.3.3 Thermal Unit Constraints

The power generating unit cannot be turn on instantly to produce power. Before put the generating unit online, it must be meet certain thermal constraints. Minimum six to seven hours required before connect the generating unit to the supply system. The generating unit need to face gradual changes in temperature. So, this thing takes few time to bring the generating unit online. Further, the manual control is required to operate the thermal units. That leads to few restrictions on operations of the thermal unit.

5.3.4 Minimum-up and Minimum-down Time Constraints

When a certain generating unit already in shut down mode then that power unit cannot start immediately. It takes few time to start over from that condition. This time is known as minimum up time. The minimum-up time can be measure from eqn. (5.9).

$$T_{i,h}^{ON} \geq T_i^{UP} \tag{5.9}$$

Where, $T_{i,h}^{ON}$ is presented as the time of power unit i^{th} is in constantly ON condition from h^{th} hours. T_i^{UP} is presented as minimum-up time (in hour) for i^{th} power unit. When the generating unit will need to decommit then there is a requirement of least time to recommit that power unit. This time is known as minimum-down time shown in Eqn. (5.10).

$$T_{i,h}^{OFF} \geq T_i^{DW} \tag{5.10}$$

Where, $T_{i,h}^{OFF}$ is that time in hour for which power unit i^{th} is in constantly OFF condition then T_i^{DW} is presented as minimum-down in hour for that i^{th} generating unit.

5.3.5 Maximum and Minimum Limits of Generating Units

All power units have the individual power generation limits within its minimum to maximum range, otherwise the unit cannot generate power. This specific limit is known as maximum/minimum generation limit of the unit. It can be measured from the eqn. (5.11)

$$P_{i(\min)} \leq P_{i,h} \leq P_{i(\max)} \tag{5.11}$$

5.3.6 Initial Status of Generating Units

It gives information related to the generating unit on-line/off-line status of each unit. This status helps to select minimum-up and minimum-down time based on the data of the previous day’s schedule. The initial stage is specified by either plus or minus signs. A ‘+’ sign is for online status and a ‘-’ sign is for offline status for the particular unit.

5.3.7 Crew Constraints

Normally thermal power plant which consists of more than one units. So it’s unable to maintain all those unit at a same time. Thus more numbers of crew members are required for attend the plant and maintain the all unit at a same time for start-up as well as shut down.

5.3.8 Availability Constraints for Power Generating Units

The availability for power generation units specified by some o circumstances: (i) Available or non-available and (ii) must be in running state.

5.4 SOLUTIONS METHODOLOGY FOR PROFIT BASED UNIT COMMITMENT PROBLEM

Profit based unit commitment problem has been identified by considering physical constraints and system of thermal power units. The current study have used hybrid versions of hCHHO-SCA algorithm and hCSMA-SCA to solve profit based unit commitment problem of power system. In order to find the hybrid version of hCHHO-SCA and hCSMA-SCA optimizer, the general operators of singer chaotic map, Harris hawks optimizer, sine cosine algorithm and slime mould algorithm are combined recursively. Stochastic as well as heuristics process are adopted to tackle different kinds of operational and physical constraints of profit based unit commitment problem. The process of system constraints of PBUCP i.e. spinning reserve constraint, minimum-up and minimum-down time constraints and de-commitment of excessive power generating units are described in the sections 5.4.1, 5.4.2 and 5.4.3 respectively. The suggested hybrid optimizers are discussed below in the following sections to get the solutions of profit based unit commitment problem.

5.4.1 Repairing for Spinning Reserve Constraints

In order to fulfill the requirement of reserve capacity of different types of power units, minimum up and down time of every power units along with time durations for that i^{th} unit have been taken into consideration. The reserve constraints must repaired as per PSEUDO code mentioned below in **Fig.5.2**.

Step 1: Sort the generators in descending order of maximum generating capacity.

Step 2: *for* $i = 1 \quad to \quad NG$

if $u_{i,h} = 0$, then $u_{i,h} = 1$, *else if* $T_{i,h}^{OFF} > T_i^{DW}$ then $T_{i,h}^{ON} = T_{i,h-1}^{ON} + 1$ and $T_{i,h}^{OFF} = 0$

Step 3: Verify new generating power of units.

Step 4: if $\sum_{i=1}^{NG} P_{i(\max)} u_{i,h} \geq PD_h + R_h$ then stop the algorithm, else go to step-2

Step 5: if $T_{i,h}^{OFF} < T_i^{DW}$ then do $l = h - T_{i,h}^{OFF} + 1$ and set $u_{i,h} = 1$

Step 6: Calculate $T_i^l = T_{i,l-1}^{ON} + 1$ and $T_{i,h}^{OFF} = 0$

Step 7: if $l > h$, Verify generator output power $\sum_{i=1}^{NG} P_{i(\max)} U_{hi} \geq PD_h + R_h$ and for and go to step-5.

Step 1: Sort the generators in descending order of maximum generating capacity.
Step 2: *for* $i = 1$ *to* NG *if* $u_{i,h} = 0$ then $u_{i,h} = 1$

else if $T_{i,h}^{OFF} > T_i^{DW}$

then $T_{i,h}^{ON} = T_{i,h-1}^{ON} + 1$ and $T_{i,h}^{OFF} = 0$
Step 3: Verify new generating power of units.
Step 4: if $\sum_{i=1}^{NG} P_{i(\max)} u_{i,h} \geq PD_h + R_h$ then stop the algorithm, else go to step-2
Step 5: if $T_{i,h}^{OFF} < T_i^{DW}$ then do $l = h - T_{i,h}^{OFF} + 1$ and set $u_{i,h} = 1$
Step 6: Calculate $T_i^l = T_{i,l-1}^{ON} + 1$ and $T_{i,h}^{OFF} = 0$
Step 7: if $1 > h$, Verify generator output power for $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} \geq PD_h + R_h$,
else
Increment 1 by 1 and go to step-5

Fig.5.2: PSEDUO code for repairing the spinning reserve constraint

5.4.2 Repairing for Minimum Up and Down Time Constraints

The Minimum up and down time requirements of thermal units can be repaired by using the mechanism is given below in **Fig.5.3**.

for $h = 1\ to\ H$

for $i = 1 : NG$***, do*** $i = 1$
if $U_{i,h} = 1$***, do*** $U_{i,(h-1)} = 0$***, if*** $T_{i,h}^{ON} < T_i^{DW}$ ***, do*** $U_{i,h} = 0$
else $U_{i,h} = 1$
end
end
if $U_{i,(h-1)} = 1$***, else if*** $U_{i,h} = 0$***, if*** $T_{i,h}^{OFF} < MUT_i$***, do*** $U_{i,h} = 1$
else $U_{i,h} = 0$
if $i = NG$ **then** stop or else **do** $i = 1$ and follow the steps
else
end
end
end

Fig.5.3: PSEUDO code for handling MUT/MDT constraints

Algorithm

Step 1: Sort the generator according to the minimum capacity of power generation.

Step 2: For $h = 1\ to\ H$ and $i = 1 : NG$, then set $i = 1$.

Step 3: If $U_{i,h} = 1$ then set $U_{i,(h-1)} = 0$.

Step 4: Verify $T_{i,h}^{ON} < T_i^{DW}$ and set $U_{i,h} = 0$, or else set $U_{i,h} = 1$.

Step 5: if $U_{i,(h-1)} = 1$, then set $U_{i,h} = 0$.

Step 6: if $T_{i,(h-1)}^{ON} < T_i^{UP}$, then set $U_{i,h} = 1$ and end if.

Step 7: if $h + T_i^{DW} - 1 \le H$ and $T_{h+MDT_i-1}^{OFF} \le MDT_i$, then set $U_{i,h} = 1$ and end if.

Step 8: if $h+T_i^{DW}-1>H$ and $\sum_{h=1}^{H} U_{i,h} > 0$, then set $U_{i,\mathrm{h}} = 1$ and end if or else go to step 5.

Step 9: Update the time duration of the committed as well as decommitted generation unit for i[th] unit by the equations $T_{i,h}^{ON} \geq T_i^{UP}$ and $T_{i,h}^{OFF} \geq T_i^{DW}$.

5.4.3 Decommitment of the Excessive Generating Units

The excessive thermal units need to be decommitted. The load demand and spinning reserve requirements of all thermal generating units must be fulfilled. The minimum-down and minimum-up time of every units along with the OFF/ON time duration of i[th] power unit is taken into consideration. The constraint can be repaired as per algorithm. The PSEDUO code is given below in **Fig.5.4**.

for h=1:H
for i=1:NG
do $i = h(NG+1-i)$ and calculate generating power $Pl = P_{i(\max)} \times (U_{i,h})$
if $u_{i,h} = 1$ **then**
if $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} - P_{i(\max)} \geq PD_h + R_h \quad (h = 1, 2, ..., H)|$
if $(T_{\mathrm{i,h}}^{ON} > T_i^{UP}) | (T_{\mathrm{i,h}}^{ON} = 1)$ **then do** $u_{i,\mathrm{h}} = 0$ and $T_{\mathrm{i,h}}^{ON} = 0$
if h==1 **then do** $T_{\mathrm{i,h}}^{OFF} = T_{i,h_0}^{OFF} + 1$ else
do $T_{i,h}^{OFF} = T_{i,h-1}^{OFF} + 1$
end
else
continue;
end
else
break;
end
end
end

Fig.5.4: PSEUDO code for Decommitment of excessive generating units

The steps for decommitment of the excessive units are discussed below:

Step 1: Sort the generator according to the minimum capacity of power generation.

Step 2: for h=1 to H and for i=1 to NG, then $i = h(NG+1-i)$ and calculate the generated power, i.e. $Pl = P_{i(\max)} \times (U_{i,\mathrm{h}})'$.

Step 3: Verify the new generating power of the unit.

Step 4: if $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} \geq PD_h + R_h \quad (h = 1, 2, ..., H)$ and $T_{i,h}^{ON} > T_i^{UP}$ then do $U_{i,h} = 0$, else stop the algorithm, or else if $T_{\mathrm{i,h}}^{ON} = 1$, do $u_{i,h} = 0$, else increase 1 by 1 and go to step 2.

Step 5: set $T_{\mathrm{i,h}}^{ON} = 0$ and calculate $T_{\mathrm{i,h}}^{OFF} = T_{i,h_0}^{OFF} + 1$.

Step 6: if $U_{i,h} = 1$, verify the generated output power.

$\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} \geq PD_h + R_h \quad (h = 1, 2, ..., H)$, else OFF the unit and go to step 4.

The complete procedure to solve PBUCP is given below.

Step 1: Enter PBUCP inputs i.e. maximum power, minimum power, revenue, energy price, minimum up time, minimum time, initial status, hot start cost and cold start cost.

Step 2: Initialize the inputs parameters for the proposed algorithm.

Step 3: Start iteration counter, K=1.

Step 4: Initialize the random location of search agents.

Step 5: Calculate the power according to priority list for search agent.

Step 6: Update the position of search agent to satisfy the spinning reserve constraint.

Step 7: Repair each position of search agent to maintain minimum-up & minimum-down time violations.

Step 8: Decommitment the excessive generating units to decrease excessive spinning reserve.

Step 9: Calculate fuel cost using startup cost and overall profit.

Step 10: Evaluate the individual cost and profit for each generating unit.

Step 11: Compare total power generation cost of every population through best value of total fuel cost.

Step 12: Upgrade the generators scheduling through proposed techniques.

Step 13: Verify the value of K for maximum number of iterations or else increase the count of iteration K through 1.

Step 14: Evaluate the actual power generation schedule and profit for the committed unit.

Step 15: Record the status of power generation scheduling and status of the commitment units and optimal profit.

5.4.4 Hybrid Chaotic Harris Hawks-Sine Cosine Optimization Algorithm

The suggested optimizer, hCHHO-SCA includes exploratory and exploitative stages which is encouraged by surprise attack of the harris hawks. The exploration phases are increased by combine sine cosine algorithm with harris hawks optimizer. This exploitation strategy of this hybrid algorithm can be upgraded by using singer chaotic map. The nature of exploration of a prey and different strategies are based on attacking phenomenon of harris hawks. This is one of the gradient-free and inhabitants based algorithms for optimization technique which can useful to solve PBUCP.

Considering the normal hunting strategy of Harris hawks, they detect the prey and track it by using their dominant eyes through which the victim cannot be realize it easily. Thus, after several hours the harris hawks delay some time by observing and monitoring the site to detect the prey. Now for hCHHO-SCA, the hawks are taken as best solution in each step which is taken as the projected prey and which is also in nearly optimum region. In this hybrid optimization technique hawks settle randomly on some positions and wait to detect and locate the prey based on two types of strategies. The standard ranges for hawks achieved over applying in the Eqn. (3.14) as cited in the section-3.2.1.3 then modify next era behalf of queries for exploitations is deliberated in the Eqn. (3.15) as cited in the section-3.2.1.3. Algorithm of whole process of PBUCP through hCHHO-SCA is specified below.

Step 1: Enter PBUCP inputs i.e. maximum power, minimum power, revenue, energy price, minimum up time, minimum time, initial status, hot start cost and cold start cost and also initialize the input parameters and maximum number of iterations.

Step 2: Initialize the inputs parameters of hCHHO-SCA technique, i.e. number of random populations, search agents, positions of the prey, population size and number of iterations.

Step 3: Set the counter for no. of iteration K=1.

Step 4: Initialize of random location for search agents using singer chaotic map. Update the position of search agent by using singer chaotic map using Eqn. (3.49) mentioned in the section-3.2.2.3. Check whether the current iteration is less than the total number of iteration and calculate the value of fitness for each Harris hawks.

Step 5: Upgrade the fitness value to find out the optimal solution by Eqn. (3.12) as mentioned in the section-3.2.1.3 and calculate the priority list of every generator according to its nature of power generated unit.

Step 6: Calculate $X_m(\text{iter})$ from eqn. (3.14) as mentioned in the section-3.2.1.3 and update the position of search agent to satisfy the spinning reserve constraint.

Step 7: Upgrade $r_{1,}\ r_{2,}\ r_{3,}\ r_4$ & b for each search agents and increase iteration by 1. Find the best fitness value from eqn. (3.14) from section-3.2.1.3. Repair each position of search agent to maintain minimum up & minimum down time violations.

Step 8: State algorithm parameters and identify input parameters that defined by eqn. (3.1) and eqn. (3.2) as mentioned in section-3.2.1.1. This optimizer improves and creates a random number sets of solutions for the specified problem, so that it has essentially benefits for large exploration. The decommitment of generating units of each location to decrease excessive spinning reserve due to minimum-up & minimum-down time repaired**.**

Step 9: Initialize the search agents, i.e. number of solutions X_m. Evaluate those search agent through objective function. Upgrade the best solution and the value of $r_{1,} r_{2,} r_{3,} r_4$. Calculate fuel cost using startup cost including minimum-up & minimum-down time, cols start cost, hot start cost and initial status of each units and calculate the profit.

Step 10: Upgrade positions of search agent by eqn. (3.3) as mentioned in section-3.2.1.1 and evaluate the cost of each generator. If $iter_{Current} < iter_{MAX}$, the best solution can obtain as global optima.

Step 11: Compare total power generation cost of every population through best value of total fuel cost.

Step 12: Upgrade the status of the unit by hCHHO-SCA as mentioned in section-3.2.1.1.

Step 13: Verify the value of K with maximum number of iterations or else Increase the count of iteration K through 1.

Step 14: Evaluate the actual power generation schedule for the committed unit.

Step 15: Record the status of hourly profit with power generation scheduling and status of the commitment units and overall profit.

5.4.5 Hybrid Chaotic Slime Moulds-Sine Cosine Optimization Algorithm

The proposed hybrid algorithm hCSMA-SCA is established to upgrade the exploration and exploitation capability to solve PBUCP. The venous of slime moulds improve with the variation of phases in contraction manners. Thus the structure of venous consist of three types of correlation between the contraction manners as well as changes of morphological manner. Slime moulds may regulate dynamically their search mode that depend upon quality of the food. The various search modes are depends on behavior of searching for food and wrapping the food. These behavior upgrade the exploration capability of sine cosine algorithm. The singer chaotic function is used to upgrade the exploitation phases of the hybrid method.

The complete procedure to solve PBUCP is given below using hCSMA-SCA**:**

Step 1: Enter PBUCP inputs i.e. maximum power, minimum power, revenue, energy price, minimum up time, minimum time, initial status, hot start cost and cold start cost and also initialize the input parameters and maximum number of iterations. Initialize the location of the slime mould.

Step 2: Initialize the inputs parameters of hCSMA-SCA technique i.e. maximum number of iterations, positions of slime mould, number of random populations and search agents.

Step 3: Set the counter for no. of iteration K=1.

Step 4: Initialize of random location for search agents using singer chaotic map. Update the position of search agent by using singer chaotic map using Eqn. (3.49) mentioned in the section-3.2.2.3. Check whether the current iteration is less than the total number of iteration and calculate the value of fitness for slime mould.

Step 5: Upgrade the fitness value to find out $\overrightarrow{S_b}$ the optimal solution and calculate $\vec{Y}$ from Eqn. (3.9) as mentioned in section 3.2.1.2. Calculate the priority list of every generator according to its nature of power generated unit.

Step 6: Calculate P, $\overrightarrow{ub}$ and $\overrightarrow{uc}$ for each search agents and upgrade the current position by eqn. (3.11) as mentioned in section 3.2.1.2 and Increase the current iteration by 1. Update the position of search agent to satisfy the spinning reserve constraint.

Step 7: Find the best fitness value $\overrightarrow{S_b}$. State algorithm parameters and identify input parameters that defined by eqn. (3.1) and eqn. (3.2) as mentioned in section-3.2.1.1. This optimizer improves and creates a random number sets of solutions for the specified problem, so that it has essentially benefits for large exploration. Repair each position of search agent to maintain minimum up & minimum down time violations.

Step 8: Initialize the search agents, i.e. number of solutions $\overrightarrow{S*}$. Evaluate those search agent through objective function. The decommitment of generating units of each location to decrease excessive spinning reserve due to minimum-up & minimum-down time repaired.

Step 9: Upgrade the best solution and the value of $r_{1,}\ r_{2,}\ r_{3,}\ r_4$. Calculate fuel cost using startup cost including minimum-up & minimum-down time, cols start cost, hot start cost and initial status of each units and overall profit.

Step 10: Upgrade positions of search agent by eqn. (3.3) as mentioned in section-3.2.1.1 and evaluate the cost of each generator. If $iter_{Current} < iter_{MAX}$, the best solution can obtain as global optima.

Step 11: Compare total power generation cost of every population through best value of total fuel cost.

Step 12: Upgrade the status of the unit by hCSMA-SCA.

Step 13: Verify the value of K with maximum number of iterations or else Increase the count of iteration K through 1.

Step 14: Evaluate the actual power generation schedule for the committed unit.

Step 15: Record the status of hourly profit with power generation scheduling and status of the commitment units and overall profit.

5.5 TEST SYSTEMS

The PBUCP has been solved by considering small, medium and large scale system and the physical constraint of power generation units. This non-convex, non-linear, mixed integer, constrained PBUCP has been solved for standard 10-generating unit system (small scale) 40-generating unit system (medium scale) and 100-generating unit system (large scale). The characteristics of the power units with cost coefficient parameters and power demand in electricity market are discussed below.

5.5.1 Ten Generating Unit System

The test system consist of 10-generating units and the parameters are shown in Table-5.1 which consists of maximum power generation ($P_{i(\max)}$), minimum power generation ($P_{i(\min)}$) limits of the system, fuel coefficient constraints (A_i , B_i and C_i), up and down time constraints, i.e. T_i^{UP} and T_i^{DW} , cost for hot start, i.e. (HSU_i), cost for cold start (CSU_i), cold start hour of unit (T_i^{COLD}) and initial status of that system (INS_i). The Table-5.2 shows the load demand. This test system has been tested for 24-hour load demand pattern at different spinning reserve capacity. Generally the 10-generating unit system have 5% and 10% spinning reserve capacity [276]. In this case, test system consists of 10-generating units with a 24-hour load demand.

Table-5.1: Unit Characteristics for 10-generating unit system

Unit Parameter	**Generating Units**									
	U1	**U2**	**U3**	**U4**	**U5**	**U6**	**U7**	**U8**	**U9**	**U10**
$P_{i(\max)}$	455	455	130	130	162	80	85	55	55	55
$P_{i(\min)}$	150	150	20	20	25	20	25	10	10	10
A_i	1000	970	700	680	450	370	480	660	665	670
B_i	16.19	17.26	16.6	16.5	19.7	22.26	27.74	25.92	27.27	27.79
C_i	0.00048	0.00031	0.002	0.00211	0.00398	0.00712	0.0008	0.00413	0.00222	0.00173
T_i^{UP}	8	8	5	5	6	3	3	1	1	1
T_i^{DW}	8	8	5	5	6	3	3	1	1	1
HSU_i	4500	5000	550	560	900	170	260	30	30	30
CSU_i	9000	10,000	1100	1120	1800	340	520	60	60	60
T_i^{COLD}	5	5	4	4	4	2	2	0	0	0
INS_i	8	8	-5	-5	-6	-3	-3	-1	-1	-1

Table-5.2: Power Demand for 10-Generating Unit System

	Hours											
	h1	**h2**	**h3**	**h4**	**h5**	**h6**	**h7**	**h8**	**h9**	**h10**	**h11**	**h12**
Load Demand	700	750	850	910	1000	1040	1040	1040	1170	1400	1412	1412
	h13	**h14**	**h15**	**h16**	**h17**	**h18**	**h19**	**h20**	**h21**	**h22**	**h23**	**h24**
	1332	1300	1200	1040	1000	1040	1040	1040	1040	1040	900	800

5.5.2 Medium and Large Scale Power System (40- and 100- Unit Test System)

In general power system consists of large network which links the power plants (small, large and medium) to electrical load. Small scale power systems are made of section or part of the medium or large scale power systems. The higher order test system consists of 40- and 100-Generating units having a 24-hour load demand [276]. The data for 40- and 100-generating unit test system are multiplied by four and ten times respectively of the 10-unit system and load demand as shown in **Fig.5.5**.

Medium Scale Power System

The medium scale power system consists of 40-generating units. The output of this system is greater than the small scale power system and less than the large scale power system. This test system is taken into consideration for 30 trails and 100 iterations. In this system the power demand for 24 hours can be measured as multiplied by 4 of the small scale power system (10-generating unit).

Large Scale Power System

The large scale power system consists of 100-generating units. The power output from that system is larger than the small and medium scale power system. The 30 trail runs and 100 number of iterations are taken into consideration. In case of 100-unit test system, the power demand for 24 hours can be measured as multiplied by 10 of the 10-generating unit system.

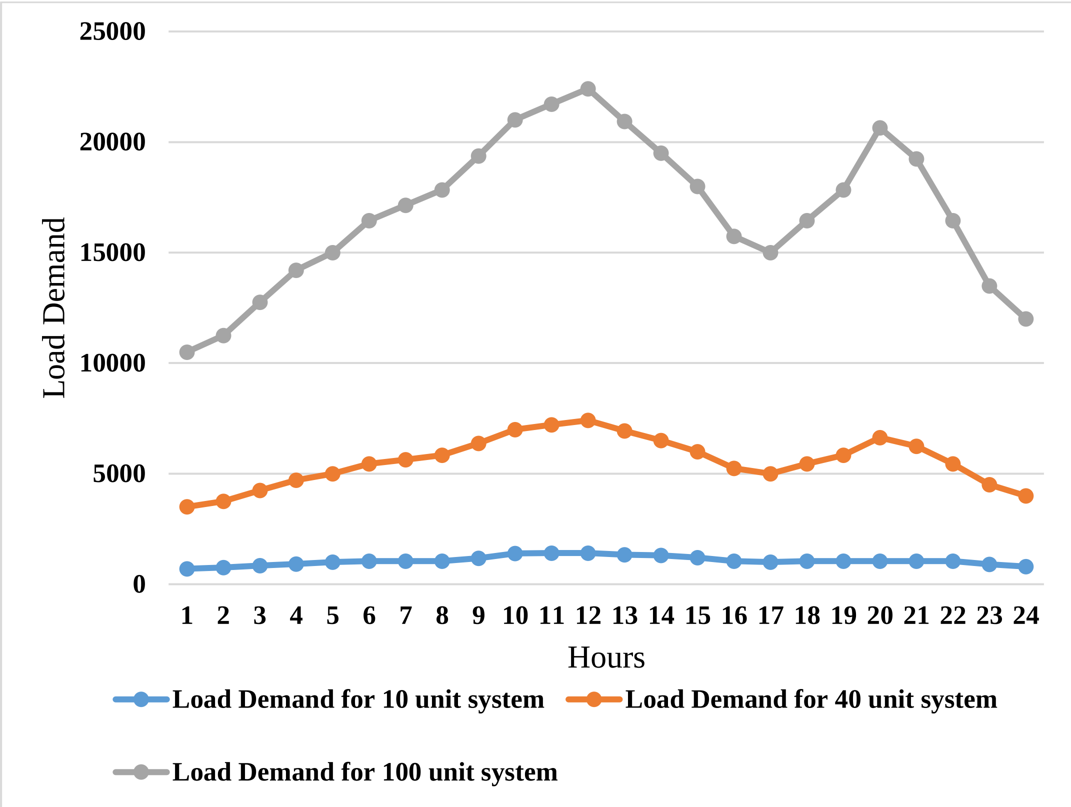


Fig.5.5: Power demand for 10-, 40- and 100- generating units

5.6 RESULTS AND DISCUSSION

In order to verify the efficiency of the proposed methods, for PBUCP, standard test systems have been taken into consideration. The 10-generating units is taken as small scale system, 40-generating unit system is considered as medium scale system and 100-generating unit system is taken as large scale systems. The proposed algorithms performance is assessed in MATLAB 2017a (8.1.0.604) software on Windows 7 Home Basic, CPU @ 2.10GHz, RAM- 3GB, Processor-Intel® Core™ i3-2310M, System Type- 64-bit operating system. The effectiveness of the proposed algorithms hCHHO-SCA and hCSMA-SCA have been justified from statistical point of view.

5.6.1 Hybrid Chaotic Harris Hawks-Sine Cosine Optimization Algorithm

A new important hybrid algorithm is established by relating chaotic maps with the hybrid

HHO as well as the SCA method i.e. hCHHO-SCA include exploratory as well as exploitative phase that is stimulated by surprise attacks, the natures of explorations of prey and various strategies are based upon aggressive attacked phenomenon of the Harris hawks birds. This is one of the gradient-free with consideration of inhabitants based calculations for the new optimization strategy, which will be helpful to detail on any kinds of optimization issues. The optimizer hCHHO-SCA have certain major performances in the phases of explorations. Not only this, but also had major approach in adaptation from phases of explorations to the phases of exploitations. The number of population are 40 for 10-, 40- and 100-generating unit systems.

5.6.1.1 Ten Generating Unit System

This test system is used to check the efficiency of the proposed hCHHO-SCA optimizer. The system consist of 10-power generating units having a 24-hour electricity demand. The hCHHO-SCA technique is evaluated for 100 iterations. The hCHHO-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.5.6**. The optimal scheduling and the profit table of the 10-generating units have been shown in Table-5.3a and Table-5.3b respectively.

The Table-5.3a presents the commitment status and optimum scheduling of the generators during 24 hours. The power generating units are represented as PGU. Here, in this case, the PGU1 and PGU2 are on for 24 hours and gives 455 MW power. From 9 to 14 hours, the PGU3 is on and 130 MW is the output power. When then unit is on, it is denoted as '1' and when the unit is off, then it is denoted as '0'. The PGU7 to PGU10 are remained off throughout the day. Further, the PGU4 is remain off for 1 to 4 hours and 23^{rd} and 24^{th} hour. It is on only for 5^{th} hour to 22^{nd} hour. In those time, for which the PFU4 is on, it generates 130 MW power for each hour. For PGU5 it is on only for 10^{th} to 15^{th} hours and for 10^{th} to 13^{th} hour, 162 MW, for 14^{th} hour 130 MW and for 15^{th} 160 MW power is generated to meet the demand.

The Table-5.3b shows the hourly profit of that unit. For PGU1 and PGU2 maximum profit can be obtained as it is on for 24 hours. For PGU3 the profit value varies from 2964 $ to 4114.5 $ only for 9^{th} hour to 14^{th} hour. For PGU7 to PGU10 no profit will be gained as it is not committed.

Table-5.3a: Commitment status and scheduling for 10-generating unit system using hCHHO-SCA optimization algorithm

Commitment status of thermal units								Scheduling of the committed generating units						
HOURS	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**
1	1	1	0	0	0	0	0	455	245	0	0	0	0	0
2	1	1	0	0	0	0	0	455	295	0	0	0	0	0
3	1	1	0	0	0	0	0	455	395	0	0	0	0	0
4	1	1	0	0	0	0	0	455	455	0	0	0	0	0
5	1	1	0	1	0	0	0	455	415	0	130	0	0	0
6	1	1	0	1	0	0	0	455	455	0	130	0	0	0
7	1	1	0	1	0	0	0	455	455	0	130	0	0	0
8	1	1	0	1	0	0	0	455	455	0	130	0	0	0
9	1	1	1	1	0	0	0	455	455	130	130	0	0	0
10	1	1	1	1	1	1	0	455	455	130	130	162	68	0
11	1	1	1	1	1	1	0	455	455	130	130	162	80	0
12	1	1	1	1	1	1	0	455	455	130	130	162	80	0
13	1	1	1	1	1	0	0	455	455	130	130	162	0	0
14	1	1	1	1	1	0	0	455	455	130	130	130	0	0
15	1	1	0	1	1	0	0	455	455	0	130	160	0	0
16	1	1	0	1	0	0	0	455	455	0	130	0	0	0
17	1	1	0	1	0	0	0	455	415	0	130	0	0	0
18	1	1	0	1	0	0	0	455	455	0	130	0	0	0
19	1	1	0	1	0	0	0	455	455	0	130	0	0	0
20	1	1	0	1	0	0	0	455	455	0	130	0	0	0
21	1	1	0	1	0	0	0	455	455	0	130	0	0	0
22	1	1	0	1	0	0	0	455	455	0	130	0	0	0
23	1	1	0	0	0	0	0	455	445	0	0	0	0	0
24	1	1	0	0	0	0	0	455	345	0	0	0	0	0

Table-5.3b: Hourly profit for 10-generating unit system using hCHHO-SCA optimization algorithm

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7 to PG10	Start-up Cost	Hourly Profit
1	10078.25	5426.75	0	0	0	0	0	0	15505
2	10010	6490	0	0	0	0	0	0	16500
3	10510.5	9124.5	0	0	0	0	0	0	19635
4	10305.75	10305.75	0	0	0	0	0	0	20611.5
5	10578.75	9648.75	0	3022.5	0	0	0	560	23250
6	10442.25	10442.25	0	2983.5	0	0	0	0	23868
7	10237.5	10237.5	0	2925	0	0	0	3360	23400
8	10078.25	10078.25	0	2879.5	0	0	0	520	23036
9	10374	10374	2964	2964	0	0	0	0	26676
10	13354.25	13354.25	3815.5	3815.5	4754.7	1995.8	0	60	41090
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	42571.8
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	44689.8
13	11193	11193	3198	3198	3985.2	0	0	60	32767.2
14	11147.5	11147.5	3185	3185	3185	0	0	320	31850
15	10237.5	10237.5	0	2925	3600	0	0	0	27000
16	10146.5	10146.5	0	2899	0	0	0	0	23192
17	10123.75	9233.75	0	2892.5	0	0	0	170	22250
18	10032.75	10032.75	0	2866.5	0	0	0	60	22932
19	10101	10101	0	2886	0	0	0	60	23088
20	10305.75	10305.75	0	2944.5	0	0	0	900	23556
21	10510.5	10510.5	0	3003	0	0	0	0	24024
22	10442.25	10442.25	0	2983.5	0	0	0	0	23868
23	10351.25	10123.75	0	0	0	0	0	0	20475
24	10260.25	7779.75	0	0	0	0	0	1080	18040

5.6.1.2 Forty Generating Unit System

This test system is used to check the efficiency of the proposed hCHHO-SCA optimizer. The system contains of 40-generating units having a 24-hour electricity demand. The hCHHO-SCA technique is evaluated for 100 iterations. The hCHHO-SCA algorithm is verified for 30 trial runs. The profit with start-up costand fuel cost of 24 hours are shown in Table-5.4. The optimal scheduling of 40-generating unit systems are shown in Table-5.5a and Table-5.5b. The hourly profit table for this system is shown in Table-5.6a and Table-5.6b respectively. The convergence graph of total profit is shown in **Fig.5.6**.

Table-5.4: Hourly profit with startup cost and fuel cost for 40-generating unit system using hCHHO-SCA optimization algorithm

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	62020	1950	54732.519	**13**	131068.8	230	107805.1
2	66000	3260	58217.999	**14**	127400	1450	104736.08
3	78540	1330	65207.559	**15**	108000	350	95671.387
4	82446	1940	69413.199	**16**	92768	960	81362.318
5	93000	1750	77468.983	**17**	89000	370	78051.083
6	95472	0	80886.976	**18**	91728	180	82085.612
7	93600	0	80886.976	**19**	92352	1680	81323.072
8	92144	170	80886.976	**20**	94224	2900	81323.072
9	106704	380	92423.035	**21**	96096	60	80855.835
10	164360	1160	115489.21	**22**	95472	2460	80886.976
11	170287.2	60	116191.91	**23**	81900	870	69908.441
12	178759.2	270	116191.91	**24**	72160	850	62525.475

Table-5.5a represents the optimal scheduling of power unit-1 to 20 for 40-unit test system. The PGU7, PGU9 and PGU10 is off for 24 hours. And the PGU17 to PGU20 is also in off conditions, whereas PGU1, PGU2, PGU11 and PGU12 is always on for 24 hours. PGU8 give 32 MW power output only for 10^{th} hour. Rest of the PGU are sometimes remain on and sometimes remain off to give the optimal output.

Table-5.5a: Generation scheduling for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20)

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU-10	PGU-11	PGU-12	PGU-13	PGU-14	PGU-15	PGU-16	PGU-17	PGU-18	PGU-19	PGU-20
1	455	245	0	0	0	0	0	0	0	0	455	245	0	0	0	0	0	0	0	0
2	455	295	0	0	0	0	0	0	0	0	455	295	0	0	0	0	0	0	0	0
3	455	395	0	0	0	0	0	0	0	0	455	395	0	0	0	0	0	0	0	0
4	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
5	455	447.5	0	130	0	0	0	0	0	0	455	447.5	0	0	0	0	0	0	0	0
6	455	455	130	130	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
7	455	455	130	130	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
8	455	455	130	130	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
9	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
10	455	455	130	130	162	80	0	32	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	157	0	0	0	0	0	455	455	130	130	157	0	0	0	0	0
14	455	455	130	130	130	0	0	0	0	0	455	455	130	130	130	0	0	0	0	0
15	455	455	0	130	160	0	0	0	0	0	455	455	0	130	160	0	0	0	0	0
16	455	448.75	0	130	0	0	0	0	0	0	455	448.75	0	130	0	0	0	0	0	0
17	455	415	0	130	0	0	0	0	0	0	455	415	0	130	0	0	0	0	0	0
18	455	447.5	0	130	0	0	0	0	0	0	455	447.5	0	130	0	20	0	0	0	0
19	455	450	0	130	0	0	0	0	0	0	455	450	0	130	0	20	0	0	0	0
20	455	450	0	130	0	0	0	0	0	0	455	450	0	130	0	20	0	0	0	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
23	455	455	0	0	0	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
24	455	365	0	0	0	0	0	0	0	0	455	365	130	0	0	0	0	0	0	0

Table-5.5b: Generation scheduling for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40)

HOURS	**PGU 21**	**PGU22**	**PG U23**	**PGU 24**	**PGU 25**	**PGU 26**	**PGU 27**	**PGU 28**	**PGU 29**	**PGU 30**	**PGU 31**	**PGU3 2**	**PGU 33**	**PGU 34**	**PGU 35**	**PGU 36**	**PGU 37**	**PGU 38**	**PGU 39**	**PGU 40**
1	455	245	0	0	0	0	0	0	0	0	455	245	0	0	0	0	0	0	0	0
2	455	295	0	0	0	0	0	0	0	0	455	295	0	0	0	0	0	0	0	0
3	455	395	0	0	0	0	0	0	0	0	455	395	0	0	0	0	0	0	0	0
4	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
5	455	447.5	0	130	0	0	0	0	0	0	455	447.5	0	130	0	0	0	0	0	0
6	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
7	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
8	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
9	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
10	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	0	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	157	0	0	0	0	0	455	455	130	130	157	20	0	0	0	0
14	455	455	130	130	130	0	0	0	0	0	455	455	130	130	130	0	0	0	0	0
15	455	455	0	130	160	0	0	0	0	0	455	455	0	130	160	0	0	0	0	0
16	455	448.75	0	130	25	0	0	0	0	0	455	448.75	0	130	0	0	0	0	0	0
17	455	415	0	130	0	0	0	0	0	0	455	415	0	130	0	0	0	0	0	0
18	455	447.5	0	130	0	0	0	0	10	0	455	447.5	0	130	0	0	0	0	0	0
19	455	450	0	130	0	0	0	0	0	0	455	450	0	130	0	0	0	0	0	0
20	455	450	0	130	0	0	0	0	0	0	455	450	0	130	0	0	0	0	0	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	455	130	130	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
23	455	455	130	0	155	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
24	455	365	130	0	25	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0

In the Table-5.5b shows the scheduling for 21 to 40 unit for 40-unit system, the PGU21, PGU22 and PGU31 is remaining always on throughout the whole day. The PGU27, PGU28, PGU30 and PGU37 to PGU40 are off for 24 hours. The PGU29 is on only for 18^{th} hours and 10 MW power is generated from that particular hour. The PGU36 is in on condition for 11th, 12^{th} and 13^{th} hour only.

The hourly profit for 40-test system is shown in Table-5.6a and Table-5.6b. The Table-5.6a shows the hourly profit for first 20 unit for 24 hours. The maximum amount of profit can be measured from the PGU1, PGU2, PGU11 and PGU12 as it was on for 24 hours. The PGU8 give 939.2 $ for 10^{th} hour only. The other units are gives several amount of profit for that particular hour when it was on. For 15- generation unit at 12^{th} hour give 5127.3 $ profit.

Table-5.6b shows that the hourly profit of unit 21 to unit 40 for this test system for 24 hours. PGU21, PGU22 and PGU32 are remain on for 24 hours, that why the profit from these units are maximum. For PGU29 the profit is 220.5 $ only for 18^{th} hour as it was on for that hour only. The maximum profit for PGU23 Is 4114.5 $ for 12^{th} hour though it is on for 9^{th} to 14^{th} and 22^{nd} to 24^{th} hour. The profit can be obtain for 5^{th} to 22^{nd} hours as PGU24 is on only for that. For PGU36 the maximum profit obtain as 2412 $ for 11^{th} hour, 2532 $ for 12^{th} hour and 492 $ for 13^{th} hour, and for others hours it remain off, so the profit is ‘0’ for that hour.

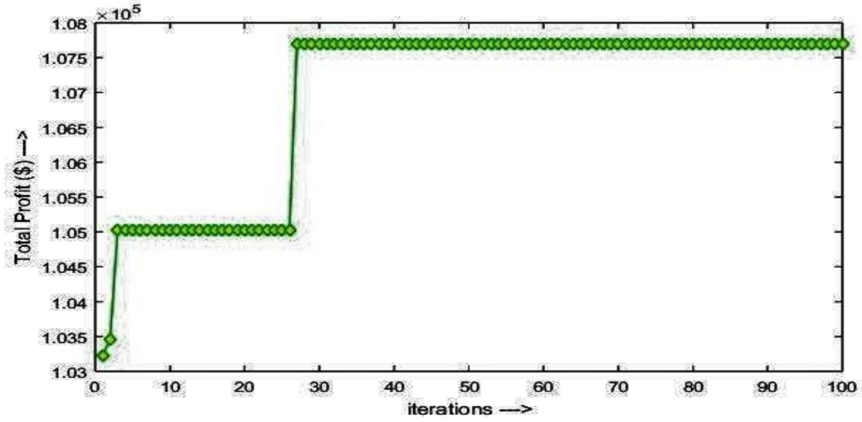
The **Fig.5.6** shows the profit of convergence curve for 10-, 40- and 100-generating unit test system using proposed hCHHO-SCA optimizer. The 100 number of iterations are taken into consideration. The 30 trail runs have been taken. Out of those 30 trails, the best profit for 10-unit system is 107702.5766 $. For 40-unit system, the best profit is 422919.4939 $ and for 100-unit test system it is 1068177.9 $ shown in the curve.

Table-5.6a: Hourly profit for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20)

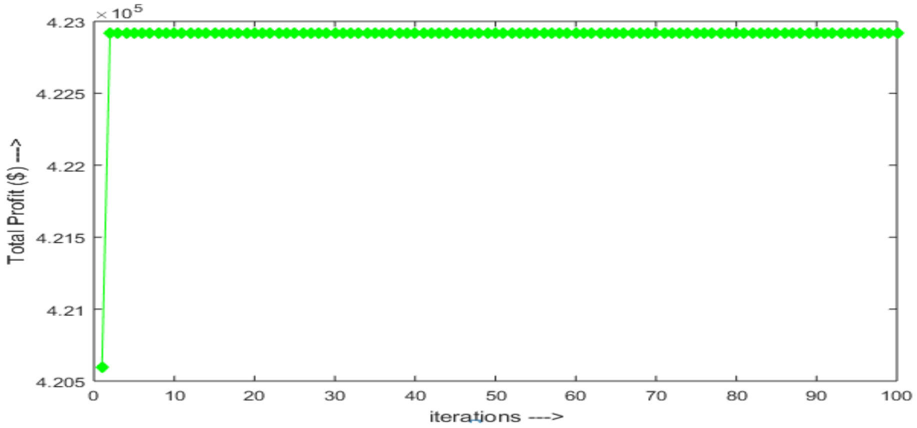
HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	GPU16	PGU17	PGU 18	PGU19	PGU 20
1	10078.25	5426.75	0	0	0	0	0	0	0	0	10078.25	5426.75	0	0	0	0	0	0	0	0
2	10010	6490	0	0	0	0	0	0	0	0	10010	6490	0	0	0	0	0	0	0	0
3	10510.5	9124.5	0	0	0	0	0	0	0	0	10510.5	9124.5	0	0	0	0	0	0	0	0
4	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
5	10578.75	10404.375	0	3022.5	0	0	0	0	0	0	10578.75	10404.375	0	0	0	0	0	0	0	0
6	10442.25	10442.25	2983.5	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
7	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	0	0	0	0	0	0	0	0
8	10078.25	10078.25	2879.5	2879.5	0	0	0	0	0	0	10078.25	10078.25	0	0	0	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	939.2	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3862.2	0	0	0	0	0	11193	11193	3198	3198	3862.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3185	0	0	0	0	0	11147.5	11147.5	3185	3185	3185	0	0	0	0	0
15	10237.5	10237.5	0	2925	3600	0	0	0	0	0	10237.5	10237.5	0	2925	3600	0	0	0	0	0
16	10146.5	10007.125	0	2899	0	0	0	0	0	0	10146.5	10007.125	0	2899	0	0	0	0	0	0
17	10123.75	9233.75	0	2892.5	0	0	0	0	0	0	10123.75	9233.75	0	2892.5	0	0	0	0	0	0
18	10032.75	9867.375	0	2866.5	0	0	0	0	0	0	10032.75	9867.375	0	2866.5	0	441	0	0	0	0
19	10101	9990	0	2886	0	0	0	0	0	0	10101	9990	0	2886	0	444	0	0	0	0
20	10305.75	10192.5	0	2944.5	0	0	0	0	0	0	10305.75	10192.5	0	2944.5	0	453	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	0	0	0	0	0	0
23	10351.25	10351.25	0	0	0	0	0	0	0	0	10351.25	10351.25	2957.5	0	0	0	0	0	0	0
24	10260.25	8230.75	0	0	0	0	0	0	0	0	10260.25	8230.75	2931.5	0	0	0	0	0	0	0

Table-5.6b: Hourly profit for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40)

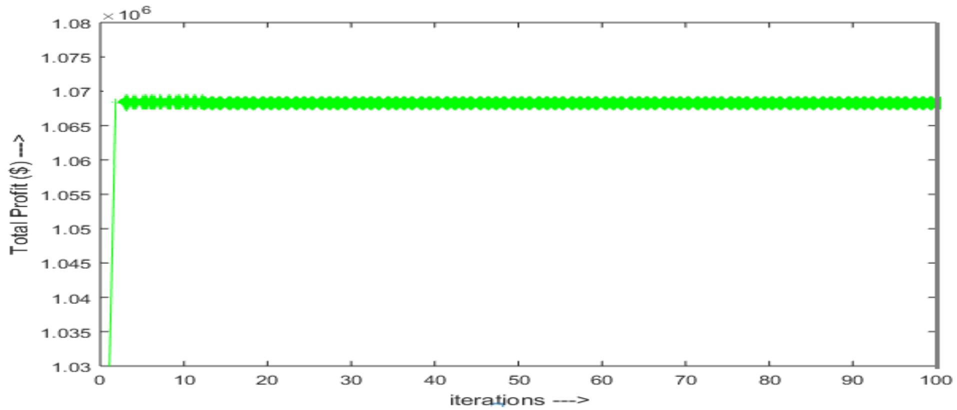
HOURS	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PG34	PGU35	GPU36	PGU37	PGU 38	PGU39	PGU 40
1	10078.25	5426.75	0	0	0	0	0	0	0	0	10078.25	5426.75	0	0	0	0	0	0	0	0
2	10010	6490	0	0	0	0	0	0	0	0	10010	6490	0	0	0	0	0	0	0	0
3	10510.5	9124.5	0	0	0	0	0	0	0	0	10510.5	9124.5	0	0	0	0	0	0	0	0
4	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
5	10578.75	10404.375	0	3022.5	0	0	0	0	0	0	10578.75	10404.375	0	3022.5	0	0	0	0	0	0
6	10442.25	10442.25	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	0	0	0	0	0	0
7	10237.5	10237.5	0	2925	0	0	0	0	0	0	10237.5	10237.5	0	2925	0	0	0	0	0	0
8	10078.25	10078.25	0	2879.5	0	0	0	0	0	0	10078.25	10078.25	0	2879.5	0	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	412114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3862.2	0	0	0	0	0	11193	11193	3198	3198	3862.2	492	0	0	0	0
14	11147.5	11147.5	3185	3185	3185	0	0	0	0	0	11147.5	11147.5	3185	3185	3185	0	0	0	0	0
15	10237.5	10237.5	0	2925	3600	0	0	0	0	0	10237.5	10237.5	0	2925	3600	0	0	0	0	0
16	10146.5	10007.125	0	2899	557.5	0	0	0	0	0	10146.5	10007.125	0	2899	0	0	0	0	0	0
17	10123.75	9233.75	0	2892.5	0	0	0	0	0	0	10123.75	9233.75	0	2892.5	0	0	0	0	0	0
18	10032.75	9867.375	0	2866.5	0	0	0	0	220.5	0	10032.75	9867.375	0	2866.5	0	0	0	0	0	0
19	10101	9990	0	2886	0	0	0	0	0	0	10101	9990	0	2886	0	0	0	0	0	0
20	10305.75	10192.5	0	2944.5	0	0	0	0	0	0	10305.75	10192.5	0	2944.5	0	0	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	10351.25	2957.5	0	3526.25	0	0	0	0	0	10351.25	0	0	0	0	0	0	0	0	0
24	10260.25	8230.75	2931.5	0	563.75	0	0	0	0	0	10260.25	0	0	0	0	0	0	0	0	0



(a) 10-unit



(b) 40-unit



(c) 100-unit

Fig.5.6: Convergence curve for 10-, 40- and 100-generating unit system using hCHHO-SCA optimization algorithm

5.6.1.3 Hundred Generating Unit System

This test system is used to verify the efficacy of the suggested hCHHO-SCA optimizer. The system contain 100-generating unit system having a 24-hour electricity demand. The hCHHO-SCA technique is evaluated for 100 iterations. The hCHHO- SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.5.6**. The profit with start-up cost and fuel cost of 24 hours are shown in Table-5.7. The optimal scheduling of 100-generating unit systems are shown in Table-5.8a to Table-5.8e. The hourly profit table for this system is shown in Table-5.9a to Table-5.9e respectively.

Table-5.7: Hourly profit with start-up cost and fuel cost for100-generating unit system using hCHHO-SCA optimization algorithm

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	155050	4560	136831.3	**13**	327672	960	269165.6
2	165000	5330	145545	**14**	318500	210	261464.94
3	196350	5560	163018.9	**15**	270000	1710	238795.97
4	206115	4700	173533	**16**	231920	1080	202139.59
5	232500	1720	193382.19	**17**	222500	2870	195127.71
6	238680	2560	202357.19	**18**	229320	810	202139.59
7	234000	3880	204409.23	**19**	230880	260	202139.59
8	230360	300	204409.23	**20**	235560	4140	202139.59
9	266760	13470	231616.97	**21**	240240	2000	202139.59
10	410900	2530	287348.71	**22**	238680	5340	202357.19
11	425718	780	290987.67	**23**	204750	3890	172970.56
12	446898	840	290987.67	**24**	180400	3060	153358.13

The Table-5.8a represents the generation scheduling of 100-generating unit system using hCHHO-SCA optimization algorithm for PGU1 to PGU20. Where PGU1, PGU2, PGU11 and PGU12 are remain on for 24 hours. The 455 MW power output can be measured from PGU1 and PGU11 for 24 hours. PGU7 to PGU10 and PGU17 to PGU20 is totally off throughout the day. So, no power generation can be obtained from those units. Further others unit are on for some few hours and off some few hours. Thus the optimal generation can be taken only those are in on condition.

Table-5.8a: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20)

HOUR	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	455	245	0	0	0	0	0	0	0	0	455	245	0	0	0	0	0	0	0	0
2	455	295	0	0	0	0	0	0	0	0	455	295	0	0	0	0	0	0	0	0
3	455	395	0	0	0	0	0	0	0	0	455	395	0	0	0	0	0	0	0	0
4	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
5	455	454	0	130	0	0	0	0	0	0	455	454	0	130	0	0	0	0	0	0
6	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
7	455	424	0	130	0	0	0	0	0	0	455	424	0	130	25	0	0	0	0	0
8	455	424	0	130	0	0	0	0	0	0	455	424	0	130	25	0	0	0	0	0
9	455	455	130	130	0	0	0	0	0	0	455	455	130	130	130	0	0	0	0	0
10	455	455	130	130	162	75.555556	0	0	0	0	455	455	130	130	162	75.555556	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	159.5	0	0	0	0	0	455	455	130	130	159.5	0	0	0	0	0
14	455	455	130	130	144.44444	0	0	0	0	0	455	455	130	130	144.44444	0	0	0	0	0
15	455	455	130	130	154.28571	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
17	455	415	0	130	0	0	0	0	0	0	455	415	0	130	0	0	0	0	0	0
18	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
19	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
20	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
23	455	455	0	0	112.5	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
24	455	455	0	0	67.5	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0

Table-5.8b: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40)

HOUR	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	245	0	0	0	0	0	0	0	0	455	245	0	0	0	0	0	0	0	0
2	455	295	0	0	0	0	0	0	0	0	455	295	0	0	0	0	0	0	0	0
3	455	395	0	0	0	0	0	0	0	0	455	395	0	0	0	0	0	0	0	0
4	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
5	455	454	0	130	0	0	0	0	0	0	455	454	0	130	0	0	0	0	0	0
6	455	455	0	130	0	0	0	0	0	0	455	455	0	130	130	0	0	0	0	0
7	455	424	0	130	0	0	0	0	0	0	455	424	130	130	25	0	0	0	0	0
8	455	424	0	130	0	0	0	0	0	0	455	424	130	130	25	0	0	0	0	0
9	455	455	130	130	0	0	0	0	0	0	455	455	130	130	130	0	0	0	0	0
10	455	455	130	130	162	75.555556	0	0	0	0	455	455	130	130	162	75.555556	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	159.5	0	0	0	0	0	455	455	130	130	159.5	0	0	0	0	0
14	455	455	130	130	144.44444	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
15	455	455	130	130	154.28571	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
17	455	415	0	130	0	0	0	0	0	0	455	415	0	130	0	0	0	0	0	0
18	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
19	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
20	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
23	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
24	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0

Table-5.8c: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 41-60)

Hour	PG U41	PGU 42	GU43	PGU44	PGU4 5	PGU4 6	PGU47- PGU-50	PG U51	PGU52	PGU 53	PGU5 4	PGU5 5	PGU56	PGU57 - PGU60
1	455	245	0	0	0	0	0	455	245	0	0	0	0	0
2	455	295	0	0	0	0	0	455	295	0	0	0	0	0
3	455	395	0	0	0	0	0	455	395	0	0	0	0	0
4	455	455	0	0	0	0	0	455	455	0	0	0	0	0
5	455	454	0	130	0	0	0	455	454	0	130	0	0	0
6	455	455	0	130	0	0	0	455	455	0	130	0	0	0
7	455	424	130	130	0	0	0	455	424	0	130	0	0	0
8	455	424	130	130	0	0	0	455	424	0	130	0	0	0
9	455	455	130	130	0	0	0	455	455	130	130	0	0	0
10	455	455	130	130	162	75.55 5556	0	455	455	130	130	162	75.5555 56	0
11	455	455	130	130	162	80	0	455	455	130	130	162	80	0
12	455	455	130	130	162	80	0	455	455	130	130	162	80	0
13	455	455	130	130	159.5	0	0	455	455	130	130	159.5	0	0
14	455	455	130	130	144.4 4444	0	0	455	455	130	130	144.4 4444	0	0
15	455	455	0	130	154.2 8571	0	0	455	455	0	130	154.2 8571	0	0
16	455	455	0	130	0	0	0	455	455	0	130	0	0	0
17	455	415	0	130	0	0	0	455	415	0	130	0	0	0
18	455	455	0	130	0	0	0	455	455	0	130	0	0	0
19	455	455	0	130	0	0	0	455	455	0	130	0	0	0
20	455	455	0	130	0	0	0	455	455	0	130	0	0	0
21	455	455	0	130	0	0	0	455	455	0	130	0	0	0
22	455	455	0	130	0	0	0	455	455	0	130	0	0	0
23	455	455	0	0	0	0	0	455	455	0	0	0	0	0
24	455	455	0	0	0	0	0	455	455	0	0	0	0	0

Table-5.8b gives the optimal power scheduling of 100-uniut system by suggested hCHHO-SCA method for PGU21 to PGU40. The PGU21, PGU22, PGU31 and PGU32 are in on condition for 24 hours. And other PGU are sometimes on and sometimes off. PGU27 to PGU30 and PGU37 to PGU40 are off during 24 hours. Table-5.8c presents the generation scheduling of 100-generating unit system using proposed hCHHO-SCA optimization algorithm for PGU41 to PGU60. Here, PGU41, PGU42, PGU51 and PGU52 are on for 24 hours. The 455 MW power can be generated from PGU41 and PGU51. The output power is '0' for PGU47 to PGU50 and PGU57 to PGU60. From 10th to 12th hours, the PGU46 is remain on and power generation is 75.555556 MW for 10th hour and 80 MW for both 11th and 12th hour. Further the other PGU are on and off for few hours and output power generation can be measured through the table.

Table-5.8d: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 61-80)

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	455	245	0	0	0	0	0	0	0	0	455	245	0	0	0	0	0	0	0	0
2	455	295	0	0	0	0	0	0	0	0	455	295	0	0	0	0	0	0	0	0
3	455	395	0	0	0	0	0	0	0	0	455	395	0	0	0	0	0	0	0	0
4	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
5	455	454	0	130	0	0	0	0	0	0	455	454	0	0	0	0	0	0	0	0
6	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
7	455	424	0	130	0	0	0	0	0	0	455	424	0	130	0	0	0	0	0	0
8	455	424	0	130	0	0	0	0	0	0	455	424	0	130	0	0	0	0	0	0
9	455	455	0	130	130	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
10	455	455	130	130	162	75.555556	0	0	0	0	455	455	130	130	162	75.555556	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	80	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	80	0	0	0
13	455	455	130	130	159.5	0	0	0	0	0	455	455	130	130	159.5	0	25	0	0	0
14	455	455	130	130	144.44444	0	0	0	0	0	455	455	130	130	144.44444	0	0	0	0	0
15	455	455	0	130	0	0	0	0	0	0	455	455	0	130	154.28571	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
17	455	415	0	130	0	0	0	0	0	0	455	415	0	130	0	0	0	0	0	0
18	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
19	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
20	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	455	0	130	0	0	0	0	0	0	455	455	0	130	130	0	0	0	0	0
23	455	455	0	0	0	0	0	0	0	0	455	455	0	0	112.5	0	0	0	0	0
24	455	455	0	0	0	0	0	0	0	0	455	0	0	0	67.5	0	0	0	0	0

Table-5.8e: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 81-100)

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	455	245	0	0	0	0	0	0	0	0	455	245	0	0	0	0	0	0	0	0
2	455	295	0	0	0	0	0	0	0	0	455	295	0	0	0	0	0	0	0	0
3	455	395	0	0	0	0	0	0	0	0	455	395	0	0	0	0	0	0	0	0
4	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
5	455	454	0	0	0	0	0	0	0	0	455	454	0	0	0	0	0	0	0	0
6	455	455	0	0	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
7	455	424	0	0	0	0	0	0	0	0	455	424	130	130	0	0	0	0	0	0
8	455	424	0	0	0	0	0	0	0	0	455	424	130	130	0	0	0	0	0	0
9	455	455	0	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
10	455	455	130	130	162	75.555556	0	0	0	0	455	455	130	130	162	0	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	0	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	0	0	0	0	0
13	455	455	130	130	159.5	0	0	0	0	0	455	455	130	130	159.5	0	0	0	0	0
14	455	455	130	130	144.44444	0	0	0	0	0	455	455	130	130	144.44444	0	0	0	0	0
15	455	455	0	130	154.28571	0	0	0	0	0	455	455	0	130	154.28571	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
17	455	415	0	130	0	0	0	0	0	0	455	415	0	130	0	0	0	0	0	0
18	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
19	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
20	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	455	0	130	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
23	455	455	0	0	0	0	0	0	0	0	455	0	130	0	0	0	0	0	0	0
24	455	0	0	0	0	0	0	0	0	0	455	0	130	0	0	0	0	0	0	0

The Table-5.8d signifies the generation scheduling of 100-generating unit by hCHHO-SCA algorithm for PGU61 to PGU80. The PGU61, PGU62, PGU71 and PGU72 is on for 24 hours. The 455 MW power output can be shown from PGU61 and PGU71 for 24 hours. The power output from PGU66 and PGU76 is same for 10^{th} to 12^{th} hour, i.e. 75.555556 MW for 10^{th} hour and 80 MW for 11^{th} and 12^{th} hours.

Table-5.8e gives the optimal power scheduling of 100-uniut system by suggested hCHHO-SCA method for PGU81 to PGU100. PGU87 to PGU90 and PGU96 to PGU100 is totally off throughout the day. So, no power generation can be obtained from those units. Further others unit are on for some few hours and off some few hours. Thus the optimal generation can be taken only those are in on condition.

Table-5.9a shows the best profit of PGU1 to PGU20 for each unit for particular hours. The duration of total hour is 24 hours. The suggested hCHHO-SCA optimizer is tested on 100-unit system. The maximum profit are obtained from PGU1. PGU2, PGU11 and PGU12. The profit from PGU 6 and PGU16 are remain same for 10^{th} to 12^{th} hours, i.e. 2217.5556 $ for 10^{th} hour, 2412 $ for 11^{th} hour and 2532 $ for 12^{th} hours are taken into consideration.

Table-5.9b represents the hourly profit for 100-generating unit system by hCHHO-SCA optimizer for PGU21 to PGU40. The PGU21, PGU22, PGU31 and PGU32 are on throughout 24 hours. So, for those units the profit values are obtained in each hour. The PGU26 and PGU36 give the same amount of profit for 10^{th} to 12^{th} hours. 5127.3 $ is the maximum profit for PGU25 in 12^{th} hour and for remaining hours it is varying from 1522.125 $ to 4884.3 $.

Table-5.9a: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 1-20)

Hour	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	10078.25	5426.75	0	0	0	0	0	0	0	0	10078.25	5426.75	0	0	0	0	0	0	0	0
2	10010	6490	0	0	0	0	0	0	0	0	10010	6490	0	0	0	0	0	0	0	0
3	10510.5	9124.5	0	0	0	0	0	0	0	0	10510.5	9124.5	0	0	0	0	0	0	0	0
4	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
5	10578.75	10555.5	0	3022.5	0	0	0	0	0	0	10578.75	10555.5	0	3022.5	0	0	0	0	0	0
6	10442.25	10442.25	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	0	0	0	0	0	0
7	10237.5	9540	0	2925	0	0	0	0	0	0	10237.5	9540	0	2925	562.5	0	0	0	0	0
8	10078.25	9391.6	0	2879.5	0	0	0	0	0	0	10078.25	9391.6	0	2879.5	553.75	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	2964	2964	2964	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2217.5556	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2217.5556	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3923.7	0	0	0	0	0	11193	11193	3198	3198	3923.7	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3538.8889	0	0	0	0	0	11147.5	11147.5	3185	3185	3538.8889	0	0	0	0	0
15	10237.5	10237.5	2925	2925	3471.4286	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	9233.75	0	2892.5	0	0	0	0	0	0	10123.75	9233.75	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	0	0	0	0
19	10101	10101	0	2886	0	0	0	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	0	0	0	0	0	0
23	10351.25	10351.25	0	0	2559.375	0	0	0	0	0	10351.25	10351.25	0	0	0	0	0	0	0	0
24	10260.25	10260.25	0	0	1522.125	0	0	0	0	0	10260.25	10260.25	0	0	0	0	0	0	0	0

Table-5.9b: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 21-40)

Hour	**PGU21**	**PGU22**	**PGU23**	**PGU24**	**PGU25**	**PGU26**	**PGU27**	**PGU28**	**PGU29**	**PGU30**	**PGU31**	**PGU32**	**PGU33**	**PGU34**	**PGU35**	**PGU36**	**PGU37**	**PGU38**	**PGU39**	**PGU40**
1	10078.25	5426.75	0	0	0	0	0	0	0	0	10078.25	5426.75	0	0	0	0	0	0	0	0
2	10010	6490	0	0	0	0	0	0	0	0	10010	6490	0	0	0	0	0	0	0	0
3	10510.5	9124.5	0	0	0	0	0	0	0	0	10510.5	9124.5	0	0	0	0	0	0	0	0
4	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
5	10578.75	10555.5	0	3022.5	0	0	0	0	0	0	10578.75	10555.5	0	3022.5	0	0	0	0	0	0
6	10442.25	10442.25	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	2983.5	0	0	0	0	0
7	10237.5	9540	0	2925	0	0	0	0	0	0	10237.5	9540	2925	2925	562.5	0	0	0	0	0
8	10078.25	9391.6	0	2879.5	0	0	0	0	0	0	10078.25	9391.6	2879.5	2879.5	553.75	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	2964	2964	2964	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2217.5556	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2217.5556	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3923.7	0	0	0	0	0	11193	11193	3198	3198	3923.7	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3538.8889	0	0	0	0	0	11147.5	11147.5	3185	3185	0	0	0	0	0	0
15	10237.5	10237.5	2925	2925	3471.4286	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	9233.75	0	2892.5	0	0	0	0	0	0	10123.75	9233.75	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	0	0	0	0
19	10101	10101	0	2886	0	0	0	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	0	0	0	0	0	0
23	10351.25	10351.25	0	0	0	0	0	0	0	0	10351.25	10351.25	0	0	0	0	0	0	0	0
24	10260.25	10260.25	0	0	0	0	0	0	0	0	10260.25	10260.25	0	0	0	0	0	0	0	0

Table-5.9c: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 41-60)

Hour	PGU41	PGU42	PGU43	PGU 44	PGU45	PGU46	PGU 47	PGU48	PGU49	PGU50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PGU56	PGU 57	PGU 58	PGU 59	PGU 60
1	10078.25	5426.75	0	0	0	0	0	0	0	0	10078.25	5426.75	0	0	0	0	0	0	0	0
2	10010	6490	0	0	0	0	0	0	0	0	10010	6490	0	0	0	0	0	0	0	0
3	10510.5	9124.5	0	0	0	0	0	0	0	0	10510.5	9124.5	0	0	0	0	0	0	0	0
4	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
5	10578.75	10555.5	0	3022.5	0	0	0	0	0	0	10578.75	10555.5	0	3022.5	0	0	0	0	0	0
6	10442.25	10442.25	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	0	0	0	0	0	0
7	10237.5	9540	2925	2925	0	0	0	0	0	0	10237.5	9540	0	2925	0	0	0	0	0	0
8	10078.25	9391.6	2879.5	2879.5	0	0	0	0	0	0	10078.25	9391.6	0	2879.5	0	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2217.5556	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2217.5556	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3923.7	0	0	0	0	0	11193	11193	3198	3198	3923.7	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3538.8889	0	0	0	0	0	11147.5	11147.5	3185	3185	3538.8889	0	0	0	0	0
15	10237.5	10237.5	0	2925	3471.4286	0	0	0	0	0	10237.5	10237.5	0	2925	3471.4286	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	9233.75	0	2892.5	0	0	0	0	0	0	10123.75	9233.75	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	0	0	0	0
19	10101	10101	0	2886	0	0	0	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	0	0	0	0	0	0
23	10351.25	10351.25	0	0	0	0	0	0	0	0	10351.25	10351.25	0	0	0	0	0	0	0	0
24	10260.25	10260.25	0	0	0	0	0	0	0	0	10260.25	10260.25	0	0	0	0	0	0	0	0

The Table-5.9c is presented the hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm for units 41 to unit 60. The PGU41 and PGU42 remain ON for 24 hours. The PGU47 to PGU50 and PGU57 to PGU60 remain close throughout the whole day. That's why no profit come from those units, the output is '0'. The PGU43 is on for 7th hour to 14th hours. 4114.5 $ is the maximum output for that unit at 12th hour. The PGU46 and PGU56 are on for some hours, i.e. 10th, 11th and 12th hours. The PGU55 is on for 10th hour to 15th hour. Other units are remained on sometime and off for few times.

The Table-5.9d is presented the hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm for units 61 to unit 80. The PGU61, PGU62, PGU71 and PGU72 are continuously on for 24 hours. PGU67 to PGU70 and PGU78 to PGU80 are continuously off for 24 hours. So, profit value is 0 for those units are continuously off. The profit from PGU77 is 2412 $ for 11th hour, 2532 $ for 12th hours and 615 $ for 13th hour. For other hours this unit is in off condition. The PGU75 is operating only from 10th to 15th hours and 22nd to 24th hours. The profit value of this unit is varying from 1522.125 $ to 5127.3 $.

The Table-5.9e is presented the hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm for units 81 to unit 100. The PGU81, PGU82 and PGU91 and PGU92 have been on for 24 hours. PGU87 to PGU90 and PGU96 to PGU100 have been off for the whole day. The profit value for PGU83 is varying from 3185 $ to 4114.5 $ as it is on from 10th hour to 14th hour. For PGU84, the maximum profit is 4114.5 $ for 12th hour and minimum profit is 2879.5 $ for 8th hour as it is operation from 9th hour to 22nd hour. The PGU85 is operating from 10th hour to 15th hour and 5127.3 $ is the maximum profit in 12th hours.

Table-5.9d: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 61-80)

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	10078.25	5426.75	0	0	0	0	0	0	0	0	10078.25	5426.75	0	0	0	0	0	0	0	0
2	10010	6490	0	0	0	0	0	0	0	0	10010	6490	0	0	0	0	0	0	0	0
3	10510.5	9124.5	0	0	0	0	0	0	0	0	10510.5	9124.5	0	0	0	0	0	0	0	0
4	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
5	10578.75	10555.5	0	3022.5	0	0	0	0	0	0	10578.75	10555.5	0	0	0	0	0	0	0	0
6	10442.25	10442.25	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	0	0	0	0	0	0
7	10237.5	9540	0	2925	0	0	0	0	0	0	10237.5	9540	0	2925	0	0	0	0	0	0
8	10078.25	9391.6	0	2879.5	0	0	0	0	0	0	10078.25	9391.6	0	2879.5	0	0	0	0	0	0
9	10374	10374	0	2964	2964	0	0	0	0	0	10374	10374	0	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2217.5556	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2217.5556	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	2412	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2532	0	0	0
13	11193	11193	3198	3198	3923.7	0	0	0	0	0	11193	11193	3198	3198	3923.7	0	615	0	0	0
14	11147.5	11147.5	3185	3185	3538.8889	0	0	0	0	0	11147.5	11147.5	3185	3185	3538.8889	0	0	0	0	0
15	10237.5	10237.5	0	2925	0	0	0	0	0	0	10237.5	10237.5	0	2925	3471.4286	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	9233.75	0	2892.5	0	0	0	0	0	0	10123.75	9233.75	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	0	0	0	0
19	10101	10101	0	2886	0	0	0	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	2983.5	0	0	0	0	0
23	10351.25	10351.25	0	0	0	0	0	0	0	0	10351.25	10351.25	0	0	2559.375	0	0	0	0	0
24	10260.25	10260.25	0	0	0	0	0	0	0	0	10260.25	0	0	0	1522.125	0	0	0	0	0

Table-5.9e: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 81-100)

Hour	**PGU81**	**PGU82**	**PGU83**	**PGU84**	**PGU85**	**PGU86**	**PGU87**	**PGU88**	**PGU89**	**PGU90**	**PGU91**	**PGU92**	**PGU93**	**PGU94**	**PGU95**	**PGU96**	**PGU97**	**PGU98**	**PGU99**	**PGU100**
1	10078.25	5426.75	0	0	0	0	0	0	0	0	10078.25	5426.75	0	0	0	0	0	0	0	0
2	10010	6490	0	0	0	0	0	0	0	0	10010	6490	0	0	0	0	0	0	0	0
3	10510.5	9124.5	0	0	0	0	0	0	0	0	10510.5	9124.5	0	0	0	0	0	0	0	0
4	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
5	10578.75	10555.5	0	0	0	0	0	0	0	0	10578.75	10555.5	0	0	0	0	0	0	0	0
6	10442.25	10442.25	0	0	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	0	0	0	0	0	0
7	10237.5	9540	0	0	0	0	0	0	0	0	10237.5	9540	2925	2925	0	0	0	0	0	0
8	10078.25	9391.6	0	0	0	0	0	0	0	0	10078.25	9391.6	2879.5	2879.5	0	0	0	0	0	0
9	10374	10374	0	2964	0	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2217.5556	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0
13	11193	11193	3198	3198	3923.7	0	0	0	0	0	11193	11193	3198	3198	3923.7	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3538.8889	0	0	0	0	0	11147.5	11147.5	3185	3185	3538.8889	0	0	0	0	0
15	10237.5	10237.5	0	2925	3471.4286	0	0	0	0	0	10237.5	10237.5	0	2925	3471.4286	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	9233.75	0	2892.5	0	0	0	0	0	0	10123.75	9233.75	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	0	0	0	0
19	10101	10101	0	2886	0	0	0	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	10351.25	0	0	0	0	0	0	0	0	10351.25	0	2957.5	0	0	0	0	0	0	0
24	10260.25	0	0	0	0	0	0	0	0	0	10260.25	0	2931.5	0	0	0	0	0	0	0

5.6.2 Hybrid Chaotic Slime Mould-Sine Cosine Optimization Algorithm

The proposed hybrid algorithm hCSMA-SCA is established to increase the penetrating capability through the entire search region. The alteration with input boundaries with chaotic map is thought about to make the hybridization SMA enhancer with SCA technique which is especially proficient to track down the ideal arrangement over the hunt locale. This technique is unrivaled as the populace based enhancers are more reasonable to tackle ongoing issue since they can ready to stay away from the caught into nearby optima and investigate the pursuit district just as take advantage of worldwide ideal arrangement more steady than the individual based analyzer. The nos. of population is 40 for 10 unit, 40 unit and 100 unit systems.

5.6.2.1 Ten Generating Unit System

This system contains of 10-generating unit system having a 24-hour electricity demand. The CSMA-SCA technique is evaluated for 100 iterations. The CSMA-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.5.7**. Thecommitment status and the optimal scheduling for this unit system are shown in Table-5.10a and the hourly profit of the 10-generating units have been shown in Table-5.10b.

The Table-5.10a presents the commitment status with optimum scheduling of the generators for 24 hours. In this case, the PGU1 and PGU2 are on for 24 hours. From 9 to 14 hours, the PGU3 is on. For 5^{th} to 22^{nd} hours PGU4 is on, PGU5 is on for 10^{th} to 15^{th} hours and PGU6 is on for 10^{th} to 12^{th} hours. The PGU7 to PGU10 are stayed off for24 hours.

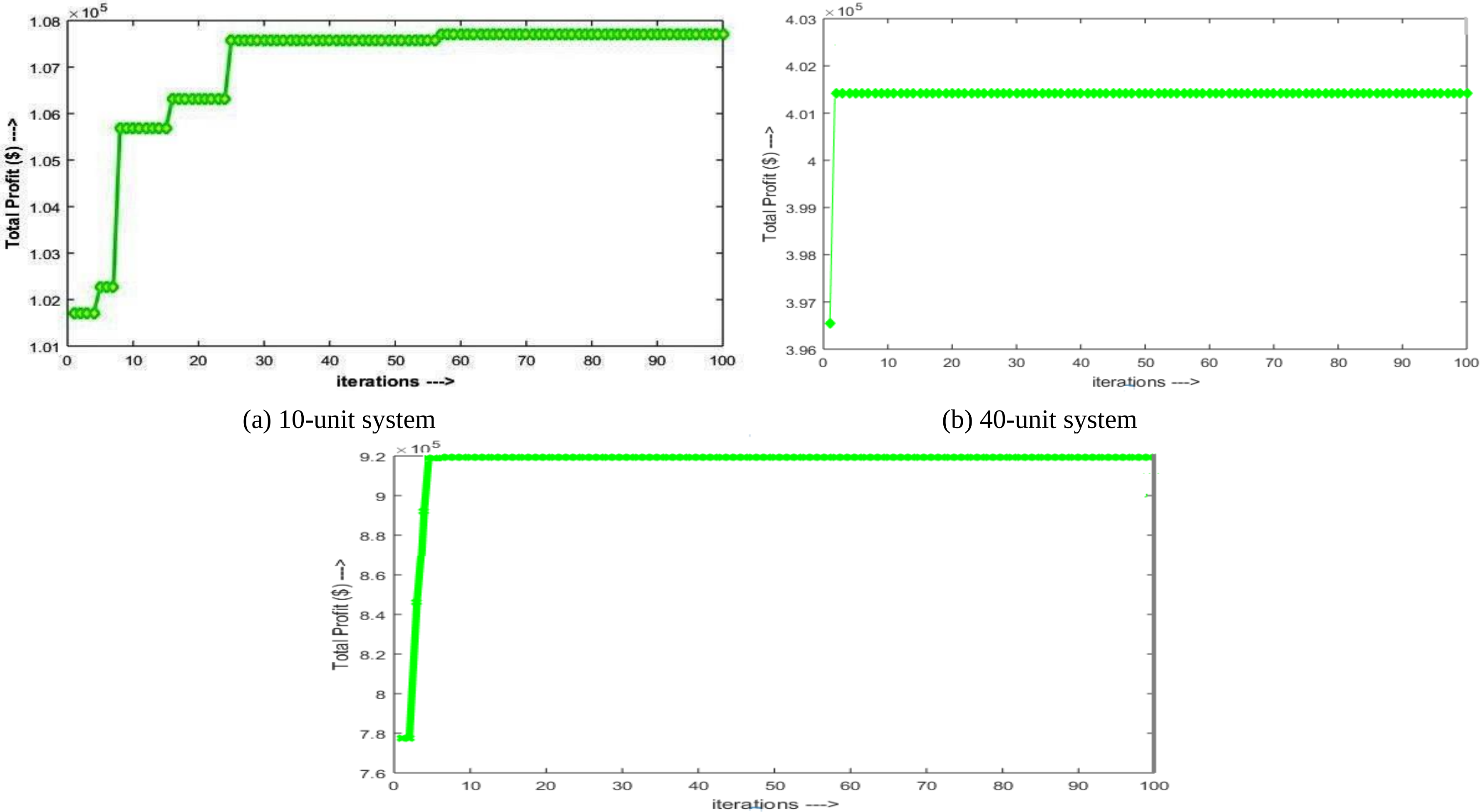
The Table-5.10b shows PGU1 generates 455 MW of power for 24 hours and PGU2 generates 455 MW power for some few hours. The PGU3 generates 130 MGW of power for 9^{th} hour to 14th hours. Further, the PGU4 stay off for 1 hour to 4^{th} hours and 23^{rd} and 24^{th} hour. It is on only for 5th hour to 22nd hour and the amount of power generation is 130 MW for each hour. For PGU5 it is on only for 10th to 15th hours. 10th to 13th hour for this unit 162 MW power is generated, for 14th hour 130 MW and for 15th 160 MW is the output power of that unit.

Table-5.10a: Commitment status and scheduling for 10-generating unit system using hCSMA-SCA optimization algorithm

Commitment status of thermal units								Scheduling of the committed generating units						
HOURS	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**
1	1	1	0	0	0	0	0	455	245	0	0	0	0	0
2	1	1	0	0	0	0	0	455	295	0	0	0	0	0
3	1	1	0	0	0	0	0	455	395	0	0	0	0	0
4	1	1	0	0	0	0	0	455	455	0	0	0	0	0
5	1	1	0	1	0	0	0	455	415	0	130	0	0	0
6	1	1	0	1	0	0	0	455	455	0	130	0	0	0
7	1	1	0	1	0	0	0	455	455	0	130	0	0	0
8	1	1	0	1	0	0	0	455	455	0	130	0	0	0
9	1	1	1	1	0	0	0	455	455	130	130	0	0	0
10	1	1	1	1	1	1	0	455	455	130	130	162	68	0
11	1	1	1	1	1	1	0	455	455	130	130	162	80	0
12	1	1	1	1	1	1	0	455	455	130	130	162	80	0
13	1	1	1	1	1	0	0	455	455	130	130	162	0	0
14	1	1	1	1	1	0	0	455	455	130	130	130	0	0
15	1	1	0	1	1	0	0	455	455	0	130	160	0	0
16	1	1	0	1	0	0	0	455	455	0	130	0	0	0
17	1	1	0	1	0	0	0	455	415	0	130	0	0	0
18	1	1	0	1	0	0	0	455	455	0	130	0	0	0
19	1	1	0	1	0	0	0	455	455	0	130	0	0	0
20	1	1	0	1	0	0	0	455	455	0	130	0	0	0
21	1	1	0	1	0	0	0	455	455	0	130	0	0	0
22	1	1	0	1	0	0	0	455	455	0	130	0	0	0
23	1	1	0	0	0	0	0	455	445	0	0	0	0	0
24	1	1	0	0	0	0	0	455	345	0	0	0	0	0

Table-5.10b: Hourly profit for 10-generating unit system using hCSMA-SCA optimization algorithm

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7 to PG10	Start-up Cost	Hourly Profit
1	10078.25	5426.75	0	0	0	0	0	1100	15505
2	10010	6490	0	0	0	0	0	550	16500
3	10510.5	9124.5	0	0	0	0	0	560	19635
4	10305.75	10305.75	0	0	0	0	0	520	20611.5
5	10578.75	9648.75	0	3022.5	0	0	0	60	23250
6	10442.25	10442.25	0	2983.5	0	0	0	0	23868
7	10237.5	10237.5	0	2925	0	0	0	0	23400
8	10078.25	10078.25	0	2879.5	0	0	0	0	23036
9	10374	10374	2964	2964	0	0	0	0	26676
10	13354.25	13354.25	3815.5	3815.5	4754.7	1995.8	0	340	41090
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	42571.8
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	44689.8
13	11193	11193	3198	3198	3985.2	0	0	0	32767.2
14	11147.5	11147.5	3185	3185	3185	0	0	0	31850
15	10237.5	10237.5	0	2925	3600	0	0	0	27000
16	10146.5	10146.5	0	2899	0	0	0	0	23192
17	10123.75	9233.75	0	2892.5	0	0	0	690	22250
18	10032.75	10032.75	0	2866.5	0	0	0	0	22932
19	10101	10101	0	2886	0	0	0	0	23088
20	10305.75	10305.75	0	2944.5	0	0	0	560	23556
21	10510.5	10510.5	0	3003	0	0	0	0	24024
22	10442.25	10442.25	0	2983.5	0	0	0	0	23868
23	10351.25	10123.75	0	0	0	0	0	0	20475
24	10260.25	7779.75	0	0	0	0	0	0	18040



(a) 10-unit system

(b) 40-unit system

(c) 100-unit system

Fig.5.7: Convergence curve for 10-, 40- and 100-generating unit system using hCSMA-SCA optimization algorithm

5.6.2.2 Forty Generating Unit System

This system contains of 40-generating unit system having a 24-hour electricity demand. This hybrid technique is evaluated for 100 iterations. The suggested hCSMA-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.5.7**. The profit with start-up cost and fuel cost of 24 hours are shown in Table-5.11. The optimal scheduling of 40 unit systems are shown in Table-5.12a and Table-5.12b. The hourly profit table for this system is shown in Table- 5.13a and Table-5.13b respectively. The profit with start-up cost and fuel cost of 24 hours are shown in Table-5.11.

Table-5.11: Hourly profit with startup cost and fuel cost for 40-generating unit system using hCSMA-SCA optimization algorithm

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	62020	4700	53787.329	**13**	131068.8	210	109118.66
2	66000	1920	57283.969	**14**	127400	1930	106282.54
3	78540	2040	65457.854	**15**	108000	300	95702.528
4	82446	1040	70828.557	**16**	92768	0	81104.579
5	93000	180	78978.19	**17**	89000	380	77500.124
6	95472	120	82395.757	**18**	91728	1200	81720.281
7	93600	470	82395.757	**19**	92352	2420	81720.281
8	92144	1410	82395.757	**20**	94224	2420	81751.422
9	106704	10320	92423.035	**21**	96096	1810	80918.117
10	164360	210	115072.85	**22**	95472	230	82631.409
11	170287.2	750	116191.91	**23**	81900	430	71786.933
12	178759.2	380	117904.13	**24**	72160	380	64037.133

Table-5.12a shows the optimal scheduling of power unit-1 to 20 for 40-generating unit test system. The PGU8 to PGU10 and PGU18 to PGU20 is off for 24 hours. The PGU1, PGU2, PGU11 and PGU12 is always remain on throughout the whole day. PGU7 and PGU17 give 65 MW power output only for 12th and 13th hours as well as 66 MW power output generated for 14th hours. Further, the PGU are sometimes remain on and off condition for optimum power generation scheduling.

Table-5.12a: Generation scheduling for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20)

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU-10	PGU-11	PGU-12	PGU-13	PGU-14	PGU-15	PGU-16	PGU-17	PGU-18	PGU-19	PGU-20
1	455	326.66667	0	0	0	0	0	0	0	0	455	326.66667	0	0	0	0	0	0	0	0
2	455	393.33333	0	0	0	0	0	0	0	0	455	393.33333	0	0	0	0	0	0	0	0
3	455	440	0	0	0	0	0	0	0	0	455	440	0	130	0	0	0	0	0	0
4	455	433.33333	0	130	0	0	0	0	0	0	455	433.33333	0	130	0	0	0	0	0	0
5	455	423.33333	130	130	0	0	0	0	0	0	455	423.33333	130	130	0	0	0	0	0	0
6	455	433.33333	130	130	0	0	0	0	0	0	455	433.33333	130	130	0	0	0	0	0	0
7	455	433.33333	130	130	0	0	0	0	0	0	455	433.33333	130	130	0	0	0	0	0	0
8	455	433.33333	130	130	0	0	0	0	0	0	455	433.33333	130	130	0	0	0	0	0	0
9	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
10	455	455	130	130	162	68	0	0	0	0	455	455	130	130	162	68	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	80	65	0	0	0	455	455	130	130	162	80	65	0	0	0
13	455	455	130	130	162	0	65	0	0	0	455	455	130	130	162	0	65	0	0	0
14	455	455	130	130	162	0	66	0	0	0	455	455	130	130	162	0	66	0	0	0
15	455	455	130	130	160	0	0	0	0	0	455	455	0	130	160	0	0	0	0	0
16	455	455	130	130	130	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
17	455	447.5	130	0	0	0	0	0	0	0	455	447.5	0	130	0	0	0	0	0	0
18	455	455	130	0	0	65	0	0	0	0	455	455	0	130	0	65	0	0	0	0
19	455	455	130	0	0	65	0	0	0	0	455	455	0	130	0	65	0	0	0	0
20	455	455	130	0	0	65	0	0	0	0	455	455	130	0	0	65	0	0	0	0
21	455	455	130	0	0	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
22	455	455	130	130	0	0	0	0	0	0	455	455	130	0	97.5	0	0	0	0	0
23	455	455	0	130	0	0	0	0	0	0	455	455	130	0	110	0	0	0	0	0
24	455	455	0	130	0	0	0	0	0	0	455	455	130	0	137.5	0	0	0	0	0

Table-5.12b: Generation scheduling for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40)

Hour	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	326.66667	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	393.33333	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	440	0	130	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
4	455	433.33333	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
5	455	423.33333	130	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
6	455	433.33333	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
7	455	433.33333	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
8	455	433.33333	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
9	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
10	455	455	130	130	162	68	0	0	0	0	455	455	130	130	162	68	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	0	162	80	0	0	0	0
13	455	455	130	130	162	0	0	0	0	0	455	455	130	0	162	0	0	0	0	0
14	455	455	130	130	162	0	0	0	0	0	455	455	0	0	162	0	0	0	0	0
15	455	455	0	130	160	0	0	0	0	0	455	455	0	0	160	0	0	0	0	0
16	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
17	455	447.5	0	0	0	0	0	0	0	0	455	447.5	0	130	0	0	0	0	0	0
18	455	455	0	0	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
19	455	455	0	0	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
20	455	455	0	0	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	455	130	130	97.5	0	0	0	0	0	455	0	130	0	0	0	0	0	0	0
23	0	455	130	130	110	0	0	0	0	0	455	0	130	0	0	0	0	0	0	0
24	0	0	130	130	137.5	0	0	0	0	0	455	0	130	0	0	0	0	0	0	0

In Table-5.12b represents the power scheduling of 21 to 40 unit for 40-unit system. The PGU21, PGU22 and PGU31 is continuing on for 24 hours. The PGU27 to PGU30 and PGU37 to PGU40 remain off throughout the whole day. The PGU26 and PGU36 is on for 10^{th} and 13^{th} hour only. For this the output is 68 MW for 10^{th} hour and 80 MW power for 11^{th} and 13^{th} hour. The PGU32 is on from 9^{th} to 21th hours and output power is 455 MW for the particular hours except 17^{th} hours. So, the scheduled power output from 17^{th} hours is 447.5 MW.

The hourly profit for 40-test system is presented in Table-5.13a and Table-5.13b. The Table-5.13a shows the hourly profit for PGU20 for whole day. The maximum number of profit can be obtained from the PGU1, PGU2, PGU11 and PGU12 as it was remain on for all hours. The PGU7 and PGU17 give 2057.25 $ for 12^{th} hour, 1599 $ for 13^{th} and 1617 $ for 14^{th} hours. The other units are gives several amount of profit for that particular hour when it was on.

Table-5.3b shows that the hourly profit for PGU21 to PGU40 for this test system for 24 hours. The PGU21, PGU22 and PGU31 are on for 24 hours, so that the profit from these units are maximum. The PGU26 and PGU36 give 1995.8 $ for 10^{th} hour, 2412 $ for 11^{th} and 2532 $ for 12^{th} hours. The profit can be obtain for 10^{th} to 15^{th} hours and 22^{nd} to 24^{th} hours for PGU25 as it is on only for that particular time. For PGU35 the maximum profit obtain as 5127.3 $ for 12^{th} hour and minimum output power obtain 3600 $ for 15^{th} hour. Moreover for the others hours as it remain off, no profit come from that hour when the generating unit remain off.

The **Fig.5.7** shows the profit of convergence curve for 10-, 40- and 100-generating unit test system using proposed hCSMA-SCA optimizer. The 100 number of iterations are taken into consideration. The 30 trail runs have been taken. Out of those 30 trails, the best profit for 10-unit system is 107702.5766 $. For 40-unit system, the best profit is 401052.096 $ and for 100-unit test system it is 923722.874 $ shown in the curve.

Table-5.13a: Hourly profit for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20)

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	GPU16	PGU17	PGU 18	PGU19	PGU 20
1	10078.25	7235.6667	0	0	0	0	0	0	0	0	10078.25	7235.6667	0	0	0	0	0	0	0	0
2	10010	8653.3333	0	0	0	0	0	0	0	0	10010	8653.3333	0	0	0	0	0	0	0	0
3	10510.5	10164	0	0	0	0	0	0	0	0	10510.5	10164	0	3003	0	0	0	0	0	0
4	10305.75	9815	0	2944.5	0	0	0	0	0	0	10305.75	9815	0	2944.5	0	0	0	0	0	0
5	10578.75	9842.5	3022.5	3022.5	0	0	0	0	0	0	10578.75	9842.5	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	9945	2983.5	2983.5	0	0	0	0	0	0	10442.25	9945	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	9750	2925	2925	0	0	0	0	0	0	10237.5	9750	2925	2925	0	0	0	0	0	0
8	10078.25	9598.3333	2879.5	2879.5	0	0	0	0	0	0	10078.25	9598.3333	2879.5	2879.5	0	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	1995.8	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	1995.8	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2057.25	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2057.25	0	0	0
13	11193	11193	3198	3198	3985.2	0	1599	0	0	0	11193	11193	3198	3198	3985.2	0	1599	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	1617	0	0	0	11147.5	11147.5	3185	3185	3969	0	1617	0	0	0
15	10237.5	10237.5	2925	2925	3600	0	0	0	0	0	10237.5	10237.5	0	2925	3600	0	0	0	0	0
16	10146.5	10146.5	2899	2899	2899	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	9956.875	2892.5	0	0	0	0	0	0	0	10123.75	9956.875	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	2866.5	0	0	1433.25	0	0	0	0	10032.75	10032.75	0	2866.5	0	1433.25	0	0	0	0
19	10101	10101	2886	0	0	1443	0	0	0	0	10101	10101	0	2886	0	1443	0	0	0	0
20	10305.75	10305.75	2944.5	0	0	1472.25	0	0	0	0	10305.75	10305.75	2944.5	0	0	1472.25	0	0	0	0
21	10510.5	10510.5	3003	0	0	0	0	0	0	0	10510.5	10510.5	3003	0	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	2983.5	0	0	0	0	0	0	10442.25	10442.25	2983.5	0	2237.625	0	0	0	0	0
23	10351.25	10351.25	0	2957.5	0	0	0	0	0	0	10351.25	10351.25	2957.5	0	2502.5	0	0	0	0	0
24	10260.25	10260.25	0	2931.5	0	0	0	0	0	0	10260.25	10260.25	2931.5	0	3100.625	0	0	0	0	0

Table-5.13b: Hourly profit for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40)

HOURS	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PG34	PGU35	GPU36	PGU37	PGU 38	PGU39	PGU 40
1	10078.25	7235.6667	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	8653.3333	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	10164	0	3003	0	0	0	0	0	0	10510.5	0	0	0	0	0	0	0	0	0
4	10305.75	9815	0	2944.5	0	0	0	0	0	0	10305.75	0	0	2944.5	0	0	0	0	0	0
5	10578.75	9842.5	3022.5	3022.5	0	0	0	0	0	0	10578.75	0	0	3022.5	0	0	0	0	0	0
6	10442.25	9945	2983.5	2983.5	0	0	0	0	0	0	10442.25	0	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	9750	2925	2925	0	0	0	0	0	0	10237.5	0	2925	2925	0	0	0	0	0	0
8	10078.25	9598.3333	2879.5	2879.5	0	0	0	0	0	0	10078.25	0	2879.5	2879.5	0	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	1995.8	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	1995.8	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	0	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	3198	0	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	0	0	0	11147.5	11147.5	0	0	3969	0	0	0	0	0
15	10237.5	10237.5	0	2925	3600	0	0	0	0	0	10237.5	10237.5	0	0	3600	0	0	0	0	0
16	10146.5	10146.5	0	0	0	0	0	0	0	0	10146.5	10146.5	0	0	0	0	0	0	0	0
17	10123.75	9956.875	0	0	0	0	0	0	0	0	10123.75	9956.875	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	0	0	0	0
19	10101	10101	0	0	0	0	0	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	2983.5	2237.625	0	0	0	0	0	10442.25	0	2983.5	0	0	0	0	0	0	0
23	0	10351.25	2957.5	2957.5	2502.5	0	0	0	0	0	10351.25	0	2957.5	0	0	0	0	0	0	0
24	0	0	2931.5	2931.5	3100.625	0	0	0	0	0	10260.25	0	2931.5	0	0	0	0	0	0	0

5.6.2.3 Hundred Generating Unit System

This test system contains of 100-generating unit system having a 24-hour electricity demand. The hCSMA-SCA technique is evaluated for 100 iterations. The hCSMA-SCA algorithmis verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.5.7**.The profit with start-up cost and fuel cost of 24 hours are shown in Table-5.14. The optimal scheduling of 100-generating unit systems are shown in Table-5.15a to Table-5.15e. The hourly profit table for this system is shown in Table-5.16a to Table-5.16e respectively.

Table-5.14: Hourly profit with start-up cost and fuel cost for 100-generating unit system using hCSMA-SCA optimization algorithm

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	155050	2820	133075.35	**13**	327672	680	273593.98
2	165000	3330	143002.8	**14**	318500	180	263304.89
3	196350	6380	166598.42	**15**	270000	440	238447.65
4	206115	3470	180322.97	**16**	231920	1500	202295.29
5	232500	2000	200725.81	**17**	222500	1010	193537.9
6	238680	5820	209977.69	**18**	229320	900	206826.37
7	234000	1800	209977.69	**19**	230880	1940	207522.48
8	230360	1640	210193.2	**20**	235560	3940	207449.77
9	266760	16620	234175.91	**21**	240240	3260	203012.91
10	410900	7040	308749.76	**22**	238680	2560	204366.65
11	425718	1670	304601.46	**23**	204750	5130	176975.85
12	446898	1090	304748.4	**24**	180400	3160	157336.91

Table-5.15a shows the optimal scheduling of PGU1 to PGU20 for 100-generating unit test system using hCSMA-SCA optimizer. The PGU9 to PGU10 and PGU19 to PGU20 is off for 24 hours. The PGU1, PGU2, PGU11 and PGU12 is always remain on throughout the whole day. PGU8 gives 55 MW power only for 10^{th} hour and PGU18 gives 55 MW power for 10^{th} to 12^{th} hour as it have been on for that particular hour only. For PGU19 55 MW power can be obtained only for 10^{th} and 12^{th} hour. Further, the PGU are sometimes remain on and off condition for optimum power generation scheduling.

Table-5.15a: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20)

HOUR	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	455	408.33333	0	0	0	0	0	0	0	0	455	408.33333	0	0	0	0	0	0	0	0
2	455	448.33333	0	130	0	0	0	0	0	0	455	448.33333	0	0	0	0	0	0	0	0
3	455	452.5	130	130	0	0	0	0	0	0	455	452.5	0	0	0	0	0	0	0	0
4	455	455	130	130	97.5	0	0	0	0	0	455	455	130	130	97.5	0	0	0	0	0
5	455	455	130	130	160.83333	0	0	0	0	0	455	455	130	130	160.83333	0	0	0	0	0
6	455	455	130	130	154.375	0	0	0	0	0	455	455	130	130	154.375	0	0	0	0	0
7	455	455	130	130	154.375	0	0	0	0	0	455	455	130	130	154.375	0	0	0	0	0
8	455	455	130	130	151.66667	0	0	0	0	0	455	455	130	130	151.66667	0	0	0	0	0
9	455	455	130	130	151.66667	0	0	0	0	0	455	455	0	130	151.66667	0	0	0	0	0
10	455	455	130	130	162	80	0	55	0	0	455	455	0	130	162	80	0	55	55	0
11	455	455	130	130	0	80	82.2	0	0	0	455	455	0	130	162	80	82.2	55	0	0
12	455	455	130	130	0	80	82.2	0	0	0	455	455	0	130	162	80	82.2	55	55	0
13	455	455	130	130	0	80	46	0	0	0	455	455	0	130	162	80	46	0	0	0
14	455	455	130	130	0	76.333333	0	0	0	0	455	455	130	130	162	76.333333	0	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	130	130	140	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
17	455	454	0	0	0	0	0	0	0	0	455	454	130	0	0	0	0	0	0	0
18	455	455	0	0	0	0	45	0	0	0	455	455	130	0	0	80	45	0	0	0
19	455	455	0	0	0	80	70	0	0	0	455	455	0	0	0	80	70	0	0	0
20	455	455	0	0	162	80	38	0	0	0	455	455	0	0	0	80	38	0	0	0
21	455	455	130	0	162	66	0	0	0	0	455	455	0	0	0	0	0	0	0	0
22	455	455	130	130	143	0	0	0	0	0	455	455	0	0	143	0	0	0	0	0
23	455	455	130	130	136	0	0	0	0	0	455	455	0	0	136	0	0	0	0	0
24	455	455	130	130	118	0	0	0	0	0	455	455	0	0	118	0	0	0	0	0

Table-5.15b: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40)

HOUR	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	408.33333	0	0	0	0	0	0	0	0	455	408.33333	0	0	0	0	0	0	0	0
2	455	448.33333	0	0	0	0	0	0	0	0	455	448.33333	0	130	0	0	0	0	0	0
3	0	452.5	0	130	0	0	0	0	0	0	455	452.5	130	130	0	0	0	0	0	0
4	0	455	0	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
5	0	455	130	130	160.83333	0	0	0	0	0	455	455	130	130	160.83333	0	0	0	0	0
6	0	455	130	130	154.375	0	0	0	0	0	455	455	130	130	154.375	0	0	0	0	0
7	0	455	130	130	154.375	0	0	0	0	0	455	455	130	130	154.375	0	0	0	0	0
8	0	455	130	130	151.66667	0	0	0	0	0	455	455	130	130	151.66667	0	0	0	0	0
9	0	455	130	130	151.66667	0	0	0	0	0	455	455	130	130	151.66667	0	0	0	0	0
10	0	455	130	130	162	80	79.375	0	55	0	455	455	0	130	162	80	79.375	55	0	0
11	455	455	130	130	162	80	82.2	55	0	0	455	455	0	130	162	80	82.2	0	0	0
12	455	455	130	130	162	80	82.2	0	0	0	455	455	0	130	162	80	82.2	0	55	0
13	455	455	130	130	162	80	0	0	0	0	455	455	0	130	162	80	0	0	0	0
14	455	455	130	130	162	76.333333	0	0	0	0	455	455	0	130	162	76.333333	0	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
17	455	454	0	0	0	0	0	0	0	0	455	454	130	0	0	0	0	0	0	0
18	455	455	0	0	0	0	0	0	0	0	455	455	130	0	0	80	0	0	0	0
19	455	455	0	0	0	0	0	0	0	0	455	455	130	0	0	80	0	0	0	0
20	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	80	0	0	0	0
21	455	455	0	0	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	455	0	0	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
23	455	455	0	0	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
24	455	0	0	0	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0

Table-5.15c: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 41-60)

Hour	PG U41	PGU42	PGU 43	PGU 44	PGU45	PGU46	PGU 47	PGU 48	PGU49	PGU50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PGU56	PGU57	PGU58	PGU59	PGU60
1	455	408.33333	0	0	0	0	0	0	0	0	455	408.33333	0	0	0	0	0	0	0	0
2	455	448.33333	0	0	0	0	0	0	0	0	455	448.33333	0	0	0	0	0	0	0	0
3	455	452.5	130	130	0	0	0	0	0	0	455	452.5	130	130	0	0	0	0	0	0
4	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
5	455	455	130	130	160.83333	0	0	0	0	0	455	455	130	130	160.83333	0	0	0	0	0
6	455	455	130	130	154.375	0	0	0	0	0	455	455	130	130	154.375	0	0	0	0	0
7	455	455	130	130	154.375	0	0	0	0	0	455	455	130	130	154.375	0	0	0	0	0
8	455	455	130	130	151.66667	0	0	0	0	0	455	455	130	130	151.66667	0	0	0	0	0
9	455	455	130	130	151.66667	0	0	0	0	0	455	455	0	130	151.66667	0	0	0	0	0
10	455	455	130	130	162	80	79.375	55	55	0	455	455	0	130	162	80	79.375	55	55	0
11	455	455	130	130	162	80	82.2	0	0	0	455	455	0	130	162	80	82.2	55	0	0
12	455	455	130	130	162	80	82.2	0	0	0	455	455	0	130	162	80	82.2	0	0	0
13	455	455	130	130	162	80	0	0	0	0	455	455	0	130	162	0	0	0	0	0
14	455	455	130	130	162	76.333333	0	0	0	0	455	455	130	130	162	0	0	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
16	455	455	0	0	0	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
17	455	454	0	0	0	0	0	0	0	0	455	454	130	0	0	0	0	0	0	0
18	455	455	0	0	0	80	0	0	0	0	455	455	130	0	0	80	0	0	0	0
19	455	455	0	0	0	80	0	0	0	0	455	455	130	0	0	80	0	0	0	0
20	455	455	0	0	0	80	0	0	0	0	455	455	130	0	0	80	0	0	0	0
21	455	455	0	0	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	455	0	0	0	0	0	0	0	0	455	455	0	130	143	0	0	0	0	0
23	455	455	0	0	0	0	0	0	0	0	455	455	0	130	136	0	0	0	0	0
24	455	455	0	0	0	0	0	0	0	0	455	455	0	130	118	0	0	0	0	0

In Table-5.15b represents the power scheduling of 21 to 40 unit for 100-unit system using hCSMA-SCA optimizer. The PGU22, PGU31 and PGU32 is continuous on for 24 hours. The PGU30 and PGU40 remain off throughout the whole day. The PGU29 and PGU38 is on for 10th hour only. For these the output is 55 MW for 10th hour only. The PGU28 is on for 11th hour and output power is 55. The power output from PGU39 is 25 MW for 12th hours.

In Table-5.15c represents the power scheduling of 41 to 60 unit for 100-unit system using hCSMA-SCA optimizer. The PGU41, PGU42, PGU51 and PGU52 is continuous on for 24 hours. The PGU50 and PGU60 remain off throughout the whole day. The PGU48, PGU49 and PGU59 is on only for 10th hour. For this the output is 55 MW for 10th hour. The PGU58 is on for 10th and 11th hour. The power output from that us is 55 MW for that particular hours.

Table-5.15d represents the power scheduling of 61 to 80 unit for 100-unit system using hCSMA-SCA optimizer. The PGU61 and PGU71 is always on and the output power is 455 MW for 24 hours. The PGU70 and PGU80 is off for the whole day. PGU69, PGU78 and PGU79, the output power is 55 MW only for 10th hour. The PGU67 and PGU77 gives 79.375 MW for 10th, 82.2 MW for 11th and 12th hours.

Table-5.15e represents the power scheduling of 81 to 100 unit for 100-unit system using hCSMA-SCA optimizer. The PGU81 and PGU91 is on for 24 hours and PGU89, PGU90, PGU99 and PGU100 is remain off throughout the whole day. From PGU98, 55MW output power can be measured in 11th and 12th hours. For PGU88 55 MW power can be obtained from 10th to 12th hours.

Table-5.15d: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 61-80)

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	0	0	0	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
4	455	0	130	0	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
5	455	0	130	0	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
6	455	0	130	0	154.375	0	0	0	0	0	455	0	130	130	154.375	0	0	0	0	0
7	455	0	130	0	154.375	0	0	0	0	0	455	0	130	130	154.375	0	0	0	0	0
8	455	0	130	130	151.66667	0	0	0	0	0	455	0	130	0	151.66667	0	0	0	0	0
9	455	455	0	130	151.66667	0	0	0	0	0	455	455	0	0	151.66667	0	0	0	0	0
10	455	455	0	130	162	80	79.375	55	55	0	455	455	0	0	162	80	79.375	55	55	0
11	455	455	0	130	162	80	82.2	55	0	0	455	455	0	0	162	80	82.2	0	0	0
12	455	455	0	130	162	80	82.2	55	0	0	455	455	0	0	162	80	82.2	0	0	0
13	455	455	0	130	162	80	0	0	0	0	455	455	0	130	162	80	0	0	0	0
14	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
16	455	455	130	0	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
17	455	454	130	0	0	0	0	0	0	0	455	454	130	130	0	0	0	0	0	0
18	455	455	130	0	0	80	0	0	0	0	455	455	130	0	0	80	0	0	0	0
19	455	455	130	0	0	80	0	0	0	0	455	455	130	0	0	80	0	0	0	0
20	455	455	130	0	162	80	0	0	0	0	455	455	0	0	0	80	0	0	0	0
21	455	455	0	130	162	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
22	455	455	0	130	143	0	0	0	0	0	455	455	0	0	143	0	0	0	0	0
23	455	0	0	130	136	0	0	0	0	0	455	0	0	0	136	0	0	0	0	0
24	455	0	0	130	118	0	0	0	0	0	455	0	0	0	118	0	0	0	0	0

Table-5.15e: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 81-100)

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
4	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
5	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
6	455	0	130	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
7	455	0	130	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
8	455	0	130	0	151.66667	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
9	455	455	130	0	151.66667	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
10	455	455	130	0	162	0	79.375	55	0	0	455	455	130	130	162	0	79.375	0	0	0
11	455	455	130	0	162	0	82.2	55	0	0	455	455	130	130	162	80	82.2	55	0	0
12	455	455	130	0	162	0	82.2	55	0	0	455	455	130	130	162	80	82.2	55	0	0
13	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
14	455	455	130	130	0	76.333333	0	0	0	0	455	455	130	130	162	0	0	0	0	0
15	455	455	130	130	0	20	0	0	0	0	455	455	130	130	140	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
17	455	454	0	130	0	0	0	0	0	0	455	454	0	0	0	0	0	0	0	0
18	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	80	0	0	0	0
19	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	80	0	0	0	0
20	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	80	0	0	0	0
21	455	455	130	0	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
22	455	455	130	0	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
23	455	0	130	0	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
24	455	0	130	0	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0

Table-5.16a: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20)

Hour	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	10078.25	9044.5833	0	0	0	0	0	0	0	0	10078.25	9044.5833	0	0	0	0	0	0	0	0
2	10010	9863.3333	0	2860	0	0	0	0	0	0	10010	9863.3333	0	0	0	0	0	0	0	0
3	10510.5	10452.75	3003	3003	0	0	0	0	0	0	10510.5	10452.75	0	0	0	0	0	0	0	0
4	10305.75	10305.75	2944.5	2944.5	2208.375	0	0	0	0	0	10305.75	10305.75	2944.5	2944.5	2208.375	0	0	0	0	0
5	10578.75	10578.75	3022.5	3022.5	3739.375	0	0	0	0	0	10578.75	10578.75	3022.5	3022.5	3739.375	0	0	0	0	0
6	10442.25	10442.25	2983.5	2983.5	3542.9063	0	0	0	0	0	10442.25	10442.25	2983.5	2983.5	3542.9063	0	0	0	0	0
7	10237.5	10237.5	2925	2925	3473.4375	0	0	0	0	0	10237.5	10237.5	2925	2925	3473.4375	0	0	0	0	0
8	10078.25	10078.25	2879.5	2879.5	3359.4167	0	0	0	0	0	10078.25	10078.25	2879.5	2879.5	3359.4167	0	0	0	0	0
9	10374	10374	2964	2964	3458	0	0	0	0	0	10374	10374	0	2964	3458	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	1614.25	0	0	13354.25	13354.25	0	3815.5	4754.7	2348	0	1614.25	1614.25	0
11	13718.25	13718.25	3919.5	3919.5	0	2412	2478.33	0	0	0	13718.25	13718.25	0	3919.5	4884.3	2412	2478.33	1658.25	0	0
12	14400.75	14400.75	4114.5	4114.5	0	2532	2601.63	0	0	0	14400.75	14400.75	0	4114.5	5127.3	2532	2601.63	1740.75	1740.75	0
13	11193	11193	3198	3198	0	1968	1131.6	0	0	0	11193	11193	0	3198	3985.2	1968	1131.6	0	0	0
14	11147.5	11147.5	3185	3185	0	1870.1667	0	0	0	0	11147.5	11147.5	3185	3185	3969	1870.1667	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	2925	3150	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	2899	2899	0	0	0	0	0	0
17	10123.75	10101.5	0	0	0	0	0	0	0	0	10123.75	10101.5	2892.5	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	0	992.25	0	0	0	10032.75	10032.75	2866.5	0	0	1764	992.25	0	0	0
19	10101	10101	0	0	0	1776	1554	0	0	0	10101	10101	0	0	0	1776	1554	0	0	0
20	10305.75	10305.75	0	0	3669.3	1812	860.7	0	0	0	10305.75	10305.75	0	0	0	1812	860.7	0	0	0
21	10510.5	10510.5	3003	0	3742.2	1524.6	0	0	0	0	10510.5	10510.5	0	0	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	2983.5	3281.85	0	0	0	0	0	10442.25	10442.25	0	0	3281.85	0	0	0	0	0
23	10351.25	10351.25	2957.5	2957.5	3094	0	0	0	0	0	10351.25	10351.25	0	0	3094	0	0	0	0	0
24	10260.25	10260.25	2931.5	2931.5	2660.9	0	0	0	0	0	10260.25	10260.25	0	0	2660.9	0	0	0	0	0

Table-5.16b: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40)

Hour	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	10078.25	9044.5833	0	0	0	0	0	0	0	0	10078.25	9044.5833	0	0	0	0	0	0	0	0
2	10010	9863.3333	0	0	0	0	0	0	0	0	10010	9863.3333	0	2860	0	0	0	0	0	0
3	0	10452.75	0	3003	0	0	0	0	0	0	10510.5	10452.75	3003	3003	0	0	0	0	0	0
4	0	10305.75	0	2944.5	0	0	0	0	0	0	10305.75	10305.75	2944.5	2944.5	0	0	0	0	0	0
5	0	10578.75	3022.5	3022.5	3739.375	0	0	0	0	0	10578.75	10578.75	3022.5	3022.5	3739.375	0	0	0	0	0
6	0	10442.25	2983.5	2983.5	3542.9063	0	0	0	0	0	10442.25	10442.25	2983.5	2983.5	3542.9063	0	0	0	0	0
7	0	10237.5	2925	2925	3473.4375	0	0	0	0	0	10237.5	10237.5	2925	2925	3473.4375	0	0	0	0	0
8	0	10078.25	2879.5	2879.5	3359.4167	0	0	0	0	0	10078.25	10078.25	2879.5	2879.5	3359.4167	0	0	0	0	0
9	0	10374	2964	2964	3458	0	0	0	0	0	10374	10374	2964	2964	3458	0	0	0	0	0
10	0	13354.25	3815.5	3815.5	4754.7	2348	2329.6563	0	1614.25	0	13354.25	13354.25	0	3815.5	4754.7	2348	2329.6563	1614.25	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	2478.33	1658.25	0	0	13718.25	13718.25	0	3919.5	4884.3	2412	2478.33	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2601.63	0	0	0	14400.75	14400.75	0	4114.5	5127.3	2532	2601.63	0	1740.75	0
13	11193	11193	3198	3198	3985.2	1968	0	0	0	0	11193	11193	0	3198	3985.2	1968	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	1870.1667	0	0	0	0	11147.5	11147.5	0	3185	3969	1870.1667	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	2899	0	0	0	0	0	0	0
17	10123.75	10101.5	0	0	0	0	0	0	0	0	10123.75	10101.5	2892.5	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	0	0	0	0	0	10032.75	10032.75	2866.5	0	0	1764	0	0	0	0
19	10101	10101	0	0	0	0	0	0	0	0	10101	10101	2886	0	0	1776	0	0	0	0
20	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	0	0	0	1812	0	0	0	0
21	10510.5	10510.5	0	0	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	0	0	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	0	0	0	0	0	0
23	10351.25	10351.25	0	0	0	0	0	0	0	0	10351.25	10351.25	0	2957.5	0	0	0	0	0	0
24	10260.25	0	0	0	0	0	0	0	0	0	10260.25	0	0	2931.5	0	0	0	0	0	0

The Table-5.16a is presented the hourly profit for 100-generating unit system using proposed hCSMA-SCA optimization algorithm. From 100 numbers of power generating units, this table shows the hourly profit of generator 1 to generator 20 for 24 hours. The first PGU1, PGU2, PGU11 and PGU12 are on for every hours, while PGU3 and PGU4 have been off for some hours. The PGU5 to PGU7 has been on only for some minimum hours. The PGU8 is on only for 10th hour and it gives 1614.25 $ profit on that particular hour. The PGU9, PGU10 and PGU20 has been off for the whole day. The PGU13 to PGU18 are on for some hours. The profit from PGU19 is 1614.25 $ for 10th hour and 1740.75 $ from 12th hour.

The Table-5.16b is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm for units 21 to unit 40. In this table, the PGU22, PGU31 and PGU32 are on for 24 hours and maximum profit are obtained. The PGU30 and PGU40 is off throughout the whole day. Others PGU are remained on for some hours and off for few hours. From those units, the profit can be measured for that particular hour when it was off.

The Table-5.16c is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm for units 41 to unit 60. The PGU41 and PGU42 remain on for 24 hours. The PGU50 and PGU60 remain close throughout the whole day. Other units are remained on sometime and off for few times.

The Table-5.16d is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm for units 61 to unit 80. The PGU61, PGU70 and PGU80 are continuously on for 24 hours. Further PGU79 is off for 24 hours. The profit from PGU77 and PGU78 is 1614.25 $ for 10th hours.

The Table-5.16e is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm for units 81 to unit 100. The PGU81 and PGU91 has been on for 24 hours. PGU89, PGU90, PGU99 and PGU100 have been off for 24 hours.

Table-5.16c: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 41-60)

Hour	PGU41	PGU42	PGU43	PGU 44	PGU45	PGU46	PGU 47	PGU48	PGU 49	PGU 50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PGU56	PGU57	PGU 58	PGU 59	PGU 60
1	10078.25	9044.5833	0	0	0	0	0	0	0	0	10078.25	9044.5833	0	0	0	0	0	0	0	0
2	10010	9863.3333	0	0	0	0	0	0	0	0	10010	9863.3333	0	0	0	0	0	0	0	0
3	10510.5	10452.75	3003	3003	0	0	0	0	0	0	10510.5	10452.75	3003	3003	0	0	0	0	0	0
4	10305.75	10305.75	2944.5	2944.5	0	0	0	0	0	0	10305.75	10305.75	2944.5	2944.5	0	0	0	0	0	0
5	10578.75	10578.75	3022.5	3022.5	3739.375	0	0	0	0	0	10578.75	10578.75	3022.5	3022.5	3739.375	0	0	0	0	0
6	10442.25	10442.25	2983.5	2983.5	3542.9063	0	0	0	0	0	10442.25	10442.25	2983.5	2983.5	3542.9063	0	0	0	0	0
7	10237.5	10237.5	2925	2925	3473.4375	0	0	0	0	0	10237.5	10237.5	2925	2925	3473.4375	0	0	0	0	0
8	10078.25	10078.25	2879.5	2879.5	3359.4167	0	0	0	0	0	10078.25	10078.25	2879.5	2879.5	3359.4167	0	0	0	0	0
9	10374	10374	2964	2964	3458	0	0	0	0	0	10374	10374	0	2964	3458	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	2329.6563	1614.25	1614.25	0	13354.25	13354.25	0	3815.5	4754.7	2348	2329.6563	1614.25	1614.25	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	2478.33	0	0	0	13718.25	13718.25	0	3919.5	4884.3	2412	2478.33	1658.25	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2601.63	0	0	0	14400.75	14400.75	0	4114.5	5127.3	2532	2601.63	0	0	0
13	11193	11193	3198	3198	3985.2	1968	0	0	0	0	11193	11193	0	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	1870.1667	0	0	0	0	11147.5	11147.5	3185	3185	3969	0	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
16	10146.5	10146.5	0	0	0	0	0	0	0	0	10146.5	10146.5	2899	0	0	0	0	0	0	0
17	10123.75	10101.5	0	0	0	0	0	0	0	0	10123.75	10101.5	2892.5	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	1764	0	0	0	0	10032.75	10032.75	2866.5	0	0	1764	0	0	0	0
19	10101	10101	0	0	0	1776	0	0	0	0	10101	10101	2886	0	0	1776	0	0	0	0
20	10305.75	10305.75	0	0	0	1812	0	0	0	0	10305.75	10305.75	2944.5	0	0	1812	0	0	0	0
21	10510.5	10510.5	0	0	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	0	0	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	3281.85	0	0	0	0	0
23	10351.25	10351.25	0	0	0	0	0	0	0	0	10351.25	10351.25	0	2957.5	3094	0	0	0	0	0
24	10260.25	10260.25	0	0	0	0	0	0	0	0	10260.25	10260.25	0	2931.5	2660.9	0	0	0	0	0

Table-5.16d: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 61-80)

Hour	**PGU61**	**PGU62**	**PGU63**	**PGU64**	**PGU65**	**PGU66**	**PGU67**	**PGU68**	**PGU69**	**PGU70**	**PGU71**	**PGU72**	**PGU73**	**PGU74**	**PGU75**	**PGU76**	**PGU77**	**PGU78**	**PGU79**	**PGU80**
1	10078.25	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0	10078.25
2	10010	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0	10010
3	10510.5	0	0	0	0	0	0	0	0	10510.5	0	3003	3003	0	0	0	0	0	0	10510.5
4	10305.75	0	2944.5	0	0	0	0	0	0	10305.75	0	2944.5	2944.5	0	0	0	0	0	0	10305.75
5	10578.75	0	3022.5	0	0	0	0	0	0	10578.75	0	3022.5	3022.5	0	0	0	0	0	0	10578.75
6	10442.25	0	2983.5	0	3542.9063	0	0	0	0	10442.25	0	2983.5	2983.5	3542.9063	0	0	0	0	0	10442.25
7	10237.5	0	2925	0	3473.4375	0	0	0	0	10237.5	0	2925	2925	3473.4375	0	0	0	0	0	10237.5
8	10078.25	0	2879.5	2879.5	3359.4167	0	0	0	0	10078.25	0	2879.5	0	3359.4167	0	0	0	0	0	10078.25
9	10374	10374	0	2964	3458	0	0	0	0	10374	10374	0	0	3458	0	0	0	0	0	10374
10	13354.25	13354.25	0	3815.5	4754.7	2348	2329.6563	1614.25	1614.25	13354.25	13354.25	0	0	4754.7	2348	2329.6563	1614.25	1614.25	0	13354.25
11	13718.25	13718.25	0	3919.5	4884.3	2412	2478.33	1658.25	0	13718.25	13718.25	0	0	4884.3	2412	2478.33	0	0	0	13718.25
12	14400.75	14400.75	0	4114.5	5127.3	2532	2601.63	1740.75	0	14400.75	14400.75	0	0	5127.3	2532	2601.63	0	0	0	14400.75
13	11193	11193	0	3198	3985.2	1968	0	0	0	11193	11193	0	3198	3985.2	1968	0	0	0	0	11193
14	11147.5	11147.5	3185	3185	0	0	0	0	0	11147.5	11147.5	3185	3185	0	0	0	0	0	0	11147.5
15	10237.5	10237.5	2925	2925	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5
16	10146.5	10146.5	2899	0	0	0	0	0	0	10146.5	10146.5	2899	2899	0	0	0	0	0	0	10146.5
17	10123.75	10101.5	2892.5	0	0	0	0	0	0	10123.75	10101.5	2892.5	2892.5	0	0	0	0	0	0	10123.75
18	10032.75	10032.75	2866.5	0	0	1764	0	0	0	10032.75	10032.75	2866.5	0	0	1764	0	0	0	0	10032.75
19	10101	10101	2886	0	0	1776	0	0	0	10101	10101	2886	0	0	1776	0	0	0	0	10101
20	10305.75	10305.75	2944.5	0	3669.3	1812	0	0	0	10305.75	10305.75	0	0	0	1812	0	0	0	0	10305.75
21	10510.5	10510.5	0	3003	3742.2	0	0	0	0	10510.5	10510.5	0	0	0	0	0	0	0	0	10510.5
22	10442.25	10442.25	0	2983.5	3281.85	0	0	0	0	10442.25	10442.25	0	0	3281.85	0	0	0	0	0	10442.25
23	10351.25	0	0	2957.5	3094	0	0	0	0	10351.25	0	0	0	3094	0	0	0	0	0	10351.25
24	10260.25	0	0	2931.5	2660.9	0	0	0	0	10260.25	0	0	0	2660.9	0	0	0	0	0	10260.25

Table-5.16e: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 81-100)

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	10078.25	0	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	0	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	0	0	3003	0	0	0	0	0	0	10510.5	0	0	3003	0	0	0	0	0	0
4	10305.75	0	0	2944.5	0	0	0	0	0	0	10305.75	0	0	2944.5	0	0	0	0	0	0
5	10578.75	0	0	3022.5	0	0	0	0	0	0	10578.75	0	0	3022.5	0	0	0	0	0	0
6	10442.25	0	2983.5	2983.5	0	0	0	0	0	0	10442.25	0	0	2983.5	0	0	0	0	0	0
7	10237.5	0	2925	2925	0	0	0	0	0	0	10237.5	0	0	2925	0	0	0	0	0	0
8	10078.25	0	2879.5	0	3359.4167	0	0	0	0	0	10078.25	0	0	2879.5	0	0	0	0	0	0
9	10374	10374	2964	0	3458	0	0	0	0	0	10374	10374	0	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	0	4754.7	0	2329.6563	1614.25	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	2329.6563	0	0	0
11	13718.25	13718.25	3919.5	0	4884.3	0	2478.33	1658.25	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	2478.33	1658.25	0	0
12	14400.75	14400.75	4114.5	0	5127.3	0	2601.63	1740.75	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2601.63	1740.75	0	0
13	11193	11193	3198	3198	3985.2	1968	0	0	0	0	11193	11193	3198	3198	3985.2	1968	0	0	0	0
14	11147.5	11147.5	3185	3185	0	1870.1667	0	0	0	0	11147.5	11147.5	3185	3185	3969	0	0	0	0	0
15	10237.5	10237.5	2925	2925	0	450	0	0	0	0	10237.5	10237.5	2925	2925	3150	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	0	0	0	0	0	0	0
17	10123.75	10101.5	0	2892.5	0	0	0	0	0	0	10123.75	10101.5	0	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	0	0	0	0	0	10032.75	10032.75	0	0	0	1764	0	0	0	0
19	10101	10101	0	0	0	0	0	0	0	0	10101	10101	0	0	0	1776	0	0	0	0
20	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	0	0	0	1812	0	0	0	0
21	10510.5	10510.5	3003	0	0	0	0	0	0	0	10510.5	10510.5	3003	3003	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	0	0	0	0	0	0	0	10442.25	0	2983.5	2983.5	0	0	0	0	0	0
23	10351.25	0	2957.5	0	0	0	0	0	0	0	10351.25	0	2957.5	2957.5	0	0	0	0	0	0
24	10260.25	0	2931.5	0	0	0	0	0	0	0	10260.25	0	2931.5	2931.5	0	0	0	0	0	0

The statistical analysis are also taken into consideration for 10-, 40 and 100-generating units. The ‘Best’, ‘Average’ and ‘Worst’ values for profit with standard deviation and median value of solutions have been stated for 30 trial result for PBUCP of power systems that are shown in Table-5.17.The Comparisons of 10-unit system for PBUCP with existing optimizer is shown inTable-5.18 and it have been shown that the method hCHHO-SCA has been performed better than other method.

Table-5.17: Statistical analysis of results for hCHHO-SCA & hCSMA-SCA optimization algorithms for PBUCP

Test Systems	10-Unit System		40-Unit System		100-Unit System	
Methods	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**
Best Profit	**107702.58**	**107702.58**	**422919.494**	401052.096	**1068177.9**	923722.874
Average Profit	107698.09	107687.39	402695.13	369142.576	972655.001	870330.085
Worst Profit	107568.01	107516.11	372765.214	349306.39	896549.374	830309.263
Std	24.567913	47.001202	11450.1242	12338.6338	40959.2319	24741.3492
Median	107702.58	107702.58	402861.3	366483.932	976296.738	869898.996

Table-5.18: Hypothetical testing of hCHHO-SCA & hCSMA-SCA optimization algorithms for PBUCP

Test Systems		10 Unit System		40 Unit System		100 Unit System	
Methods		**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**
Wilcoxon-rank sum test [p-value]		6.80E-08	1.44E-07	1.7344E-06	1.7344E-06	1.7344E-06	1.7344E-06
t-test	**p-value**	2.19E-107	3.25E-99	1.28804E-46	1.39652E-44	1.12323E-41	1.27995E-46
	h-value	1	1	1	1	1	1

The p-value for Wilcoxon-rank sum test and t-test and h-value for t-test is used to verify the efficiency of hCHHO-SCA optimizer that are shown in Table-5.19. The best, average and worst time are also taken into consideration, are shown in Table.5.24.

Table-5.19: Comparison of computational time for hCHHO-SCA & hCSMA-SCA optimization algorithms for PBUCP

Test Systems	**10 Unit System**		**40 Unit System**		**100 Unit System**	
Methods	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**
Best time(sec.)	0.015625	0.01275	0.015625	0.015625	0.015625	0.015625
Average time (sec.)	0.0171875	0.015625	0.01822917	0.01666667	0.0328125	0.04322917
Worst time (sec.)	0.03125	0.03125	0.03125	0.03125	0.0625	0.0625

5.7 COMPARISION OF RESULTS

Improved solutions of profit based unit commitment problem by various techniques show that the integration of hCHHO-SCA and hCSMA-SCA have severely improvement of performances of classical exixting optimizers. The comparisons of the results are in term of best profit have been shown in **Fig.5.8** to **Fig-5.10**

It is observed from comparison table that the performances of the proposed hCHHO-SCA and hCSMA-SCA are preforming better than conventional ACO [109], MM [9], PSO & PPSO [13], IPPD & MM [9], ICA-DBD approach [293], NACO [109], VTS-PEPSO [294], PABC [12], GSA [293], ICA [29], BFWA [295], DBD [293], CICA [26], CICA-SCM [26], CICA-ICM [26], CICA-LCM [26], TS-EPSO [294], MOPSO [296], LR-Secant-DE [31], HAIS [297], MBDE [47], BSA-CSO [39] and another recently implemented evolutionary, heuristics and meta-heuristics type search optimization techniques.

Table-5.20: Comparison of best profit

10-Generating Unit System								
Sl. No	**Method**	**Profit ($)**	**Sl. No**	**Method**	**Profit ($)**	**Sl. No**	**Method**	**Profit ($)**
1	[TS-RP] [299]	101086	12	[ICA] [295]	106340	23	[ABC] [12]	105878
2	[MM] [9]	103296	13	[BFWA] [295]	106850.69	24	[BSCA 1] [35]	107344.9
3	[ACO] [109]	103890	14	[DBD] [293]	107075	25	[BSCA 2] [35]	104379.6
4	[PSO] [13]	104356	15	[CICA] [295]	107682	26	[BSCA 3] [35]	107356.1
5	[IPPD -MM] [9]	105164	16	[CICA-SCM] [295]	107686	27	[BSCA 4] [35]	106778.6
6	[ICA-DBD] [293]	105490	17	[CICA-ICM] [295]	107698	28	[MOPSO] [296]	106240
7	[NACO] [109]	105549	18	[CICA-LCM] [295]	107702	29	[LR-Secant-DE] [31]	107000
8	[VTS-PEPSO] [294]	105873.8	19	[BWOA-1] [298]	107260.34	30	[HAIS] [297]	107316.11
9	[PABC] [12]	105878	20	[BWOA-2] [298]	107396.5	31	**hCHHO-SCA**	**107702.5766**
10	[PNACO] [13]	105942	21	[BDE] [47]	107702.57	32	**hCSMA-SCA**	**107702.5766**
11	[GSA] [293]	106018.21	22	[TSEPSO] [296]	105873.8			

Comparison of the performances of results for 10-, 40- and 100-generating unit system are shown with other existing hybrid optimizer and the suggested method hCHHO-SCA is performing better than other existing methods. Intention to get the more profit stated in ICA[295], CICA [295] as well as BWOA [298], cost for cold start is not measured and the data for energy price at 17th interval of time is reserved as 23.25 $/MW as an alternative of 22.25 $/MW and for this the best profit value is 449072.4068 $. In case of taken actual value of the energy price at 17th interval, i.e. 22.25 $/MW, then the profit value is performing better than the existing methods. Table-5.20 shows the comparison of 10-generating unit system for PBUCP with existing method, such as TR-RP [299], MM [9], ACO [109], PSO [13], ICA-DBD [293], NACO [109], VTS-PEPSO [294], PNACO[13], GSA[293] and proposed optimization methods so on.

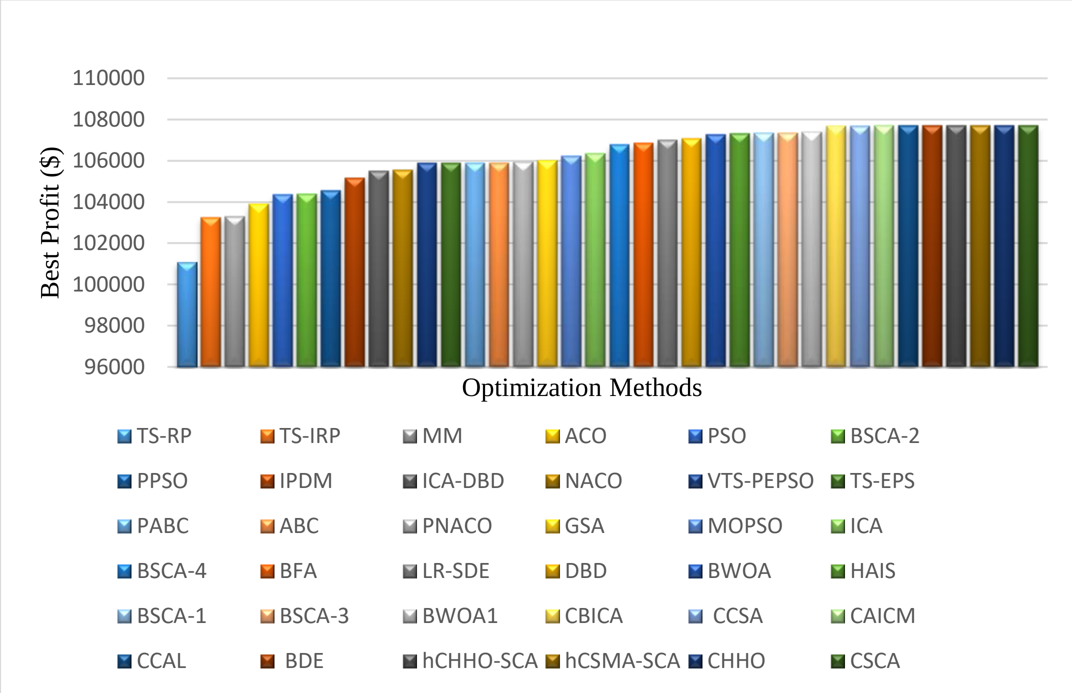


Fig.5.8: Comparison of CHHO, CSCA, hCHHO-SCA and hCSMA-SCA optimizer for small scale power system with existing optimizers

The comparison of hCHHO-SCA optimizer for small scale power system with existing optimizers is shown in **Fig.5.8**. The profit of existing techniques, i.e. BFWA [295] is 106850.69 ($), CICA [26] is 107682 ($), CICA-SCM [26] is 107686 ($), CICA-ICM [26] is 107698 ($), BWOA-1 [298] is 107260.34 ($), BWOA-2 [298] is 107396.5 ($), TS-EPSO [294] is 105873.8 ($), ABC [12] is ($), BSCA 1 [35] is 107344.9 ($), BSCA 2 [35] is 104379.6 ($), BSCA 3 [35] is 107356.1 ($), BSCA 4 [35] is 106778.6 ($), MOPSO [296] is 106240 ($), LR-Secant-DE [31] is 107000 ($),TS-RP optimizer [299] is 101086 ($), the TS-IRP [299] is 103261 ($), the MM [9] is 103296 ($), the ACO [109] is 103890 ($), the PSO [13] is 104356 ($), the IPPD & MM [9] is 105164 ($), the ICA-DBD approach [293] is 105490 ($), the NACO [109] is 105549 ($), the VTS-PEPSO [294] is 105873.8 ($), the PABC [12] is 105878 ($), the PNACO [13] is 105942 ($), GSA [293] is 106018.21 ($), the ICA [29] is 106340 ($), the DBD optimizer [293] is 107075 ($), the HAIS technique [297] is 107316.11 ($). The profit for proposed hCHHO-SCA and hCSMA-SCA optimizer is 107702.5766 ($), the profit for CHHO and CSCA is 107702.576639973 ($). So, from these comparision, the suggested optimizer hCHHO-SCA is performing better than other existing optimization algorithms.

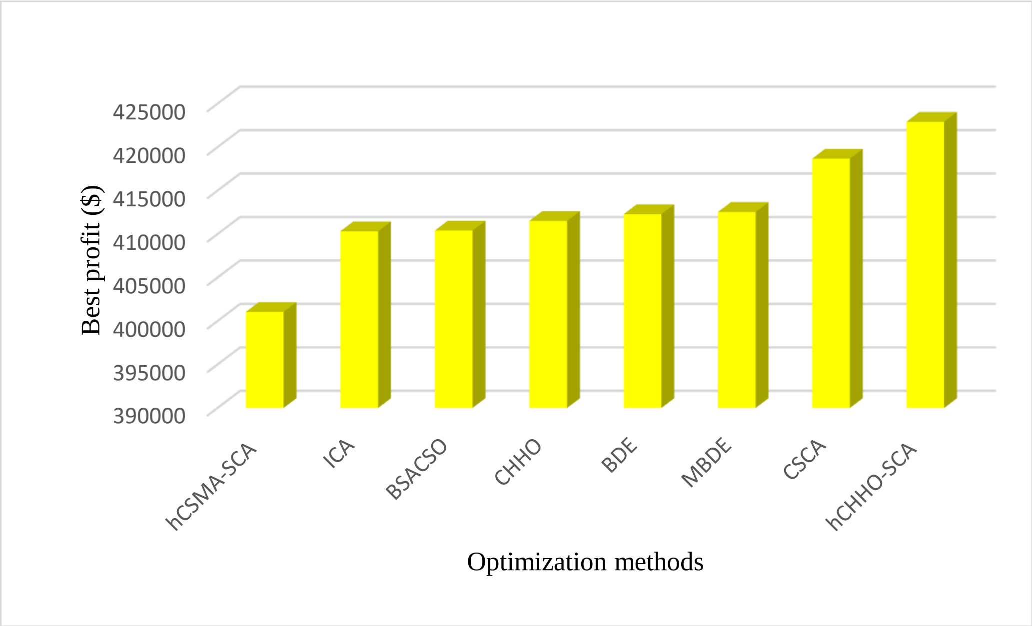


Fig.5.9: Comparison of CHHO, CSCA, hCHHO-SCA and hCSMA-SCA optimizer for medium scale power system with existing optimizers

The Comparison of CHHO, CSCA, hCHHO-SCA and hCSMA-SCA optimizer for medium scale power system with existing optimizers is shown in **Fig.5.9**. The profit of proposed techniques, i.e., CHHO is performing better than ICA and BSACSO optimizers. Further the proposed CSCA, hCHHO-SCA and hCSMA-SCA are performing better than all existing optimizers.

The comparison of CHHO, CSCA, hCHHO-SCA and hCSMA-SCA optimizer for large scale power system with existing optimizers is shown in **Fig.5.10**. The profit of proposed hCHHO-SCA has been performed better than the ICA [26], PPSO [294], PNACO [13], PABC [12], TS-RP [299], TS-IRP [299], MM [9], ACO [109], PSO [13] and IPPD [9] optimizer.

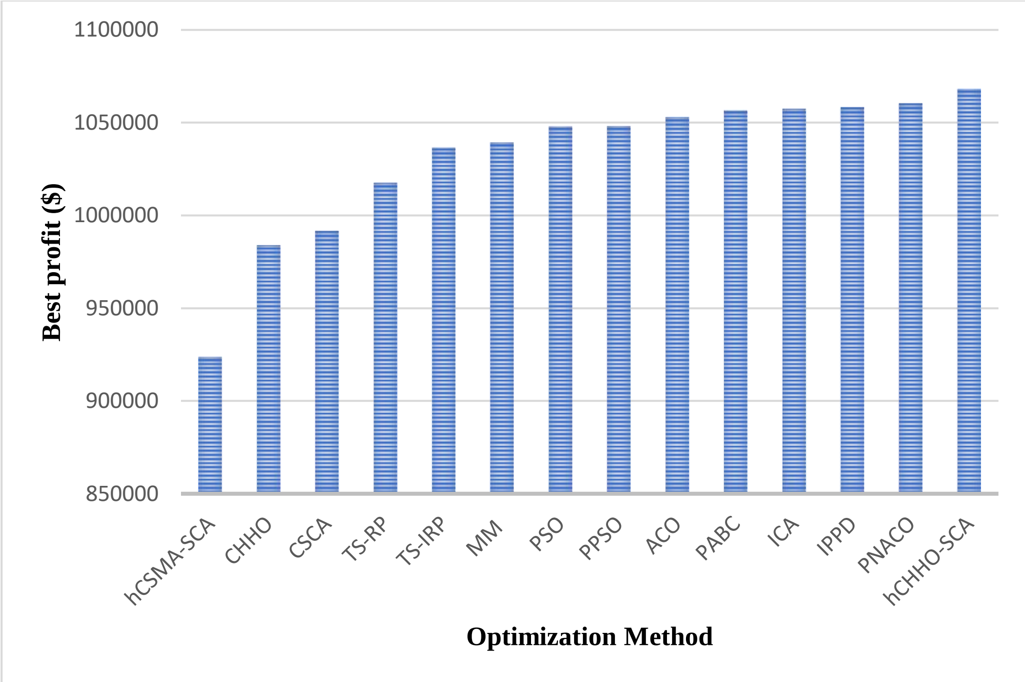


Fig.5.10: Comparison of CHHO, CSCA, hCHHO-SCA and hCSMA-SCA optimizer for large scale power system with existing optimizers

From the above comparison, it has been analysed that, for 10-generating unit system, the profit increased up to 6.146% by using proposed CHHO, CSCA, hCHHO-SCA and hCSMA-SCA optimizer. For 40-generating unit test system, the maximum profit increased up to 5.17% by using proposed hCHHO-SCA optimizer. For 100-generating unit test system, the maximum profit increased up to 0.5% by using proposed hCHHO-SCA optimizer.

5.8 CONCLUSION

In this chapter, profit based unit commitment problem has been resolved using proposed hybrid techniques. The test units are consists of 10, 40 and 100-unit generating systems have been scheduled successfully. The maximum profits can measured using suggested hybrid optimizers. For 10 generating unit system, the profit increased up to 6.146% by using proposed hCHHO-SCA optimizer. 40 unit test system, the maximum profit increased up to 5.17%. For 100 unit test system, the maximum profit increased up to 0.5%. From the simulated results for profit of hCHHO-SCA optimizer is better than the others existing as well as recently established heuristics, meta-heuristics and evolutionary search optimizer.

The suggested optimizer determines the satisfactory profit value with commitment scheduling within a reasonable time of computation. Such a powerful optimizer can be applied to get solution of PBUCP for modern power sectors. Analysis of the variation in profit value, i.e. best, average and worst value, standers deviation and median value are taken into considerations. Some of the hypothesis testing including Wilcoxon rank sum method and t-test are taken into consideration through which p-value and h-value can be determined. The computational times are also analyzed as best, average and worst time of simulations.

CHAPTER-6

PROFIT BASED UNIT COMMITMENT PROBLEM WITH PEVs & SOLAR ENERGY SOURCES

6.1 INTRODUCTION

The electrification of transport systems is one of the important options to decrease the dependency on fossils fuel. The reduction of greenhouse gas is not potential for a short time as the resources of energy in our country are stable, but in the case of the transportation sector, the usage of PEVs is estimated to be a favorable solution. A sufficient amount of coordinated Plug-in Electric Vehicles utilization for transportation could be a possible solution for minimizing emissions released from generating energy by the combustion of fossil fuels. The advance technology, PEVs can be applied as removable small electricity plant to improvement of reliability of network including improvement of the operating cost. The charging and discharging operations are used to improvement of stability and reliability of grid in the power sector, alleviate the shortage of electricity and reduction of power in peak level, spinning reserve, frequency and voltage regulation.

PEVs were purely regarded as dispatch able peak level power plant to take participation for planning in the profit based unit commitment. Although electric vehicles are seeming to getting more popularized these days, it has a surprising historical background. In 1834 Thomas Davenport developed first non-rechargeable battery-operated EV in tricycle form. After the invention of lead-Acid batteries in 1874, David Salomon was successful in developing electric vehicle with rechargeable battery. This development led to construction of commercial EVs in late 1886 by many companies. The present scenario of electric vehicle is given in Table-6.1.

Table-6.1: Present scenario of Electric Vehicle in India

Sl No.	Manufacturing Company	Model	Power Consumption	Battery Range	Kwh	Torque	Transmission	Maximum Speed
1	Tata Motors	Tata Tigor EV	40 bhp@4500 rpm	142 Km/Full Charge	16.2 kWh battery powers a 72 volt	105 Nm@2500 rpm	Automatic	80
2	Hyundai	Hyundai Kona Electric	31 Kw @ 4000 rpm power	Li-Poloymer Battery	31 Kw @ 4000 rpm power	91 Nm @ 3000 rpm	Automatic	85 Km/h
3	Mahindra	Mahindra e2oPlus	40 bhp @ 3500 RPM	210AH Lithium Ion, 99.9Km/Full Charge	40 bhp @ 3500 RPM	91 Nm @ 2500 RPM	Automatic	85 Km/h
4	Toyota	Toyota Prius	96.55 bhp	26.3Km/Full Charge	72 kW @ 5200 rpm	142 Nm (14.48 kg-m) @ 3600 rpm	Automatic (CVT)	120 kmph
5	Mahindra	Mahindra e-Verito	30.5kW @ 3500rpm	200Ah Li-ion battery, 99.9Km/Full Charge	30.5kW @ 3500rpm	91Nm @3000rpm	Automatic	110kms
6	India-spec MG ZS EV	MG ZS EV	105 kW (143 PS)	230 km	44.5kWh	353 Nm	Automatic	140 km/h
7	Mahindra	eKUV100	39.6 BHP @ 3500 RPM	140 kms (Full Charge)	39.6 BHP @ 3500 RPM	91 Nm @ 1050 RPM	Automatic	60 km/hr
8	Tata Nexon EV	Nexon EV	127bhp	312km	30.2kWh battery pack	245nm	Automatic	0-100kmph in 9.9 seconds
9	Tata Altroz EV	Altroz EV		250 km-300 km	lithium-ion battery		Automatic	10 sec 0-100kph
10	KIA Soul EV	KIA Soul EV	110bhp	250km on a single charge	30kWh Li-polymer battery	285Nm	Automatic	145km/h

In the current scenario, the EVs are extremely popular and they are able to compete with conventional ICE. Some of the examples are; Tesla Road star (2007), Model-S (2012), Model-3(2017), Nissan leaf, Chevy Bolt, BMW i3, etc.

Currently available HEVs are mostly PHEV variants. Examples are; Honda Accord Hybrid, Toyota Camry, Prius hybrid, etc. Also, some luxuries sedan is available such as Ford Fusion Hybrid, Lexus RX 450h, Volvo XC 60 T8, BMW 740e XDrive, etc. The another newly invent EV is Tata Tigor Electric Sedan. Here 26 kWh Li-Ion Battery is used. The top speed is 120 kmph. Peak power is 55 kw and the torque is 170 Nm. Hyundai Kona electric SUV is another EV in modern India. It consists of 39.20 kWh Li-Po Battery, 155 kmph top speed, 100 kW peak power and 395 Nm torque. Tata Tigor XPRES-T Electric Sedan is another creation from TATA Group. It consists of 21.50 kWh $LiFePO_4$ Battery, 80 kmph Top Speed, 30 kW @ 4500 RPM Power and torque is 105 Nm @ 2500 RPM. Tata Nexon EV is really doing well and Tata universe ecosystem and EV vision is appreciated by the EV community. Strom Electric Car, from a Mumbai based Indian startup will launch affordable electric cars in 2022. In India, according to a report by India Energy Storage Alliance (IESA), the EV market is predictable to hit over 63 lakh unit mark per annum by 2027. In the base case scenario, the EV market is expected to grow 44 per cent between 2020-2027 and is expected to hit 6.34-million-unit annual sales by 2027," the IESA report said. Similarly, the annual battery demand is forecasted to grow at 32 per cent to hit 50GWh by 2027, of this, 40 plus GWh will be on lithium-ion batteries, it added. The estimated battery market potential is USD 580 million in 2019 and is forecasted to grow to USD 14.9 billion by 2027.

Now a days, renewable energy sector has developed as a significant player in India specially affecting the electricity generation capacity. This thing supports the government's schedule for sustainable growth while become an essential part in meet the energy needs in India. However Indian government have implemented several schemes for renewable sources, such as, introduce the concept of solar park and initiation of a huge grid connected rooftop solar program. Indian government are also organized RE-Invest 2015—a global investors' meet, assigning of Rs.38,000/- crore (Euros 4 billion) for Green Energy Corridor, solar pump scheme including the target for installing 100,000 solar pumps and to train 50,000 persons for the solar installation under the Surya Mitra scheme. According the survey from

31 March 2018 (RES MNRE), with increasing the Indian economy, electric power consumption is expected to reach 15,280 TWh by 2040. At present India have 21,651 MW install capacity for solar power, 34,046 MW install capacity for wind power, 8,701 MW install capacity for biomass power, 4,486 MW install capacity for small size hydro power sector and 138 MW from Waste-to-Power. So, till now the total installed capacity of RES is 69,022 MW in India. But the target of total installation capacity from RES in the year 2022 is 1,75,000 MW. The target of installation capacity for solar energy is 1,00,000 MW, wind energy is 60,000 MW, biomass energy is 10,000 MW and from small hydro power is 5,000 MW. As per survey from MNRE, it comes to know that, India receives around 5,000 trillion KWh per year with the 300 bright sunny days, which is far more than the total amount of energy consumption of India today. The worldwide electricity demand is 1013 W for all need of civilizations whereas the solar power on the surface of the earth is 1016 W. So, 1000 times more power can consume from sun than actually we need. Indian Prime Minister and France Prime Minister launched the International Solar Alliance on 30^{th} November, 2015. Some of the large numbers of projects have been suggested by government of Indian, such as, 35,000 km^2, i.e., 14,000 sq mi area of Thar Desert has been set sidewise for solar energy projects which sufficient to generate the power generation up to 700 to 2,100 gigawatts. India also has 100% of solar powered railway station in Guwahati, Assam and only 100% solar powered airport, located at Cochin, Kerala.

But it is mentioned, only the alternative of PEVs with internally combustion vehicles will have a small effect to reduce greenhouse gas and save the fossils fuel. If the development of PEVs is overlapped with the development of renewable energy sources (RES), with supply of energy of PEVs by solar PV, the fossils fuel consumption with greenhouse gas emission can be reduced. The RES are the key of solution for reduction of dependency upon fossils fuel. Because due to the benefits with significant reductions in cost of operations, low level depreciation with long-lasting competence and capability to make availability of electric power for widespread applications, that is more desirable to use in power sectors. The **Fig.6.1** shows the electricity generation and Fig.2 shows the energy demand according to survey from NITI Ayog.

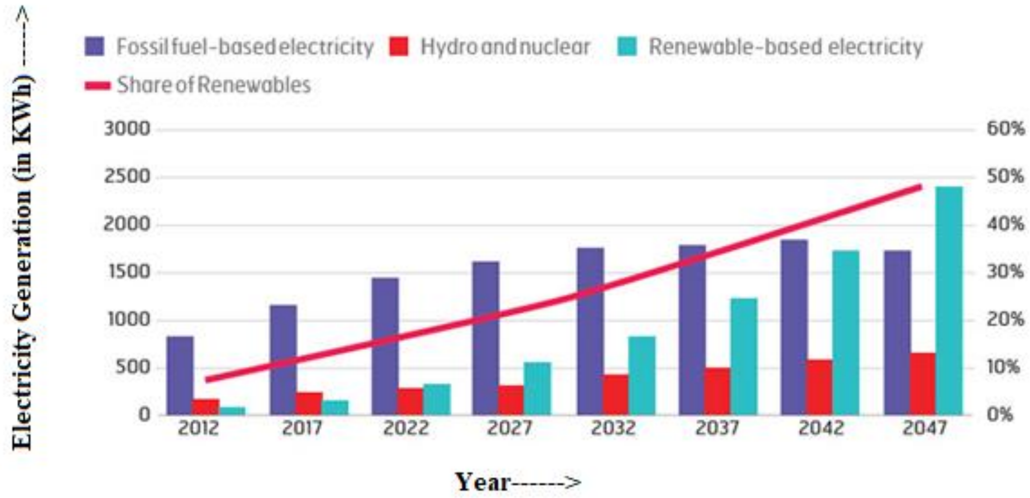


Fig.6.1: Survey of electricity generation

It is clear that if PEVs occupy large session of total vehicles of on the road. Let's say typically 20 to 40% penetration if there in vehicle segment it can creates its own autonomous power storage as well as power generation capacity. If this is the kind of coordination, PEVs can carry a new opportunity and technology under development. But now also the system has also take care of power system dynamics and stability. PEVs can have the maximum power of 80 KW on higher models but on an average it typically lies between 10 to 15 KW. So if we operate such a system it will very ineffective and inefficient. Thus, it is always advised to create a pool of PEVs and make a common power aggregator which can club these pool of PEVs and present a total system as a one system to the grid. The power aggregator has to take care of internal energy flow such that it minimizes the power demand and losses. **Fig.6.2** shows the energy demand according to survey from NITI Ayog. Means some of the vehicles may like to charge slowly, some vehicles may like to charge using fast charging. But, there may be many vehicles who are ready to generate excess power and ready to feedback power to the grid.

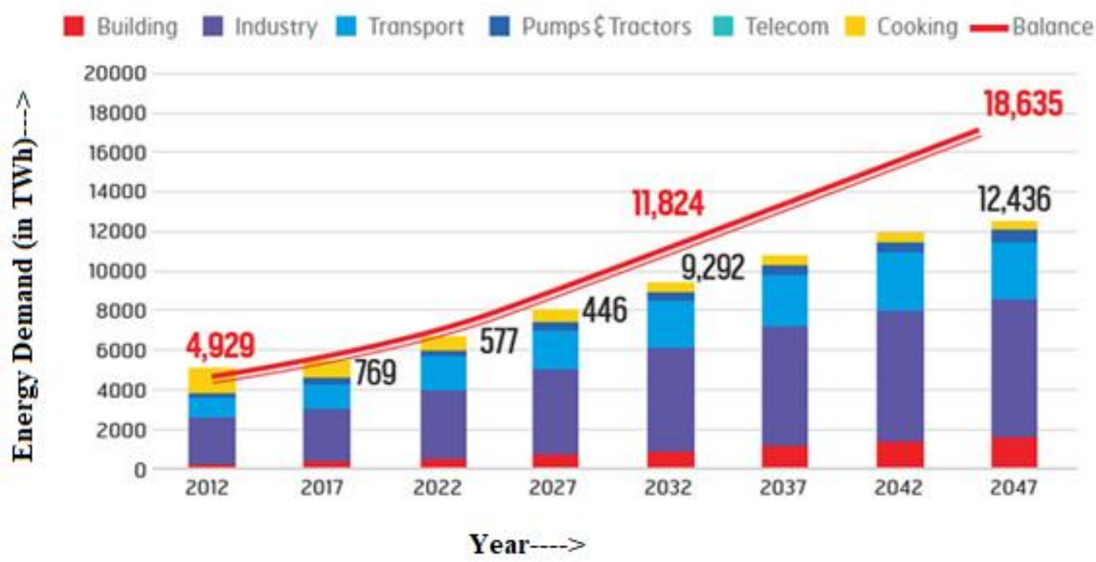


Fig.6.2: Survey of energy demand

In addition to that, charging and discharging of PEVs has lot of application to power system. Thus, if there are lot of aggregators connected to grid, it will act as power generator system, capable of taking energy, storing energy and capable of delivering energy. If such a system is connected to a power system, it can support power system in many ways. We all know, the power generation always try to match the load demand but there will be lot of fluctuations between the peak hours during the day and off-peak hours in the night.

The charging and discharging operations of PEVs can help the grid by energy generation during day time and to support the peak load demand or it is called peak shaving. It can also support regulation of grid voltage. Spinning reserve are basically the systems which are dominant and are started only during peak load demand. Typically, these are stand-by generators or diesel generators which are started during peak load demand.

The profit based unit commitment and economic dispatch effort pair in power generation industry to empower grid management and power generation, along these lines adding to a system's general steady quality. For the expanding utilization of RES, (for example, solar based and wind based power) is adding uncommon measures of vulnerability to a system operator's power generation scheduling and grid management. The block of transmission halls because of wind power is getting less surprising since locales with the best wind power potential are regularly situated a long way from load focuses. The stochastic idea of wind modifies the unit responsibility and dispatch issue and large diminish anticipated expenses. One of the errands of the PBUCP is to envision this circumstance and execute preventive and remedial control activities by submitting suitable reserve margins or by planning wind power shortening.

The efficient power management is required for economic power distribution in daily basis. The PBUCP has important part in economic operations of energy sectors by maintain the V2G and G2V operations which are occurred by charging as well as discharging nature of PEVs with maintain the uncertainty of the RES (i.e. solar power). Determining the appropriate timing for exiting as well as log in the circuits of the plant between possible modes can lead for huge save of electricity. Traditionally PBUCP deals with maximize profit with scheduling of generating units in power sectors. The main purpose of this kind of scheduling is to increase the rate of profit by decreasing the total operating costs by maintain the system constraints, such as power balance, reserve capability as well as minimum up and down timing limits in a specific time period. The basic structure shown in **Fig.6.3**, that are considered for the uncertainty incorporation in stochastic nature of profit based unit commitment including generation of wind and solar power.

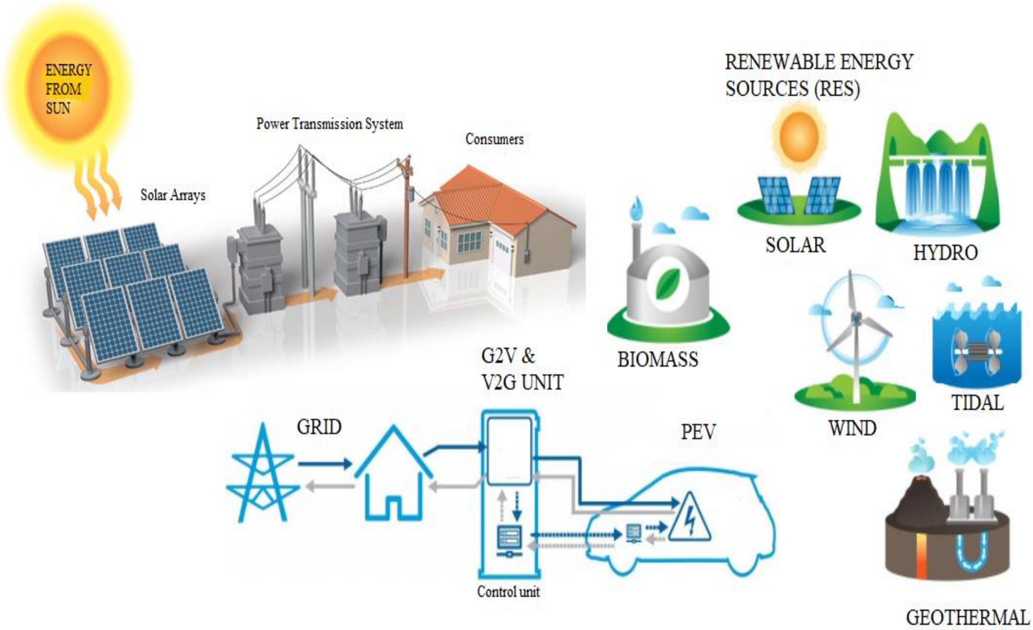


Fig.6.3: The structure of PBUCP with PEVs and solar PV in power system

The PEVs are presented as companionable transportation systems for the environment. The manufacturer of PEVs must bring the opportunity to design them as one kind of energy storage systems. Expanding usages of solar PV have the major role for storage of energy which can be highlighted for overcome the electric power fluctuations. PEVs are uncertain and mobile consumers that can have a side effect on electrical grid with especially high-level penetration for future. The PEVs have the potential for exchange of power with grid into two stages of discharging (V2G) as well as charging (G2V) of batteries. The power grid can be used PEVs as huge numbers of the storage of energy to provide in local load and compensate intermittent of the generation of solar energy as well as trade the energy with grid.

6.2 PROBLEM FORMULATION: PBUCP WITH PEVs AND SOLAR ENERGY

The performances of GENCO increased by increasing profit which depends on scheduling under the availability of assets to maintain different types of appropriate services considering unit characteristics and operational cost. In the modern power sector, it is important to gain optimal scheduling to solve PBUCP as the actual objective is associated with minimization of cost due to increase in fuel prices as well as maximize with profit. The complication of conventional PBUCP has increased due to discharging and charging behaviour of PEVs. The minimization of the environmental pollution and economic cost, the execution of smart grid need more tools for computation with faster improvement of generation of renewable energy sources, PEVs and further modified electricity storages in power system. The ever-rising interest for vitality has driven experts to pay special mind to inexhaustible wellsprings of vitality and with its developing impact.

An unnatural weather change, corruption of the environment and nature of air requires genuine game plan. More work should be done right now. Motivated by these research challenges, intend of the suggested research is to develop a hybrid meta-heuristics research algorithm for the solution of PBUCP of electrical power sector considering power demand of solar energy and PEVs. So that, the requirement for power reserve and load forecasting of power networks provides the limitation of participation for GENCO. Thus, for the self-scheduling process do not execute any requirements which are related to fulfilment of power reserve capacity as well as meet the load demand however previous models are partially took consideration of revenues and costs for power reserve. The PBUC is aimed at devising a proper commitment schedule of generating units for power system over a time period of a day to a week with maximum profit. The main objective for PBUCP is to maximize the profit with minimize the total production cost over the study period & to satisfy the constraints imposed on the system are given Eqn. (6.1) to Eqn. (6.3).

$$\text{Profit} = (RV - TFC) \tag{6.1}$$

Energy price is the main parameter to calculate revenue. The power generation from each units and the commitment status of every unit can be measured from eqn. (5.2). Where ∂_h is energy price of the generating units at hth hour, $P_{i,h}$ is the power if ith unit at h hour and $U_{i,h}$ is the commitment status of ith generating unit at hth hour.

$$RV = \sum_{h=1}^{H}\sum_{i=1}^{NG}\partial_h \times P_{i,h}U_{i,h} \tag{6.2}$$

Total operating cost includes fuel cost, start-up cost and shut-down cost of ith generating unit at hth hour. The operating cost must be minimized to increase the profit. The eqn. (6.3) is used to minimize the total operating cost.

$$\min(TFC) = \sum_{h=1}^{H}\sum_{i=1}^{NG}\left\{F_{\text{cosi,h}}\,(P_{i,h}) + SUC_{i,h} + SDC_{i,h}\right\} \tag{6.3}$$

Where, fuel cost is $F_{\cos i,h}(P_{i,h})$ in quadratic manner. The start-up cost is $SUC_{i,h}$ and the shut-down cost is $SDC_{i,h}$.

It is scientifically a non-smooth, non-convex and quadratic equation of electric power of the each committed power generators at hour hth and after including the fuel cost coefficient the modified eqn. (6.3) can be presented by eqn. (6.4). Where, TFC is related with total operating cost. A_i B_i and C_i are suggested as cost coefficient in $\$/h$ $\$/MWh$ and. $\$/MWh^2$ respectively.

$$TFC = \sum_{h=1}^{H}\sum_{i=1}^{NG}[(A_i P_{i,h}^2 + B_i P_{i,h} + C_i)\times U_{i,h} + SUC_{i,h}(1-U_{i,(h-1)})\times \text{U}_{i,h}] \tag{6.4}$$

6.2.1 Startup and Shutdown Cost

Start-up cost is the cost that occurs when the thermal generating units are bringing online. This is expressed as in terms of hours for which generating unit has been shut-down. The eqn. (6.5) represents the mathematical expression of shut down cost.

$$SUC_{i,h} = \begin{cases} HSU_i\,; & for \quad T_i^{DW} \le T_i^{OFF} \le (T_i^{DW} + T_i^{COLD}) \\ CSU_i\,; & for \quad T_i^{OFF} > (T_i^{DW} + T_i^{COLD}) \end{cases} \quad C_i \; (i \in NU \quad ; \quad h = 1,2,3,...,H) \tag{6.5}$$

Where, $SUC_{i,h}$ is start-up cost of ith generating unit at hth hour. This cost is associated with hot start cost and cold start cost. HSU_i is hot start cost of ith unit and CSU_i is cold start cost of ith unit. T_i^{DW} is minimum down time of ith generating unit. T_i^{OFF} is the OFF time duration of ith generating unit throughout the hth hour. T_i^{COLD} is cold start hour of ith generating unit.

The shut-down time of each generator is one of the important parameters for start-up cost. If the summation of the shut-down time and the cold start hour for generating unit is higher, then cold start cost is taken into consideration. Otherwise, if the shut-down time for ith generating unit is less, then the hot-start cost is in taken into consideration.

The shut-down cost can be measure from eqn. (6.6), where K is represented as incremental cost of the ith generating unit at hth hour.

$$\mathrm{SDC}_{i,h} = \mathrm{KP}_{i,h} \tag{6.6}$$

6.2.2 Charging Constraints for PBUCP with PEVs and Solar Energy

The constraints maintaining problems are represented in below sub-sections. This section includes maximum as well as minimum limitations of fuel. These kinds of constraints are known as the global constraint. That are important in maintaining the problem associated with PBUCP.

6.2.2.1 Power Balance Constraint for PBUCP with PEVs during Charging

The vehicle electrification will significantly affect the power grid because of the expansion in power utilization. It is essential to perform intelligent planning for charging and discharging of PEVs. In any case, there are two significant difficulties in the scheduling issue.

In power system the constraint including power balance or load balance is more important parameter consist of summation of whole committed generating unit at hth time span must be larger than or equivalent to the power demand for the particular time span ‘h’. The power balance constraints during charging of PEVs is given in eqn. (6.7).

$$\sum_{i=1}^{NG} P_{i,h} U_{i,h} = D_h + D_h^{EVs/BEVs} \tag{6.7}$$

The total power generation from the committed units at hth hour must be meet the load demand considering charging of PEVs. The sum of the electricity generation from ith unit at hth hour must be meet the load demand D_h and the load demand due to charging of PEVs, i.e. $D_h^{EVs/BEVs}$.

6.2.2.2 Power Balance Constraint for PBUCP with Solar Energy

In recent years, renewable energy sources have been one of the quickly developing vitality change frameworks. Renewable energy sources assume significant job in satisfying the electricity demand and environmental protection. The deep penetration of solar energy is a basic part of things to future power grid. In any case, the irregularity and stochasticity of solar energy carry significant difficulties to the dependable and financial activity of intensity frameworks. Considering solar energy as RES, the power through solar PV (renewable) are taken into consideration and mathematical formulation is given in eqn. (6.8).

$$\sum_{i=1}^{NG} P_{i,h} U_{i,h} + P_h^{\mathrm{Re}newable} = D_h \tag{6.8}$$

The total power generation at hth hour and the total power generation from solar PV at hth hour, i.e. $P_h^{\mathrm{Re}newable}$ must be meet the load demand. The sum of the electricity generation from ith unit at hth hour must be meet the load demand D_h.

6.2.2.3 Power Balance Constraint for PBUCP with PEVs and Solar Energy during Charging

The complication of conventional PBUCP has increased due to discharging and charging behaviour of PEVs. The minimization of the environmental pollution and economic cost, the execution of smart grid need more tools for computation with faster improvement of generation of renewable energy sources, PEVs and further modified electricity storages in power system. The total power generation at h^{th} hour and the total power generation from solar PV at h^{th} hour, i.e. $P_h^{\mathrm{Re}newable}$ must be meet the load demand and and the load demand due to charging of PEVs, i.e. $D_h^{EVs/BEVs}$. The sum of the electricity generation from i^{th} unit at h^{th} hour must be meet the load demand D_h and $D_h^{EVs/BEVs}$. Considering solar PV as renewable energy sources, the power balance equation is given in eqn. (6.9).

$$\sum_{i=1}^{NG} P_{i,h}U_{i,h} + P_h^{\mathrm{Re}newable} = D_h + D_h^{EVs/BEVs} \tag{6.9}$$

Where, $P_h^{\mathrm{Re}newable}$ is the generated power from solar PV at h^{th} hour, D_h is the power demand at h^{th} hour and $D_h^{EVs/BEVs}$ is the power demand considering PEVs.

6.2.2.4 Spinning Reserve Constraint for PBUCP with PEVs and Solar Energy during Charging

The operations of PEV and uncertainty of solar energy in summer and winter days are taken into consideration. As the reliability of the power generating units is always providing for the extra capability of power generation that may be necessary instantly to withstand with unexpected failure of the running power generating unit or unexpected rise of load demand. This type of failure can be happened due to sudden tripping of the electricity generating units. Some addition of the auxiliary generating unit is required to cope up with the shortfall and meet the sudden increase of power demand. The additional power generation capacity is known as spinning reserve. It can be calculated from eqn. (6.10).

$$\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} \geq D_h + D_h^{EVs/BEVs} + R_h \tag{6.10}$$

The mathematical formulation of Spinning Reserve Constraints considering solar PV is given in eqn. (6.11).

$$\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} + P_h^{\mathrm{Re}newable} \geq D_h + R_h \tag{6.11}$$

The Spinning Reserve Constraints considering solar PV and charging behavior of PEVs is shown in eqn. (6.12).

$$\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} + P_h^{\mathrm{Re}newable} \geq D_h + D_h^{EVs/BEVs} + R_h \tag{6.12}$$

6.2.3 Discharging Constraints for PBUCP with PEVs and Solar Energy

The particular constraint related through particular generating units during discharging of PEVs. In this condition some of the unit may require to be into online at a specific time for run that system or may be turn out to be unavailable condition due to outage or maintenance of the unit. This is occurred due to issues in reliability and operating limitation. The photovoltaic energy of solar power generation with the discharging of PEV, it is conceivable to amplify the advantages and limit the expenses, through high entrances of the two penetrations in the power part, what increases outflows from the PEV discharging at peak time. The first one gives power during top noontime in summer, diminishing the requirement for extra generation limit. The second one retains vitality from photovoltaic plants that would be wasted because of low power demand in the winter time. Numerical construction for unit commitment problem considering the impact of PEVs/BEVs are discussed below.

6.2.3.1 Power Balance Constraint for PBUCP with PEVs during Discharging

The plug-in electric vehicles (PEVs) represents the alternatives of the outflow of poisons from vehicles controlled by petroleum derivatives. The plug-in electric vehicle charging is recurrent, variable and to some degree of unpredictable, as it goes about as a load to the power grid. Power balance constraints during discharging of PEVs is shown in eqn. (6.13).

$$\sum_{i=1}^{NG} P_{i,h} U_{i,h} = D_h - D_h^{EVs/BEVs} \tag{6.13}$$

Power Balance Constraints considering solar PV is shown in eqn. (6.14).

$$\sum_{i=1}^{NG} P_{i,h} U_{i,h} + P_h^{\mathrm{Re}newable} = D_h \tag{6.14}$$

Power Balance Constraints considering RES and impact of charging nature of PEVs are shown in eqn. (6.15).

$$\sum_{i=1}^{NG} P_{i,h} U_{i,h} + P_h^{\mathrm{Re}newable} = D_h + P_{hL} - D_h^{EVs/BEVs} \tag{6.15}$$

6.2.3.2 Spinning Reserve Constraint for PBUCP with PEVs and Solar Energy during Discharging

The power generation system's reliability may be measured as an ability to more capable for electricity generations which are more significant to do instantly as the unit is failure to generate power to meet the demand due to sudden change of load for that system which is already in running conditions. The more capability of the system generation is known as spinning reserve considering discharging nature of PEVs for the unit are presented in eqn. (6.16).

$$\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} \geq D_h - D_h^{EVs/BEVs} + R_h \tag{6.16}$$

Spinning Reserve Constraints considering solar PV is shown in eqn. (6.17).

$$\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} + P_h^{\mathrm{Re}newable} \geq D_h + R_h \tag{6.17}$$

Spinning Reserve Constraints considering RES and discharging behavior of PEVs are shown in eqn. (6.18).

$$\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} + P_h^{\mathrm{Re}newable} \geq D_h - D_h^{EVs/BEVs} + R_h \qquad (6.18)$$

6.3. Thermal Unit Constraints

In the thermal power plants units are controlled in manual way. That need to take care of gradually changes in temperature which takings certain hours for access the power unit. So, few numbers of crew members are must need for maintain those power generation units. Separately from the system constraint, also the PBUCP is associated through thermal power unit constraints which need to be fulfilled during commitment of the unit, de-commitment of that unit then power distribution to the generator according to economic load dispatch (ELD).

6.3.1 Minimum Up and Down Time Constraints

When a certain generating unit already in shut down mode then that power unit cannot start immediately. It takes few times to start over from that condition. This time is known as minimum up time (MUT) shown in eqn. (6.19).

$$T_{i,h}^{ON} \geq T_i^{UP} \qquad (6.19)$$

Where, $T_{i,h}^{ON}$ is presented as the interval over the power unit ith is in constantly ON condition from hth hours then T_i^{UP} is presented as MUT (in hour) for that power unit i. When the generation unit will need to decommit then there is a requirement of least time to recommit that power unit. This time is known as minimum down time (MDT) shown in eqn. (6.20).

$$T_{i,h}^{OFF} \geq T_i^{DW} \qquad (6.20)$$

Where, $T_{i,h}^{OFF}$ is that time in hour for which power unit i is in constantly OFF condition then T_i^{DW} is presented as MDT in hour for that ith unit.

6.3.2 Maximum and Minimum Limits of Generating Units

All power units have the individual power generation limits within its minimum to maximum range, otherwise the unit cannot generate power. This specific limit below as well as beyond which the unit is unable to operate is identified as maximum/minimum generation limits shown in eqn. (6.21)

$$P_{i(\min)} \leq P_{i,h} \leq P_{i(\max)} \tag{6.21}$$

6.3.3 Initial Status of Generating Units

Each units have its initial operational situation that must continue as a day's earlier power generating scheduled which are taken into considerations. Therefore, all power generation units can achieve its lowermost up/down time.

6.3.4 Crew Constraints

Normally thermal power plant which consists of more than one unit. So, it's unable to maintain all those unit at a same time. Thus, more numbers of crew members are required for attend the plant and maintain the whole unit at a same time for start-up as well as shut down.

6.3.5 Availability Constraints for Power Generating Units

The availability for power generation units surrounded by some of resulting different kinds of circumstances: (i) available or non-available and (ii) must be in running state

6.4 SOLUTIONS METHODOLOGY FOR PBUCP WITH PEVs AND RES

Profit based unit commitment problem has been identified by considering physical constraints and system of thermal power units. The chaotic version of HHO, SMA and SCA are taken into consideration, i.e., CHHO and CSCA, for solving PBUCP including the discharging and charging impact of PEVs with RES. Also, this research has used hCHHO-SCA algorithm and hCSMA-SCA to solve profit based unit commitment problem of power system considering impact of solar PV in summer and winter with impact of charging and discharging nature of PEVs to find the optimum scheduling for operating the thermal units in the most economical way to achieve the time varying power demand and at the same time achieve the physical and system constraint requirements.

In order to find the hybrid version of hCHHO-SCA and hCSMA-SCA optimizer, the general operators of Singer Chaotic map, Harris Hawks Optimizer, Sine Cosine Algorithm and Slime Mould Algorithm are combined recursively. Stochastic as well as heuristics process are adopted to tackle different kinds of operational and physical constraints of profit based unit commitment problem. The process to satisfy various types of system constraints of PBUCP i.e., Spinning Reserve Constraint, Minimum Up and Down Time constraints and De-commitment of excessive power generating units are described in the mentioned sections 6.3.1, 6.3.2 and 6.3.3 respectively. The suggested hybrid optimizers are discussed below in the following sections to get the solutions of profit based unit commitment problem.

6.4.1 Spinning Reserve Constraint for PBUCP with PEVs during Charging and Discharging

In order to fulfil the requirement of reserve capacity of different types of power units, minimum up and down time of every power units along with time durations for that i^{th} unit is in continuously OFF condition should considered and reserve constraints must repaired as per the flowchart is given below in **Fig.6.4**.

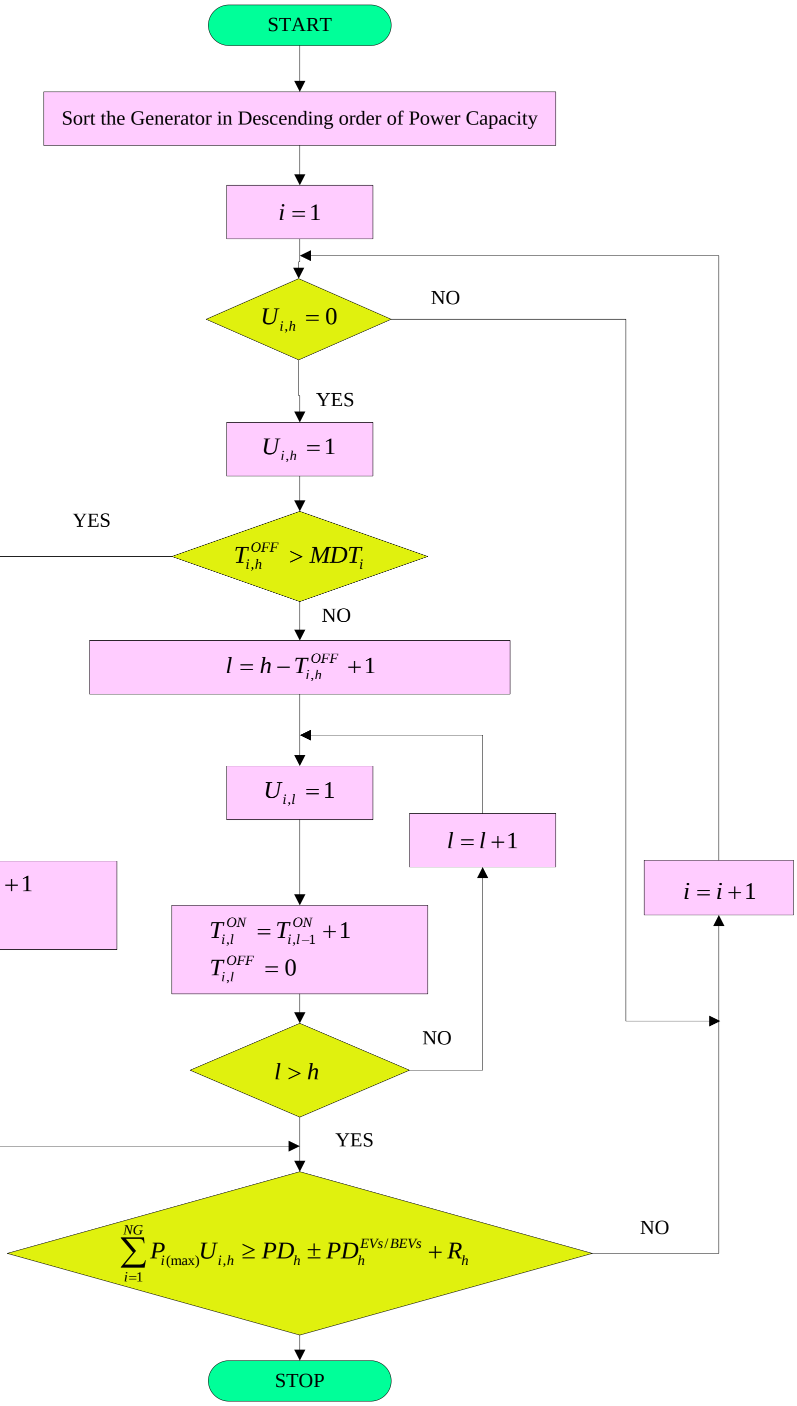


Fig.6.4: Flowchart for repairing spinning reserve constraints considering impact of PEVs

6.4.2 Spinning Reserve Constraint for PBUCP with Solar Energy

In order to fulfil the requirement of reserve capacity of different types of power units, minimum up and down time of every power unit along with time durations for that ith unit is in continuously OFF condition should considered and reserve constraints must repair as per the flowchart is given below in **Fig.6.5**. The solar energy has been considered as solar PV.

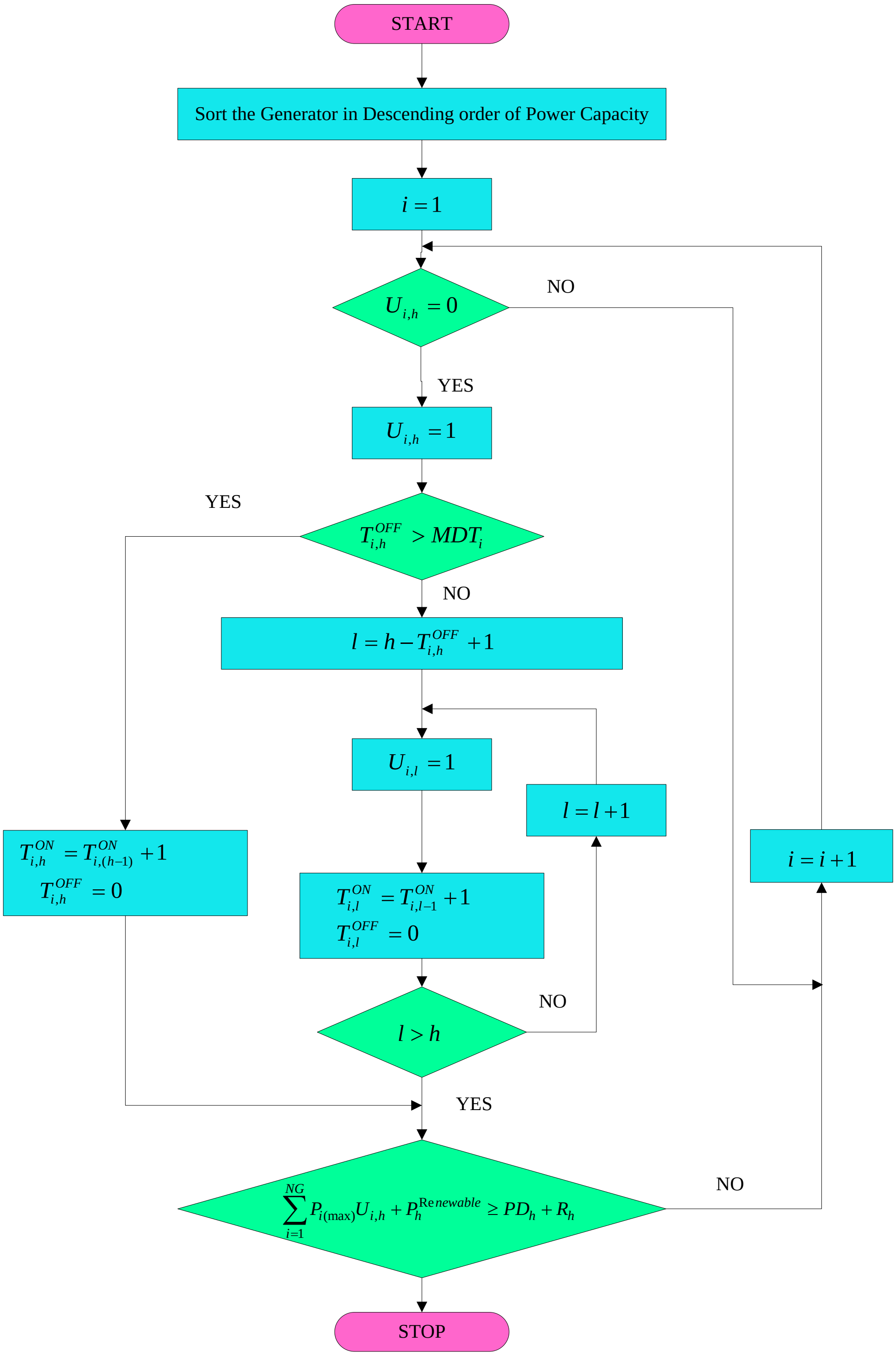


Fig.6.5: Flowchart for repairing spinning reserve constraint considering impact of solar PV

6.4.3 Spinning Reserve Constraint for PBUCP with PEVs and Solar Energy during Charging and Discharging

In order to fulfil the requirement of reserve capacity of different types of power units, minimum up and down time of every power unit along with time durations for that i^{th} unit is in continuously OFF condition should considered and reserve constraints must repair as per the flowchart is given below in **Fig.6.6**.

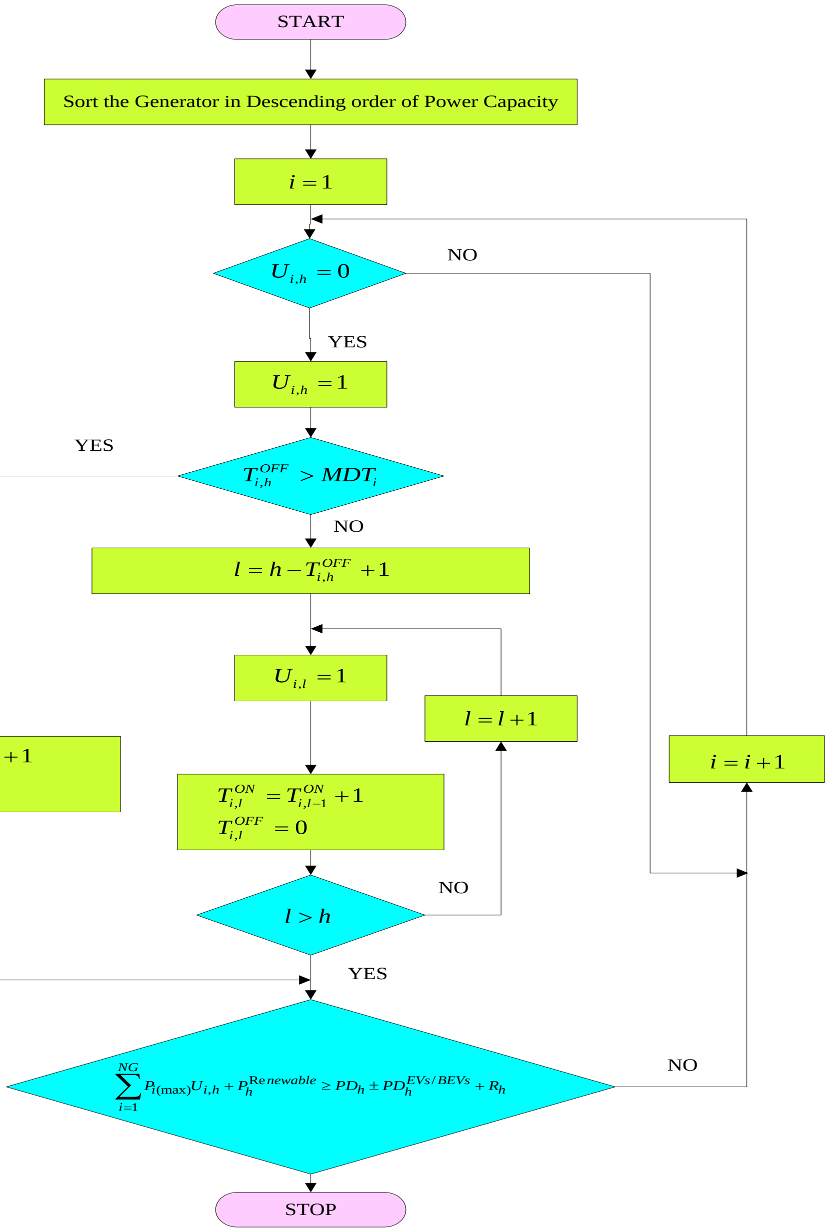


Fig.6.6: Flowchart for repairing spinning reserve constraint considering impact of solar PV and PEVs

6.4.4 Repairing Minimum Up and Down Time Constraints

The Minimum up and down time requirements of thermal units can be repaired by using the mechanism which is given below in **Fig.6.7**.

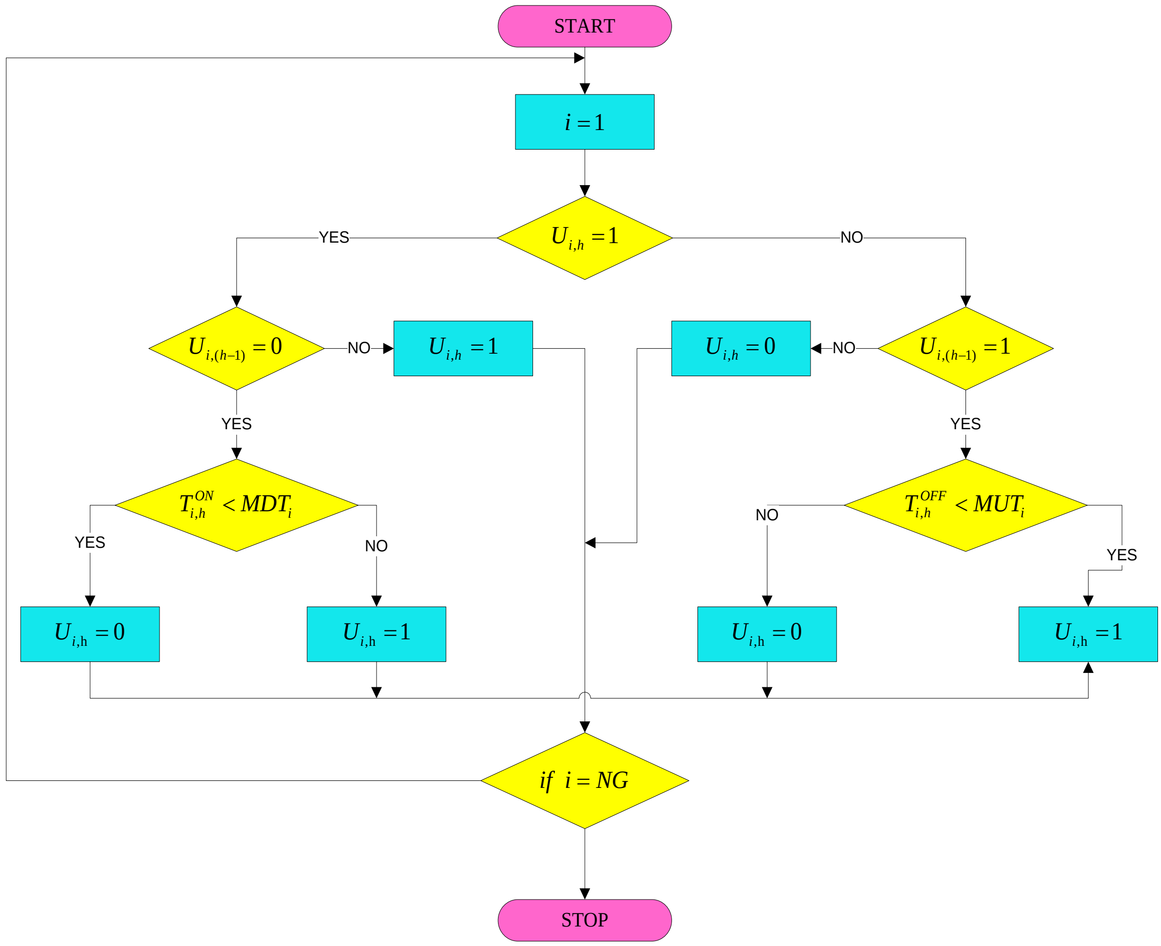


Fig.6.7: Flowchart for minimum up and down time constraint considering PEVs and RES

6.4.5 Decommitment of the Excessive Thermal Units with PEVs and Solar Energy during Charging and Discharging

The decommitment of units are obtained for charging and discharging behaviour of PEVs and considering impact of solar PV which are discuss in given sub sections in details.

6.4.5.1 Decommitment of the Excessive Thermal Units with PEVs during Charging and Discharging

The excessive thermal units need to decommit and the load demand, reserve requirements of all thermal units must be fulfilled with maintain the minimum Down and Up time of every unit along with the duration through which i[th] power unit is in continuously OFF condition and the constraint can be repaired as per the flowchart is given below in **Fig.6.8**.

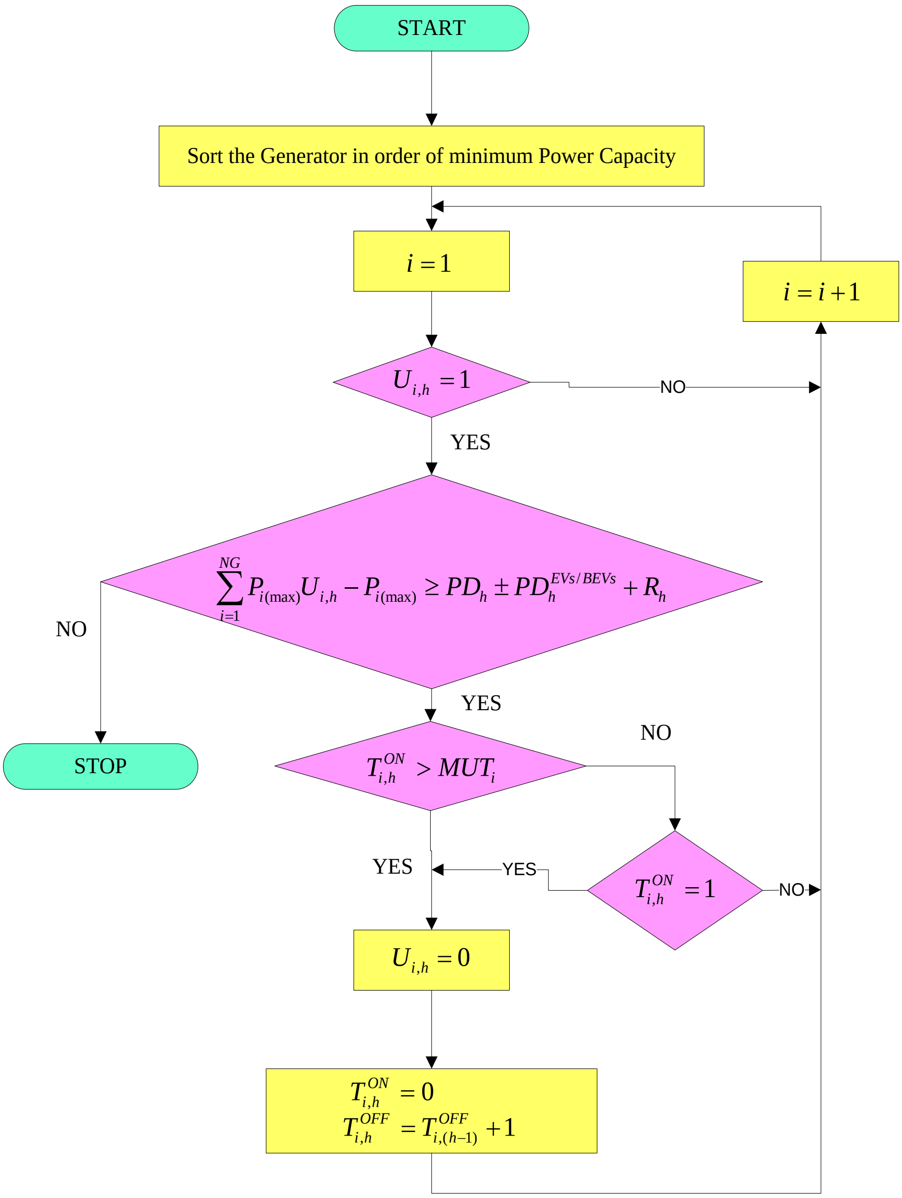


Fig.6.8: Flowchart for decommitment of excessive generating units considering PEVs

6.4.5.2 Decommitment of the Excessive Thermal Units with Solar Energy

The excessive thermal units need to decommit and the load demand, reserve requirements of all thermal units must be fulfilled with maintain the minimum down and up time of every unit along with the duration through which i[th] power unit is in continuously OFF condition and the constraint can be repaired as per the flowchart is given below in **Fig.6.9**.

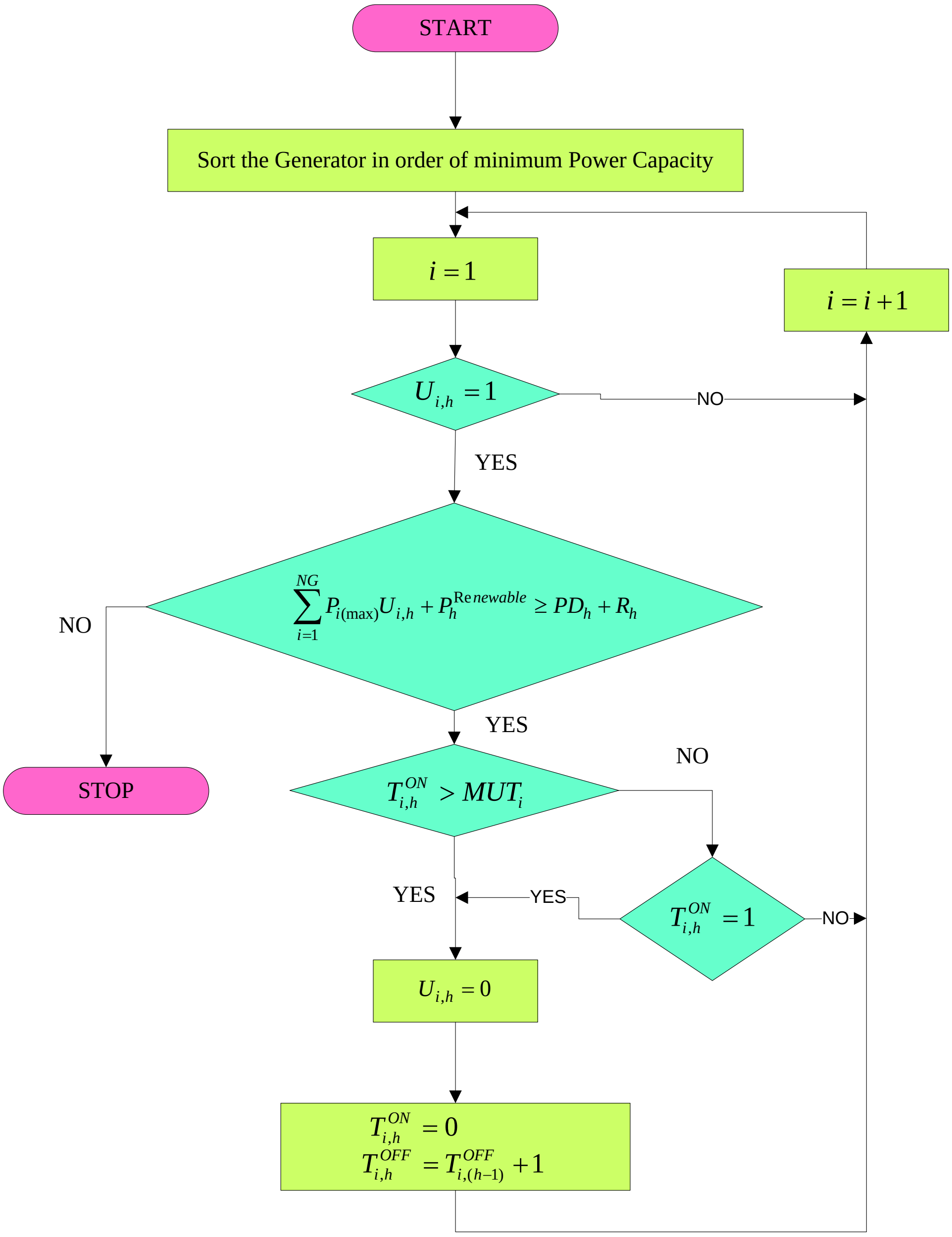


Fig.6.9: Flowchart for decommitment of unit considering solar PV

6.4.5.3 Decommitment of the Excessive Thermal Units with PEVs and Solar Energy during Charging and Discharging

The excessive thermal units need to decommit and the load demand, reserve requirements of all thermal units must be fulfilled with maintain the minimum down and up time of every unit along with the duration through which i[th] power unit is in continuously OFF condition and the constraint can be repaired as per the flowchart is given below in **Fig.6.10**.

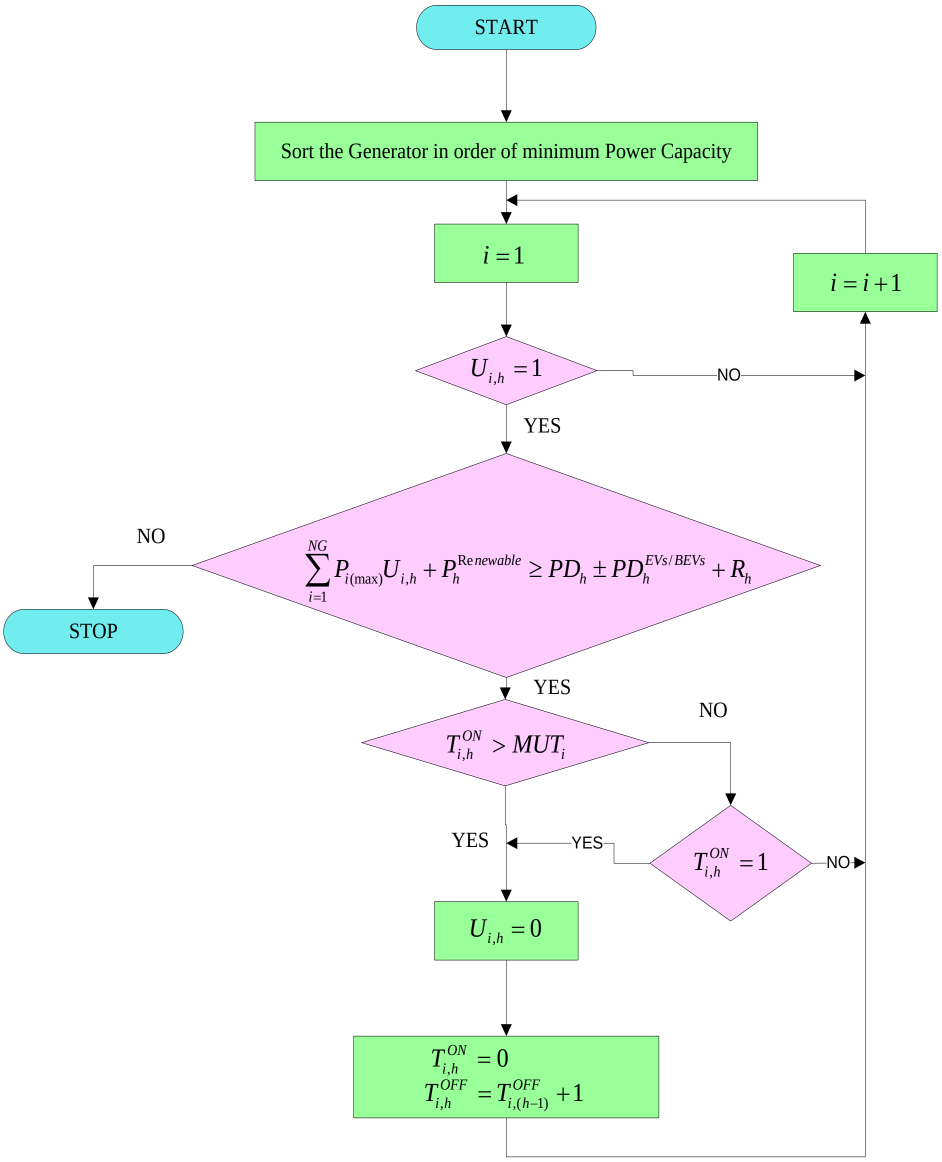


Fig.6.10: Flowchart for decommitment of unit considering PEVs and solar PV

A complete procedure to PBUCP including the impact of charging and discharging nature of PEVs and impact of solar PV in summer and winter days is given below and the flowchart is shown in **Fig.6.11**.

6.4.6 Chaotic Harris Hawks Optimization

The important technique, HHO optimizer is upgraded by singer chaotic strategy to improve the exploitation and exploration phases with conversion, strategy of exploitation including hard encircle and soft encircle by using Eqn. (3.49) as mentioned as singer chaotic map in section 3.2.2.3. The soft encircle considering advanced fast dives and hard encircle considering advanced fast dives. The exploration with conversion which indicate about hunting technique of Harris hawks birds in normal way. Using this strategy, the prey is detected by the hawks and they track the prey and the prey cannot realize this thing easily. After detecting the prey, the Hawks nature is to perform surprise attack for their attacking behaviour. Then prey attempt to escape from this situation. Hence, there are different types of strategies for hunting and escaping techniques of the detected prey which can occur in real situations by using Eqn. (3.12) to Eqn. (3.14) as mentioned in section 3.2.1.3. The levy flight strategy as mentioned in Eqn. (3.20) in section 3.2.1.3 is used for this algorithm. Harris hawks executes their rapid dives around the detected prey and after that try to increase their positions correctly and update their locations as per the directions and escaping motions of the prey. The random arbitrary numbers are taken as $r_{1,} r_{2,} r_{3,} r_{4,}$ & b in mid of [0 & 1] that are progressive in every sequences, $X(iter+1)$ represents the positions of Rabbit where P represents individual as whole numbers of the hawks.

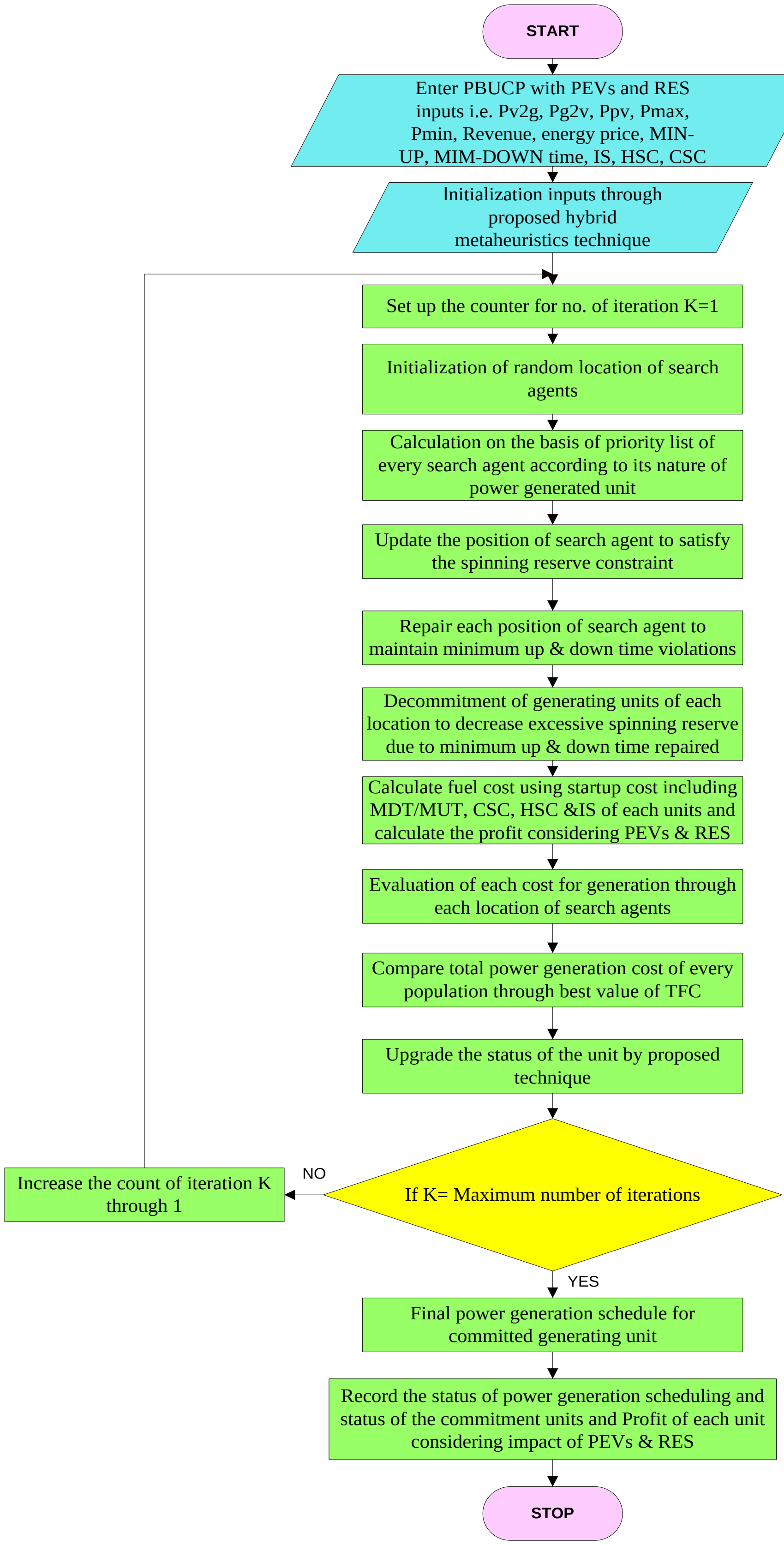


Fig.6.11: Flowchart for PBUCP considering PEVs and solar PV

6.4.7 Chaotic Slime Mould Algorithm

Chaos is an arbitrary deterministic cycle that probably found in unique framework, nonlinear frameworks which are non-joining, limited and nonlinear in nature. Moreover, it is a lot of delicate wards upon its boundary and beginning conditions. The conduct of tumult is plainly irregular and subjective in nature just as capricious and it in like manner has a segment of consistency. Singer function of chaotic maps has been utilised by the Eqn. (3. 3.49) as stated in section 3.2.2.3. Slime moulds referenced to physarum polycephalums. As it was firstly categorized as fungus, so that was titled as ‘‘slime mould’’. This technique suggested frequently simulates the environmental furthermore change in the morphological patterns of slime mould physarums polycephalums in case of the foraging as well as doesn't show its whole life cycles. For pretending variation purposes $\vec{Y}$, $\vec{ub}$ as well as $\vec{uc}$ are applied as appreciate of this variation through venous of slime moulds. For communications and moving towards conducted in the way of numerical formulations, the supplementary formulae are suggested to imitate the constructional phase is presented in Eqn. (3.5) as stated in section 3.2.1.2. The Eqn. (3.5) to Eqn. (3.8) uses to search the individual in all ways to find the optimal solution. Thus, circular structures of slime moulds are prepared for approaching the food into close regions.

6.4.8 Chaotic Sine Cosine Algorithm

In simulation complex phenomenon, examining, numerical examination, dynamic and especially heuristic enhancer needs arbitrary groupings with a broad long time-frame and extraordinary consistency. Mathematically, chaos has haphazardness of an essential deterministic dynamical structure and chaotic framework may be considered as wellspring of the arbitrariness displayed in Eqn. (3. 3.49) as referenced in section 3.2.2.3. After initialization of main four parameter are r_1, r_2 , r_3 as well as r_4 for the optimizer SCA is used to apprise. r_1 parameter used to direct the movement dictate that could be in among destinations and solutions in search regions or outside of the region. r_2 Parameter defines directions of the movements outward or toward of the endpoint. r_3 Definea the randomness of weights to accentuate i.e. *r3* > 1 then deemphasize si.e.

$r3 < 1$, the effect of absolutely recognizing the expanse. At last, r_4 parameter specifies equality of switch among sine function as well as cosine functional elements over the Eqn. (3.3) as stated in the section-3.2.1.1.

6.4.9 Hybrid Chaotic Harris Hawks-Sine Cosine Optimization Algorithm

A new important hybrid algorithm is established by relating chaotic maps with the HHO as well as the SCA method, hCHHO-SCA include exploratory as well as exploitative phase that is stimulated by surprise attacks, the natures of explorations of prey and various strategies are based upon aggressive attacked phenomenon of the Harris hawks birds. The optimizer hCHHO-SCA have certain major performances in the phases of explorations. Additionally, it had a significant procedure in transformation from period of the investigation to the period of the explorations. The parameter $r_{1,}r_{2,}r_{3,}r_4$ & b are random account in mid of the value (0, 1) which are progressive at each sequence, $X_{Hawks}(\text{iter}+1)$ is indicated as locations of the preys as well as P is separate as entire numbers of the hawk birds. An implausible social nature has been strangled by the Hawks to trajectory and jumps on their prey. Looking for preys, surprising jump, and numerous attacking performances achieve the explorative as well as exploitative periods of the technique. The standard ranges for hawks attain through smearing in the Eqn. (3.14) as stated in the section-3.2.1.3 and adapt subsequently the age on behalf of enquiry for exploitations is deliberated in Eqn. (3.15) as stated in section-3.2.1.3. The random nos. i.e., r_1, r_2, r_3 and r_4 are main four parameter for the optimizer. r_1 helps to find out directions as well as movement that can dictates. r_2 helps to find out the direction as well as the movement outward or toward of the destination. r_3 helps to find the random number of the weights to put emphasis on i.e., r3 > 1 as well as deemphasize i.e., r3 < 1, the effect of totally identifying distances. At last, helps through indicates equality of switches in between the sine function as well as cosine features by the Eqn. (3.3). For the usages of the sine function and cosine formulation, this method is known as SCA as mentioned in section-3.2.1.1. The flowchart of complete procedure of PBUCP with hCHHO-SCA is given in **Fig.6.12**.

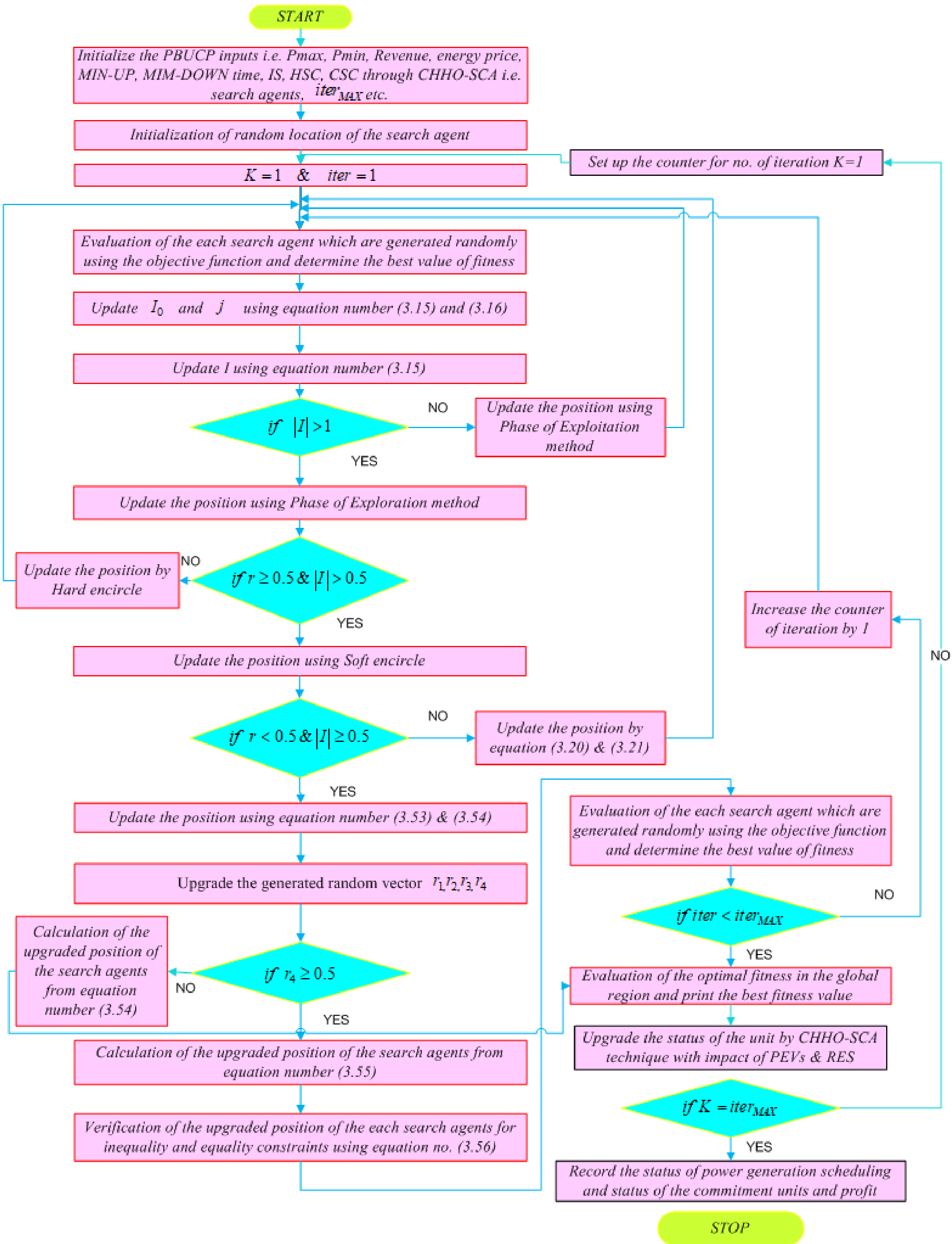


Fig.6.12: Flow chart for solution of PBUCP with PEVs and solar PV using hCHHO-SCA optimization algorithm

6.4.10 Hybrid Chaotic Slime Mould-Sine Cosine Optimization Algorithm

The proposed hCSMA-SCA optimizer is established to increase the penetrating capability through the entire search region. Slime moulds basically depend on wave of propagations created by natural oscillators to changes the cytoplasmic streams in the veins. They will in general can be in the better situations of concentrations for foods.

For the simulating variation purposes, $\vec{Y}, \overrightarrow{ub}$ as well as $\overrightarrow{uc}$ are used as the realizer of these variation through venous of slime moulds. $\vec{Y}$ is statistically simulates frequency oscillation of slime moulds that close to the one at the various stages of concentrations in food, so it can moves towards food and immediately when discover the higher quality foods, while search the foods all more gradually then the concentrations of the foods are lower in each individual location, accordingly successfully improve productivity of slime moulds in the choose optimum foods sources.

The parameter, $\overrightarrow{ub}$ create random number by random oscillations in-between [-a, a] and when no. of iterations are increased then that continuously upcoming towards the value zero. After that the parameters $\overrightarrow{uc}$ create oscillations in-between the no. [-1, 1] then furthermore it move towards the value zero accordingly growing then iterations numbers.

To find out the best sources for foods, if slime moulds can discover better solution, it will be detached from the organic matter for explorations to endeavors to find out highest quality of solution, i.e. sources for foods, moderately exploration of it within the one solution. The flowchart for the complete process of PBUCP by hCSMA-SCA is specified in **Fig.6.13**.

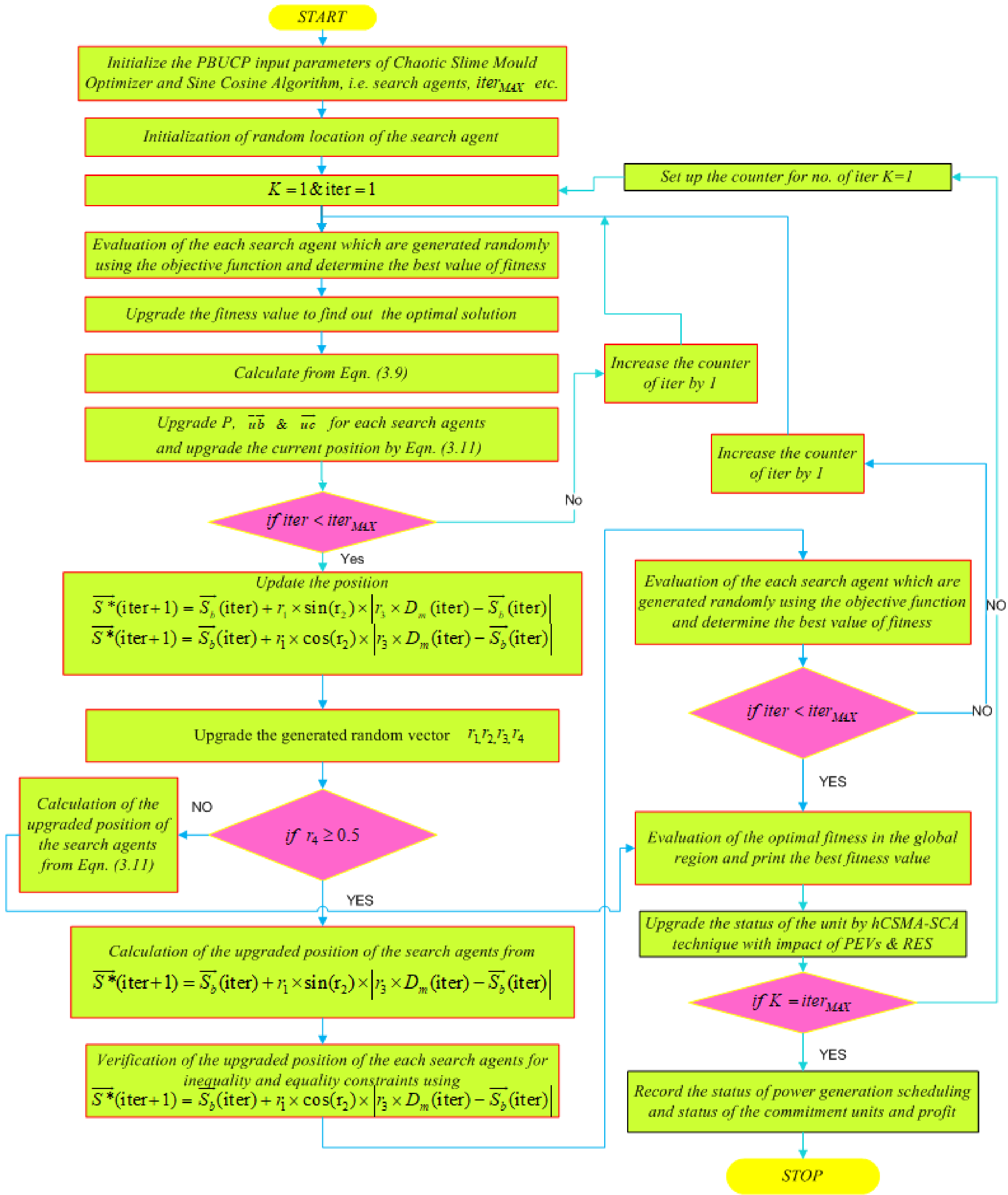


Fig.6.13: Flow chart for solution of PBUCP with PEVs and solar PV using hCSMA-SCA optimization algorithm

6.4.11 Mathematical Model for Solar Power Uncertainty considering Operation of PEVs

Electrical energy is the primary requirement for the functioning almost whole day activities. With the development and advancement in modern civilised environment, the demand of energy for fulfilment of these requirement, has been increased enormously. Fossil fuels are the major ingredient of power industries to produce large bunk amount of power. Though energy production from fossil is simpler but, also causes results in harmful hazardous effects on environment by releasing fossil emissions. If the process of energy usage continues to stay with no alternatives may result in fast usage of fossil fuels and ultimately reach to an end one day it becomes necessary to have great attention toward usage of these non–conventional sources for their long existence. However, with the participation of renewable energy sources has somehow lowered the burden on fossil fuels for satisfying load demand to some extent.

Solar and wind energy sources are the foremost renewable energy sources contributing towards total energy production throughout the world. In India solar power industries are the fastest developing sector as renewable power industries till now. The total installation capacity of solar power in India is 47.7 GW as of 31st October, 2021.

The solar energy is taken into consideration in this research. In this research work, the solar radiation and temperature depends on climate [60]. So, the solar radiation and temperature are varied in summer and winter times. Thus, in this research, for both conditions, i.e., summer and winter the solar radiations are taken into consideration.

In India PEVs are already started in several cities. The charging and discharging of PEVs may significantly build the interest to meet the load demand. The manufacturing industries are established in India and increase the transport demand. So, the recent interest on electric vehicles has opportunity to crate domestic PEV industries in India. The various problems occur due to use of fossils fuel. The electrification of transport system is one of the important options to decrease dependency of fossils fuel. The alteration of transport system as well as low carbon energy required for the efficiency measurements of clean technology.

Further, the nitrogen oxide and carbon dioxide emissions are reduced by using PEVs. The 400,000 electric vehicle cars can avoid 4 million ton of carbon dioxide and 120 million barrel of oil according to the data from National Electric Mobility Mission Plan (NEMMP) 2020. According through Centre for Science and Environment, future plan for several cities have 60% to 80% PEVs public transport by 2025 to 2030. Also, the greenhouse gas emissions have been controlled by using PEVs. The PEV is used to improvement of stability and reliability of grid in the power sector due to its charging and discharging nature.

In general, the energy of the photovoltaic cell can be measured from given eqn. (6.23).

$$E_N = a \times \eta \times h_{sr} \times pr \tag{6.23}$$

Where, E_N is the energy in KWh, a is total area of the panel in m^2, η is the efficiency of the panel, h_{sr} is average annual radiation of the panel and pr is the performance ratio. The performance ratio is depended on loss coefficient of the panel. The ranges of the loss coefficient can vary from 0.5 to 0.9. The default value of the loss coefficient can be taken as 0.75.

In this research, the photovoltaic (PV) panels are used for this power plant. The area of this plant is considered as 150 ha and the capacity of that panel as respect to the base power is 60 MW. As solar PV panel are low efficient, a little fraction of the radiation of solar energy is converted to the electrical power. In this case, the efficacy of PV array has been taken as 0.3. The output power from the solar radiations can be measured from eqn. (6.24).

$$P_{out(\max)} = \eta \times I\left(1 - \frac{5(t_{ambient} - 25)}{1000}\right) \times S \tag{6.24}$$

Where, $P_{out(\max)}$ is the maximum power output, η is power conversion efficiency, S is solar irradiation intensity in watt/m^2 and $t_{ambient}$ is ambient temperature. To calculate the maximum output power, the temperature coefficient is taken as 5 percent per degree centigrade. The reference temperature is taken as 25 degrees centigrade and the reference solar radiation is 1000 watt/m^2. The maximum power conversion efficiency can be calculated from eqn. (6.25).

$$\eta_{\max} = \frac{P_{\text{out(max)}}}{Ac \times E} \times 100\% \tag{6.25}$$

Where, $\eta_{\max}$ is the maximum power conversion efficiency, $P_{\text{out(max)}}$ is the maximum power output, Ac is area of the collector and E is the incident radiation flux in W/m^2. The maximum power output from the solar radiation is different in summer times and winter times. Table-6.2 shows the information about solar energy for summer days and Table-6.3 shows about information of solar energy in winter days.

Table-6.2: Output power and solar radiation during summer

Hour	Solar Radiation	Output Power	Temperature	Hour	Solar Radiation	Output Power	Temperature
1	0	0	37	13	919.5	51.86	37
2	0	0	37	14	965.79	54.47	37
3	0	0	37	15	790.64	44.59	37
4	0	0	37	16	866.43	48.86	37
5	0	0	37	17	670.97	37.84	37
6	0	0	37	18	595.89	33.6	37
7	0	0	37	19	346.83	19.59	37
8	80.67	4.55	37	20	115.42	6.51	37
9	277.98	15.67	37	21	2.97	0.16	37
10	484.89	27.34	37	22	0	0	37
11	659.06	37.17	37	23	0	0	37
12	816.76	46.06	37	24	0	0	37

Table-6.3: Output power and solar radiation during winter

Hour	Solar Radiation	Output Power	Temperature	Hour	Solar Radiation	Output Power	Temperature
1	0	0	22	13	361.11	21.99	22
2	0	0	22	14	271.34	16.52	22
3	0	0	22	15	527.44	32.12	22
4	0	0	22	16	496.76	28.6	22
5	0	0	22	17	379.27	23.09	22
6	0	0	22	18	301.46	18.32	22
7	0	0	22	19	131.16	7.98	22
8	0	0	22	20	3.06	0.18	22
9	9.4	0.5729	22	21	0	0	22
10	58.52	3.56	22	22	0	0	22
11	10.42	6.6	22	23	0	0	22
12	296.24	18.04	22	24	0	0	22

In summer days the 37-degree centigrade temperature is taken into consideration. And for winter days 22-degree centigrade temperature has been taken into consideration. In order to complete the evaluation, the information of radiation from solar energy and the ambient temperature have been taken into consideration for summer shown in Table-6.4.

Table-6.4: Transfer of power during V2G and G2V operations during summer

Time	1	2	3	4	5	6	7	8	9	10	11	12
^{P}g2v (MW)	32.4	20.5	44.5	48.2	28.5	31.2	7.18	1.4	0	0	0	0
^{P}v2g(MW)	0	0	0	0	0	0	0	0	50	44.8	43.3	48.1
^{P}pv(MW)	0	0	0	0	0	0	0	4.55	15.67	27.34	37.17	46.06
Time	13	14	15	16	17	18	19	20	21	22	23	24
^{P}g2v (MW)	0	0	27.4	36.7	15.2	44.3	18.1	0	0	0	0	0
^{P}v2g(MW)	48.9	15.9	0	0	0	0	0	50	33.2	39.7	17.8	32.1
^{P}pv(MW)	51.84	54.47	50.23	43.22	32.2	27.96	19.56	6.51	0	0	0	0

The PEVs enables a fixed number of registered vehicles to participate in PBUCP. Electric vehicles are assumed to be charged during off-load period by utility grid or from renewable energy sources. Charging- discharging duration depends upon battery size and charging facilities. It is assumed that all vehicles charged by stand–alone system available at the parking slot. In order to complete the evaluation, the information of radiation from solar energy and the ambient temperature have been taken into consideration for winter day shown in Table-6.5.

Table-6.5: Transfer of power during V2G and G2V operations during winter

Time	1	2	3	4	5	6	7	8	9	10	11	12
^{P}g2v (MW)	39.2	41.9	47.9	47.1	42.2	26.9	0.58	23.1	0	0	0	0
^{P}v2g(MW)	0	0	0	0	0	0	0	0	48	50	46.6	39.8
^{P}pv(MW)	0	0	0	0	0	0	0	0	0.57	3.56	6.6	22.9
Time	13	14	15	16	17	18	19	20	21	22	23	24
^{P}g2v (MW)	0	0	1.6	50	42.2	23.3	4.6	0	0	0	0	0
^{P}v2g(MW)	48.9	37.9	0	0	0	0	0	29.8	47.6	15.4	20.3	1.73
^{P}pv(MW)	28.3	32.1	16.5	15.9	13.3	12.2	7.98	0.18	0	0	0	0

In this research work, the vehicle balance constraints are taken into considerations. The vehicle balance constraints are consists of two major data [60]. First one is the total number of forecasted or registered PEVs can available on the network and second one is numbers of vehicles are connected and operated for 24 hours. The two important parameters have been taken into consideration to select number of PEVs for scheduling in that specific time. As per forecasted or registered PEVs, total numbers of PEVs must be equal or less than to maximum numbers of PEV for the purpose of scheduling in a specific time period. Mathematically it can be written as in eqn. (6.26).

$$\sum_{h=1} PEV_{v2g}(h) = PEV_{v2g(\max)} \tag{6.26}$$

Where, PEV_{v2g} is the number of PEVs are operating and connected to grid and $PEV_{v2g(\max)}$ is the maximum number of registered PEVs.

Maximum number of PEVs per hour have been considered as b% of the total number of vehicles in the parking lot can be measured from eqn. (6.27).

$$PEV_{v2g(\max)}(h) = b\% PEV_{v2g(\max)} \tag{6.27}$$

In this research work, it is assumed that there is a fleet of 40,000 PEVs [60], of that which 20% of the PEVs are involved only in the operations of charging and discharging. 15KW is the battery capacity of each PEVs. Thus, number of 8000 PEVs can participate for discharge and charge. Further considering solar PV, the information about number of PEVs operate discharge and charging operations in summer and winter days are given in Table-6.6 and Table-6.7.

Table-6.6: Numbers of PEVs operate discharge and charging operations in summer

Hour	**Number of PEVs/BEVs/HEVs**	**Hour**	**Number of PEVs/BEVs/HEVs**
1	5096	**13**	7330
2	3378	**14**	388
3	3646	**15**	4552
4	6643	**16**	1069
5	1918	**17**	5460
6	6155	**18**	6363
7	3633	**19**	4426
8	577	**20**	7367
9	7335	**21**	2606
10	7134	**22**	7442
11	5213	**23**	5635
12	7541	**24**	6967

Table-6.7: Numbers of PEVs operate discharge and charging operations in winter

Hour	Number of PEVs/BEVs/HEVs	Hour	Number of PEVs/BEVs/HEVs
1	6159	**13**	7681
2	6588	**14**	5946
3	7528	**15**	253
4	7394	**16**	7844
5	6631	**17**	6630
6	4230	**18**	3657
7	93	**19**	734
8	3629	**20**	4689
9	7535	**21**	7481
10	7844	**22**	2423
11	7325	**23**	3193
12	6252	**24**	273

The total generated power and the transferred power considering the charging as well as discharging nature of PEVs, i.e., V2G and G2V operations is shown in Table-6.8.

Table-6.8: Transfer of power during V2G and G2V operations with PEVs

Hour	**h1**	**h2**	**h3**	**h4**	**h5**	**h6**	**h7**	**h8**	**h9**	**h10**	**h11**	**h12**
Power(g2v) in MW	32.4	21.5	21.24	42.35	22.99	39.24	13.54	3.67	0	0	0	0
Power(v2g) in MW	0	0	0	0	0	0	0	0	46.76	45.48	33.23	48.73
Total Power (MW)	700	750	850	910	1000	1040	1040	1040	1170	1400	1412	1412
Hour	**h13**	**h14**	**h15**	**h16**	**h17**	**h18**	**h19**	**h20**	**h21**	**h22**	**h23**	**h24**
Power(g2v) in MW	0	0	29.02	6.81	34.8	40.56	41.21	0	0	0	0	0
Power(v2G) in MW	46.73	2.47	0	0	0	0	0	46.96	16.58	47.44	35.92	44.41
Total Power (MW)	1332	1300	1200	1040	1000	1040	1040	1040	1040	1040	900	800

6.5 TEST SYSTEMS

The PBUCP has been solved by considering small, medium and large-scale system and the physical constraint of power generation units. This non-convex, non-linear, mixed integer, constrained PBUCP has been solved for standard 10-generating unit system (small scale) 40-generating unit system (medium scale) and 100-generating unit system (large scale). The characteristics of the power units with cost coefficient parameters and power demand in electricity market are discussed below.

6.5.1 Ten Generating Unit System

The test system consist of 10-generating units and the parameters are shown in Table-6.9 which consists of maximum power generation ($P_{i(\max)}$), minimum power generation ($P_{i(\min)}$) limits of the system, fuel coefficient constraints (A_i , B_i and C_i), up and down time constraints, i.e. T_i^{UP} and T_i^{DW} , cost for hot start, i.e. (HSU_i), cost for cold start (CSU_i), cold start hour of unit (T_i^{COLD}) and initial status of that system (INS_i). The Table-5.2 shows the load demand. This test system has been tested for 24-hour load demand pattern at different spinning reserve capacity. Generally the 10-generating unit system have 5% and 10% spinning reserve capacity [2]. In this case, test system consists of 10-generating units with a 24-hour load demand and spinning reserve is not taken into consideration to gain the maximum profit.

Table-6.9: Unit Characteristics for 10-generating unit system

Unit Parameter	**Generating Units**									
	U1	**U2**	**U3**	**U4**	**U5**	**U6**	**U7**	**U8**	**U9**	**U10**
$P_{i(\max)}$	455	455	130	130	162	80	85	55	55	55
$P_{i(\min)}$	150	150	20	20	25	20	25	10	10	10
A_i	1000	970	700	680	450	370	480	660	665	670
B_i	16.19	17.26	16.6	16.5	19.7	22.26	27.74	25.92	27.27	27.79
C_i	0.00048	0.00031	0.002	0.00211	0.00398	0.00712	0.0008	0.00413	0.00222	0.00173
T_i^{UP}	8	8	5	5	6	3	3	1	1	1
T_i^{DW}	8	8	5	5	6	3	3	1	1	1
HSU_i	4500	5000	550	560	900	170	260	30	30	30
CSU_i	9000	10,000	1100	1120	1800	340	520	60	60	60
T_i^{COLD}	5	5	4	4	4	2	2	0	0	0
INS_i	8	8	-5	-5	-6	-3	-3	-1	-1	-1

The forecasted energy prices for production are required to solve PBUCP related issues. The energy price along with forecasted market price are shown in Table-6.10.

Table-6.10: Energy Price along with forecasted market price

Hours	Forecasted Market Price (Rs/MWh)	Energy Price	Hours	Forecasted Market Price (Rs/MWh)	Energy Price
1	996.75	22.15	13	1107	24.6
2	990	22	14	1102.5	24.5
3	1039.5	23.1	15	1012.5	22.5
4	1019.25	22.65	16	1003.5	22.3
5	1046.25	23.25	17	1001.25	22.25
6	1032.75	22.95	18	992.25	22.05
7	1012.5	22.5	19	999	22.2
8	996.75	22.15	20	1019.25	22.65
9	1026	22.8	21	1039.5	23.1
10	1320.75	29.35	22	1032.75	22.95
11	1356.75	30.15	23	1023.75	22.75
12	1424.25	31.65	24	1014.75	22.55

6.5.2 Medium and Large-Scale Power System (40- and 100-Generating Unit System)

In general power system consists of large network which links the power plants (small, large and medium) to electrical load. Small scale power systems are made of section or part of the medium or large-scale power systems.

The higher order test system consists of 40- and 100-Generating units having a 24-hour load demand [2]. The power demand data for 40- and 100-generating unit test system are multiplied by four and ten times respectively of the 10-unit system.

Medium Scale Power System

The medium scale power system consists of 40-generating units. The output of this system is greater than the small-scale power system and less than the large-scale power system. This test system is taken into consideration for 30 trails and 100 iterations. In this system the power demand for 24 hours can be measured as multiplied by 4 of the small-scale power system (10-generating unit).

Large Scale Power System

The large-scale power system consists of 100-generating units. The power output from that system is larger than the small and medium scale power system. The 30 trail runs and 100 number of iterations are taken into consideration. In case of 100-unit test system, the power demand for 24 hours can be measured as multiplied by 10 of the 10-generating unit system.

6.6 RESULTS AND DISCUSSION

The efficiency of the proposed methods for resolving the PBUCP including impact of PEVs and RES (solar), some standard test systems have been taken into consideration, such as, small, medium and large-scale power systems possessing standard IEEE bus systems are taken into concern. The 10 generating units is taken as small-scale system, 40 generating units is considered as medium scale system and 100 generating unit is taken as large-scale systems. The uncertainty of solar energy and discharging and charging nature of PEVs are taken into consideration. So, the results and discussions part are followed by some cases which are given below.

- Solution of PBUCP considering only effect of PEVs.
- Solution of PBUCP considering only effect of solar energy in summer days.
- Solution of PBUCP considering only effect of solar energy in winter days.
- Solution of PBUCP considering both effect of PEVs and solar energy in summer days.
- Solution of PBUCP considering both effect of PEVs and solar energy in winter days.

The proposed algorithms performance is assessed in MATLAB 2017a (8.1.0.604) software on Windows 7 Home Basic, CPU @ 2.10GHz, RAM- 3GB, Processor-Intel® Core™ i3-2310M, System Type- 64-bit operating system. The effectiveness of the proposed algorithms CHHO, CSCA, CSMA, CHHO-SCA and CSMA-SCA have been justified from practical point of view, the results of the algorithms have been compared with CHHO, CSCA and CSMA has been discussed in this section.

6.6.1 Hybrid Chaotic Harris Hawks-Sine Cosine Optimization Algorithm with PEVs during Charging and Discharging

A new important hybrid algorithm hCHHO-SCA, include exploratory as well as exploitative phase that is stimulated by surprise attacks, the natures of explorations of prey and various strategies are based upon aggressive attacked phenomenon of the Harris hawks birds. The number populations are taken as 40 for 10-, 40- and 100-generating unit systems. While solving the problem using optimization algorithm, the first step is to represent the possible solutions to the problem. Each possible solution is called as an individual. This possible solution together forms the population. Thus, the maximum profit can be achieved.

6.6.1.1 Ten Generating Unit System

This test system is used to verify the efficacy of the suggested hCHHO-SCA optimizer considering discharge and charging effect of PEVs. The system consist of 10-power generating units having a 24-hour electricity demand. The hCHHO-SCA technique is evaluated for 100 iterations. The hCHHO-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.14**. According to number of iterations the profit of the unit test systems is shown in convergence curve.

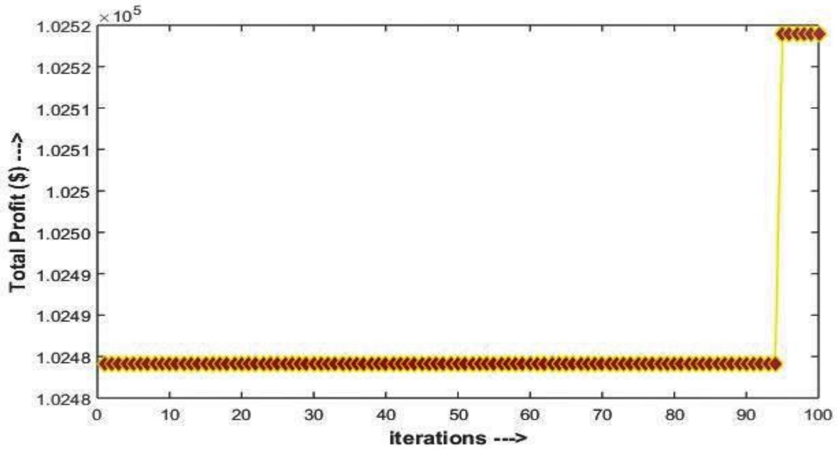
The Table-6.11a presents the commitment status and optimum scheduling of the generators during 24 hours considering PEVs. The units are presented as PGU. In this case, the PGU1 and PGU2 are on for 24 hours. PGU1 generates 455 MW of power for 24 hours. Further, displays The PGU3 generates 130 MGW of power for 10^{th}, 11^{th}, 12^{th}, 13^{th}, 14^{th} and 15^{th} hours. The PGU4 is remain off for 1 to 5 hours and 23^{rd} and 24^{th} hour. It is on only for 6^{th} hour to 22^{nd} hour. In those time, for which the PFU4 is on, it generates 130 MW power for each hour. The Table-6.11b shows the hourly profit of 10-unit system. For PGU1 and PGU2 maximum profit can be obtained because it is on for the whole day. For PGU3 the profit value differs from 2925 $ to 4114.5 $ only for 10^{th} hour to 15^{th} hour. For PGU7 to PGU10 no profit will be gained as it is not committed.

Table-6.11a: Commitment status and scheduling for 10-generating unit system using hCHHO-SCA optimization algorithm with PEVs

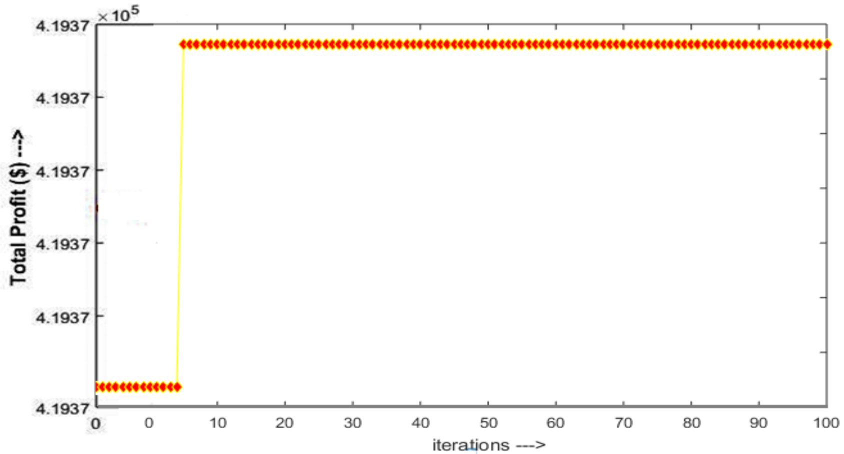
Commitment status of thermal units								Scheduling of the committed generating units						
HOURS	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**
1	1	1	0	0	0	0	0	455	277.4	0	0	0	0	0
2	1	1	0	0	0	0	0	455	316.5	0	0	0	0	0
3	1	1	0	0	0	0	0	455	416.24	0	0	0	0	0
4	1	1	0	0	1	0	0	455	455	0	0	42.35	0	0
5	1	1	0	0	1	0	0	455	455	0	0	112.99	0	0
6	1	1	0	1	1	0	0	455	455	0	130	39.24	0	0
7	1	1	0	1	1	0	0	455	443.54	0	130	25	0	0
8	1	1	0	1	1	0	0	455	433.67	0	130	25	0	0
9	1	1	0	1	1	0	0	455	455	0	130	83.24	0	0
10	1	1	1	1	1	1	0	455	455	130	130	162	22.52	0
11	1	1	1	1	1	1	0	455	455	130	130	162	46.77	0
12	1	1	1	1	1	1	0	455	455	130	130	162	31.27	0
13	1	1	1	1	1	0	0	455	455	130	130	115.27	0	0
14	1	1	1	1	1	0	0	455	455	130	130	127.53	0	0
15	1	1	1	1	1	0	0	455	455	130	130	59.02	0	0
16	1	1	0	1	0	1	0	455	441.81	0	130	0	20	0
17	1	1	0	1	0	1	0	455	429.8	0	130	0	20	0
18	1	1	0	1	0	1	0	455	455	0	130	0	40.56	0
19	1	1	0	1	0	1	0	455	455	0	130	0	41.21	0
20	1	1	0	1	0	0	0	455	408.04	0	130	0	0	0
21	1	1	0	1	0	0	0	455	438.42	0	130	0	0	0
22	1	1	0	1	0	0	0	455	407.56	0	130	0	0	0
23	1	1	0	0	0	0	0	455	409.08	0	0	0	0	0
24	1	1	0	0	0	0	0	455	300.59	0	0	0	0	0

Table-6.11b: Hourly profit for 10-generating unit system using hCHHO-SCA optimization algorithm with PEVs

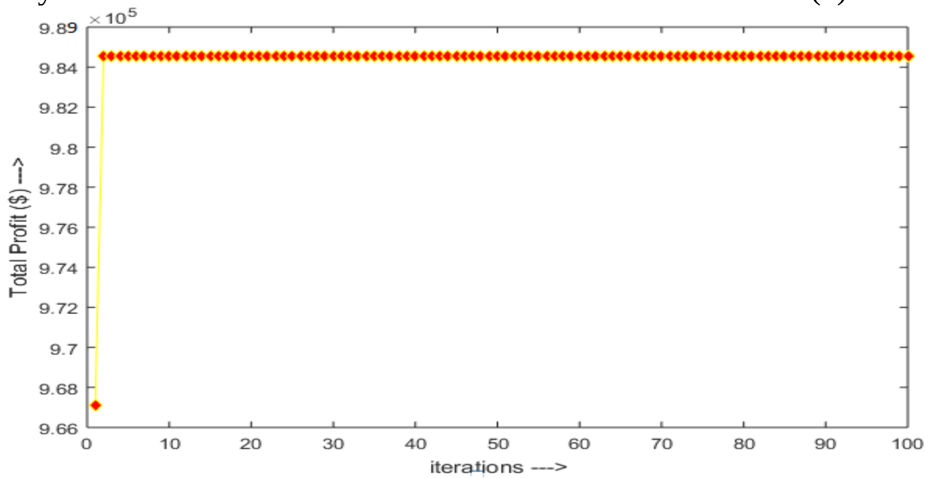
HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7 to PG10	Start-up Cost	Hourly Profit
1	10078.25	6144.41	0	0	0	0	0	2010	16222.66
2	10010	6963	0	0	0	0	0	0	16973
3	10510.5	9615.144	0	0	0	0	0	0	20125.644
4	10305.75	10305.75	0	0	959.2275	0	0	340	21570.7275
5	10578.75	10578.75	0	0	2627.0175	0	0	0	23784.5175
6	10442.25	10442.25	0	2983.5	900.558	0	0	0	24768.558
7	10237.5	9979.65	0	2925	562.5	0	0	520	23704.65
8	10078.25	9605.7905	0	2879.5	553.75	0	0	0	23117.2905
9	10374	10374	0	2964	1897.872	0	0	60	25609.872
10	13354.25	13354.25	3815.5	3815.5	4754.7	660.962001	0	0	39755.162
11	13718.25	13718.25	3919.5	3919.5	4884.3	1410.1155	0	0	41569.9155
12	14400.75	14400.75	4114.5	4114.5	5127.3	989.6955	0	0	43147.4955
13	11193	11193	3198	3198	2835.642	0	0	260	31617.642
14	11147.5	11147.5	3185	3185	3124.485	0	0	60	31789.485
15	10237.5	10237.5	2925	2925	1327.95	0	0	0	27652.95
16	10146.5	9852.363	0	2899	0	446	0	0	23343.863
17	10123.75	9563.05	0	2892.5	0	445	0	0	23024.3
18	10032.75	10032.75	0	2866.5	0	894.348	0	170	23826.348
19	10101	10101	0	2886	0	914.862	0	120	24002.862
20	10305.75	9242.106	0	2944.5	0	0	0	900	22492.356
21	10510.5	10127.502	0	3003	0	0	0	0	23641.002
22	10442.25	9353.502	0	2983.5	0	0	0	0	22779.252
23	10351.25	9306.57	0	0	0	0	0	0	19657.82
24	10260.25	6778.3045	0	0	0	0	0	1110	17038.5545



(a) 10-Unit system



(b) 40-Unit system



(c) 100-Unit system

Fig.6.14: Convergence curve for 10-, 40- and 100-generating unit system using hCHHO-SCA optimization algorithm with PEVs

6.6.1.2 Forty Generating Unit System

This test system is used to check the efficiency of the proposed hybrid CHHO-SCA optimizer considering the effect of PEVs during charging and discharging. The system contains of 40-generating unit system having a 24-hourelectricity demand. The profit analysis for each generating unit during charging as well as discharging of PEVs with proper generation scheduling and status of the committed units can easily take into consideration. The profit with start-up costand fuel cost of 24 hours are shown in Table-6.12. In this table the hourly start-up cost, fuel cost and hourly profit are shown in tabular form. The hCHHO-SCA technique is evaluated for 100 iterations. The hCHHO-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.14**. According to number of iterations the profit of the unit test systems is shown in convergence curve. The optimal scheduling of 40-generating unit systems is shown in Table-6.13a and Table-6.13b. In those table, researcher can optimize the running conditions of power generating unit and which units are kept off for the particular hour. The hourly profit table for this system is shown in Table-6.14a and Table-6.14b respectively. Those generating units are in running conditions, from those units the optimal profit can be optimized.

Table-6.12: Hourly profit with startup cost and fuel cost for 40-generating unit system using hCHHO-SCA optimization algorithm with PEVs

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	61302.34	1370	54914.0068	**13**	132218.358	580	109184.455
2	65527	1710	57843.0125	**14**	127460.515	300	105258.138
3	78049.356	1430	64835.7899	**15**	107347.05	0	95063.5711
4	81486.7725	2100	68670.4301	**16**	92616.137	320	80736.3769
5	92465.4825	1850	77065.8377	**17**	88225.7	290	77441.5748
6	94571.442	1120	80167.6023	**18**	90833.652	1620	81642.7121
7	93295.35	180	80618.3292	**19**	91437.138	1540	81613.0084
8	92062.7095	1120	80791.4565	**20**	95287.644	460	82640.2475
9	107770.128	260	94396.278	**21**	96478.998	550	81946.7239
10	165694.838	2430	116132.957	**22**	96560.748	2020	82299.8875
11	171289.085	990	117717.794	**23**	82717.18	2560	69954.3475
12	180301.505	430	118025.558	**24**	73161.4455	1330	62179.7393

Table-6.13a: Generation scheduling for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with PEVs

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU-10	PGU-11	PGU-12	PGU-13	PGU-14	PGU-15	PGU-16	PGU-17	PGU-18	PGU-19	PGU-20
1	455	234.4	0	0	0	0	0	0	0	0	455	234.4	0	0	0	0	0	0	0	0
2	455	289.625	0	0	0	0	0	0	0	0	455	289.625	0	0	0	0	0	0	0	0
3	455	389.69	0	0	0	0	0	0	0	0	455	389.69	0	0	0	0	0	0	0	0
4	455	444.4125	0	0	0	0	0	0	0	0	455	444.4125	0	0	0	0	0	0	0	0
5	455	441.7525	0	130	0	0	0	0	0	0	455	441.7525	0	130	0	0	0	0	0	0
6	455	445.19	0	130	0	0	0	0	0	0	455	445.19	0	130	0	0	0	0	0	0
7	455	451.615	0	130	0	0	0	0	0	0	455	451.615	0	130	0	0	0	0	0	0
8	455	454.0825	0	130	0	0	0	0	0	0	455	454.0825	0	130	0	0	0	0	0	0
9	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
10	455	455	130	130	162	79.37	0	0	0	0	455	455	130	130	162	79.37	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	33.23	0	0
12	455	455	130	130	162	80	48.73	0	0	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	162	0	46.73	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	156.8675	0	25	0	0	0	455	455	130	130	156.8675	0	0	0	0	0
15	455	455	0	130	152.745	0	0	0	0	0	455	455	0	130	152.745	0	0	0	0	0
16	455	453.2975	0	130	0	0	0	0	0	0	455	453.2975	0	130	0	0	0	0	0	0
17	455	406.3	0	130	0	0	0	0	0	0	455	406.3	0	130	0	0	0	0	0	0
18	455	436.11	0	130	0	0	0	0	10	0	455	436.11	0	130	0	0	25	0	0	0
19	455	435.9475	0	130	0	0	0	0	0	0	455	435.9475	0	130	0	0	25	0	0	0
20	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	46.96	0	0	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	434.36	130	130	0	0	0	0	0	0	455	434.36	0	130	0	0	0	0	0	0
23	455	421.48	130	0	0	0	0	0	0	0	455	421.48	0	0	0	0	0	0	0	0
24	455	431.47	130	0	0	0	0	0	0	0	455	431.47	0	0	0	0	0	0	0	0

Table-6.13b: Generation scheduling for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40) with PEVs

HOURS	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	234.4	0	0	0	0	0	0	0	0	455	234.4	0	0	0	0	0	10	0	0
2	455	289.625	0	0	0	0	0	0	0	0	455	289.625	0	0	0	0	0	0	0	0
3	455	389.69	0	0	0	0	0	0	0	0	455	389.69	0	0	0	0	0	0	0	0
4	455	444.4125	0	0	0	0	0	0	0	0	455	444.4125	0	0	0	0	0	0	0	0
5	455	441.7525	0	130	0	0	0	0	0	0	455	441.7525	0	0	0	0	0	0	0	0
6	455	445.19	0	130	0	0	0	0	0	0	455	445.19	0	130	0	0	0	0	0	0
7	455	451.615	0	130	0	0	0	0	0	0	455	451.615	0	130	0	0	0	0	0	0
8	455	454.0825	0	130	0	0	0	0	0	0	455	454.0825	0	130	0	0	0	0	0	0
9	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	46.76
10	455	455	130	130	162	79.37	0	0	0	0	455	455	130	130	162	79.37	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	156.8675	0	0	0	0	0	455	455	0	130	156.8675	0	0	0	0	0
15	455	455	0	130	152.745	0	0	0	0	0	455	455	0	130	152.745	0	0	0	0	0
16	455	453.2975	0	130	0	0	0	0	0	0	455	453.2975	0	130	0	0	0	0	0	0
17	455	406.3	0	130	0	0	0	0	0	0	455	406.3	0	130	0	0	0	0	0	0
18	455	436.11	0	130	0	0	0	0	0	0	455	436.11	0	130	0	0	0	0	0	0
19	455	435.9475	0	130	0	0	0	10	0	0	455	435.9475	0	130	0	0	0	0	0	0
20	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
21	455	455	0	130	0	0	0	16.58	0	0	455	455	0	130	0	0	0	0	0	0
22	455	434.36	0	130	0	0	0	0	0	0	455	434.36	0	130	0	0	0	0	0	0
23	455	421.48	0	0	0	0	0	0	0	0	455	421.48	0	0	0	0	0	0	0	0
24	455	431.47	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0

Table-6.13a represents the optimal scheduling of power PGU1 to PGU20 for 40-unit test system with effect of PEVs. The PGU8, PGU10, PGU19 and PGU20 is off for 24 hours, while PGU1, PGU2, PGU11 and PGU12 is always on for 24 hours. PGU9 gives 10MW only for 18^{th} hour as it is on in that particular hour. The rest of the PGU are sometimes remain on and sometimes remain off to give the optimal output. PGU18 gives 33.23 MW for 11^{th} hour and other times it remains off. So, the power output is 0 MW for remaining hours.

In the Table-6.13b shows the scheduling for PGU21 to PGU40 unit for 40-unit system with PEVs. The PGU21, PGU22, PGU31 and PGU32 is remaining always on for 24 hours. The PGU27, PGU29, PGU30, PGU37 and PGU39 are off for whole day. The PGU38 is on only for 1^{th} hours and 10 MW power is generated from that particular hour. PGU40 is generated 46.76 MW power for 9^{th} hour. PGU36 is remaining on from 10^{th} hours to 12^{th} hours. In 10^{th} hour it gives 79.37 MW of power and from 11^{th} and 12^{th} hour it gives 80 MW power. Remaining hours PGU36 is not committed and thus the power output is 0 MW for remaining hours.

The hourly profit for 40-test system is shown in Table-6.14a and Table-6.14b. The Table-6.14a shows the hourly profit for PGU20 unit for 24 hours. The maximum amount of profit can be measured from the PGU1, PGU2, PGU11 and PGU12 as it was on for the whole day. The PGU8, PGU10, PGU19 and PGU20 remain off for 24 hours. The other units are gives several amount of profit for that particular hour when it was on. For PGU9 at 18^{th} hour 220.5 $ profit can be measured.

Table-6.14b shows that the hourly profit of PGU21 to PGU40 for this test system for 24 hours. PGU21, PGU22, PGU31 and PGU32 are remain on for 24 hours, that why the profit from these units are maximum. For PGU38 the profit is 221.5 $ only for 1^{th} hour as it was on for that hour only. For PGU25 maximum 5127.3 $ profit can be obtained for 12^{th} hours and others are varying from 3436.7625 $ to 4884.3 $ and ‘0’ for that particular hour when it is in off condition.

Table-6.14a: Hourly profit for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with PEVs

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	10078.25	5191.96	0	0	0	0	0	0	0	0	10078.25	5191.96	0	0	0	0	0	0	0	0
2	10010	6371.75	0	0	0	0	0	0	0	0	10010	6371.75	0	0	0	0	0	0	0	0
3	10510.5	9001.839	0	0	0	0	0	0	0	0	10510.5	9001.839	0	0	0	0	0	0	0	0
4	10305.75	10065.9431	0	0	0	0	0	0	0	0	10305.75	10065.9431	0	0	0	0	0	0	0	0
5	10578.75	10270.7456	0	3022.5	0	0	0	0	0	0	10578.75	10270.7456	0	3022.5	0	0	0	0	0	0
6	10442.25	10217.1105	0	2983.5	0	0	0	0	0	0	10442.25	10217.1105	0	2983.5	0	0	0	0	0	0
7	10237.5	10161.3375	0	2925	0	0	0	0	0	0	10237.5	10161.3375	0	2925	0	0	0	0	0	0
8	10078.25	10057.9274	0	2879.5	0	0	0	0	0	0	10078.25	10057.9274	0	2879.5	0	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2329.509	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2329.5095	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	1001.8845	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	1542.30	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3985.2	0	1149.558	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3843.2537	0	612.5	0	0	0	11147.5	11147.5	3185	3185	3843.25375	0	0	0	0	0
15	10237.5	10237.5	0	2925	3436.7625	0	0	0	0	0	10237.5	10237.5	0	2925	3436.7625	0	0	0	0	0
16	10146.5	10108.5343	0	2899	0	0	0	0	0	0	10146.5	10108.5343	0	2899	0	0	0	0	0	0
17	10123.75	9040.175	0	2892.5	0	0	0	0	0	0	10123.75	9040.175	0	2892.5	0	0	0	0	0	0
18	10032.75	9616.2255	0	2866.5	0	0	0	0	220.5	0	10032.75	9616.2255	0	2866.5	0	0	551.25	0	0	0
19	10101	9678.0345	0	2886	0	0	0	0	0	0	10101	9678.0345	0	2886	0	0	555	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	1063.644	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	9968.562	2983.5	2983.5	0	0	0	0	0	0	10442.25	9968.562	0	2983.5	0	0	0	0	0	0
23	10351.25	9588.67	2957.49999	0	0	0	0	0	0	0	10351.25	9588.67	0	0	0	0	0	0	0	0
24	10260.25	9729.6485	2931.5	0	0	0	0	0	0	0	10260.25	9729.6485	0	0	0	0	0	0	0	0

Table-6.14b: Hourly profit for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40) with PEVs

HOURS	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PG34	PGU35	GPU36	PGU37	PGU 38	PGU39	PGU 40
1	10078.25	5191.96	0	0	0	0	0	0	0	0	10078.25	5191.96	0	0	0	0	0	221.5	0	0
2	10010	6371.75	0	0	0	0	0	0	0	0	10010	6371.75	0	0	0	0	0	0	0	0
3	10510.5	9001.839	0	0	0	0	0	0	0	0	10510.5	9001.839	0	0	0	0	0	0	0	0
4	10305.75	10065.9431	0	0	0	0	0	0	0	0	10305.75	10065.9431	0	0	0	0	0	0	0	0
5	10578.75	10270.7456	0	3022.5	0	0	0	0	0	0	10578.75	10270.7456	0	0	0	0	0	0	0	0
6	10442.25	10217.1105	0	2983.5	0	0	0	0	0	0	10442.25	10217.1105	0	2983.5	0	0	0	0	0	0
7	10237.5	10161.3375	0	2925	0	0	0	0	0	0	10237.5	10161.3375	0	2925	0	0	0	0	0	0
8	10078.25	10057.9274	0	2879.5	0	0	0	0	0	0	10078.25	10057.9274	0	2879.5	0	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	1066.128
10	13354.25	13354.25	3815.5	3815.5	4754.7	2329.5095	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2329.5095	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3843.25375	0	0	0	0	0	11147.5	11147.5	0	3185	3843.25375	0	0	0	0	0
15	10237.5	10237.5	0	2925	3436.7625	0	0	0	0	0	10237.5	10237.5	0	2925	3436.7625	0	0	0	0	0
16	10146.5	10108.5343	0	2899	0	0	0	0	0	0	10146.5	10108.5343	0	2899	0	0	0	0	0	0
17	10123.75	9040.175	0	2892.5	0	0	0	0	0	0	10123.75	9040.175	0	2892.5	0	0	0	0	0	0
18	10032.75	9616.2255	0	2866.5	0	0	0	0	0	0	10032.75	9616.2255	0	2866.5	0	0	0	0	0	0
19	10101	9678.0345	0	2886	0	0	0	222	0	0	10101	9678.0345	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	382.998	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	9968.562	0	2983.5	0	0	0	0	0	0	10442.25	9968.562	0	2983.5	0	0	0	0	0	0
23	10351.25	9588.67	0	0	0	0	0	0	0	0	10351.25	9588.67	0	0	0	0	0	0	0	0
24	10260.25	9729.6485	0	0	0	0	0	0	0	0	10260.25	0	0	0	0	0	0	0	0	0

6.6.1.3 Hundred Generating Unit System

This test system is used to check the efficiency of the proposed hybrid CHHO-SCA optimizer considering the effect of PEVs. The system contains of 100-generating unit system having a 24-hour electricity demand. The issue of electrical load fluctuations in the distribution side networks and expanding the cost of power grid cost caused by the unpredictable nature of PEVs. So, the optimum management for charging as well as discharging nature of PEVs users may provide electricity supply for power grid in case of shortage of power, alleviate balance of electricity demand as well as supply and it has a great significance to improvement of the power grid stability. The profit analysis for each generating unit during charging as well as discharging of PEVs with proper generation scheduling and status of the committed units can easily take into consideration. The spinning reserve is not considered due to maximize the profit values. The hCHHO-SCA technique is evaluated for 100 iterations. The hCHHO-SCA algorithm is verified for 30 trial runs. Table-6.15 shows the hourly profit with start-up cost and fuel cost for100-generating unit system using hCHHO-SCA optimization algorithm with PEVs. The convergence graph of total profit is shown in **Fig.6.14**. The optimal scheduling of 100-generating unit systems are shown in Table-6.16a to Table-6.16e. The hourly profit table for this system is shown in Table-6.17a to Table-6.17e respectively.

Table-6.15: Hourly profit with start-up cost and fuel cost for100-generating unit system using hCHHO-SCA optimization algorithm with PEVs

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	155767.66	4710	133642.83	**13**	326522.44	750	271113.46
2	165473	2760	143379.89	**14**	318439.49	2100	261638.28
3	196840.64	5390	165590.22	**15**	270652.95	750	239619.41
4	207074.23	7200	179511.51	**16**	232071.86	120	202995.41
5	233034.52	5320	198855.96	**17**	223274.3	1870	194728.89
6	239580.56	760	208635.89	**18**	230214.35	510	204905.24
7	234304.65	320	208101.66	**19**	231794.86	2160	206523.22
8	230441.29	1970	207896.83	**20**	234496.36	2890	204637.04
9	265693.87	15870	230644.49	**21**	239857	2840	203515.69
10	409565.16	2930	293986.52	**22**	237591.25	3800	201369.74
11	424716.12	1690	298113.76	**23**	203932.82	4730	174043.54
12	445355.7	180	297116.54	**24**	179398.55	3840	153929.64

Table-6.16a: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with PEVs

HOUR	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	455	413.73333	0	0	0	0	0	0	0	0	455	413.73333	0	0	0	0	0	0	0	0
2	455	451.91667	0	130	0	0	0	0	0	0	455	451.91667	0	0	0	0	0	0	0	0
3	455	445.20667	130	130	0	0	0	0	0	0	455	445.20667	0	0	0	0	0	0	0	0
4	455	440.39167	130	130	0	0	0	0	0	0	455	440.39167	130	130	0	0	0	0	0	0
5	455	455	130	130	142.99001	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
6	455	455	130	130	139.81	0	0	0	0	0	455	455	130	130	139.81	0	0	0	0	0
7	455	455	130	130	133.385	0	0	0	0	0	455	455	130	130	133.385	0	0	0	0	0
8	455	455	130	130	130.9175	0	0	0	0	0	455	455	130	130	130.9175	0	0	0	0	0
9	455	455	0	130	150.81	0	0	0	0	0	455	455	0	130	150.81	0	0	0	0	0
10	455	455	0	130	162	80	0	55	0	0	455	455	0	130	162	80	83.69	0	0	0
11	455	455	0	130	162	80	0	55	0	0	455	455	0	130	162	80	80.196667	0	0	0
12	455	455	0	130	162	80	0	0	0	0	455	455	0	130	162	80	84.585556	0	0	0
13	455	455	0	130	162	0	0	0	0	0	455	455	0	130	162	80	0	0	0	0
14	455	455	130	130	156.39222	0	0	0	0	0	455	455	130	130	156.39222	0	0	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
16	455	442.681	130	130	0	0	0	0	0	0	455	442.681	130	130	0	0	0	0	0	0
17	455	444.48	130	130	0	0	0	0	0	0	455	444.48	130	130	0	0	0	0	0	0
18	455	455	130	130	0	75.14	0	0	0	0	455	455	130	130	0	75.14	0	0	0	0
19	455	455	0	130	0	70.15125	0	0	0	0	455	455	0	130	0	70.15125	0	0	0	0
20	455	455	0	130	0	75.38	0	0	0	0	455	455	0	130	0	75.38	0	0	0	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	450.256	0	130	0	0	0	0	0	0	455	450.256	0	130	0	0	0	0	0	0
23	455	421.76	0	0	0	0	0	0	0	0	455	421.76	0	0	0	0	0	0	0	0
24	455	415.93167	0	0	0	0	0	0	0	0	455	415.93167	0	0	0	0	0	0	0	0

Table-6.16b: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40) with PEVs

HOUR	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	413.73333	0	0	0	0	0	0	0	0	455	413.73333	0	0	0	0	0	0	0	0
2	455	451.91667	0	130	0	0	0	0	0	0	455	451.91667	0	0	0	0	0	0	0	0
3	455	445.20667	0	130	0	0	0	0	0	0	455	445.20667	0	130	0	0	0	0	0	0
4	455	440.39167	130	130	0	0	0	0	0	0	455	440.39167	130	130	0	0	0	0	0	0
5	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
6	455	455	130	130	139.81	0	0	0	0	0	455	455	130	130	139.81	0	0	0	0	0
7	455	455	130	130	133.385	0	0	0	0	0	455	455	130	130	133.385	0	0	0	0	0
8	455	455	130	130	130.9175	0	0	0	0	0	455	455	130	130	130.9175	0	0	0	0	0
9	455	455	0	130	150.81	0	0	0	0	0	455	455	0	130	150.81	0	0	0	0	0
10	455	455	0	130	162	80	83.69	0	0	0	455	455	0	130	162	80	0	0	0	0
11	455	455	0	130	162	80	80.196667	0	0	0	455	455	0	130	162	80	80.196667	0	0	0
12	455	455	0	130	162	80	84.585556	0	0	0	455	455	0	130	162	80	84.585556	0	0	0
13	455	455	0	130	162	0	0	0	0	0	455	455	0	130	162	80	43.27	0	0	0
14	455	455	130	130	156.39222	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
16	455	442.681	130	130	0	0	0	0	0	0	455	442.681	130	130	0	0	0	0	0	0
17	455	444.48	130	130	0	0	0	0	0	0	455	444.48	130	0	0	0	0	0	0	0
18	455	455	130	130	0	75.14	0	0	0	0	455	455	130	0	0	0	0	0	0	0
19	455	455	130	130	0	70.15125	0	0	0	0	455	455	0	0	0	70.15125	0	0	0	0
20	455	455	130	0	0	75.38	0	0	0	0	455	455	0	0	0	75.38	0	0	0	0
21	455	455	130	0	0	0	0	0	0	0	455	455	0	0	0	60.855	0	0	0	0
22	455	450.256	0	0	0	0	0	0	0	0	455	450.256	0	130	0	0	0	0	0	0
23	455	421.76	0	0	0	0	0	0	0	0	455	421.76	0	130	0	0	0	0	0	0
24	455	415.93167	0	0	0	0	0	0	0	0	455	415.93167	0	130	0	0	0	0	0	0

The Table-6.16a represents the generation scheduling of 100-generating unit system with effect of PEVs using hCHHO-SCA optimization algorithm for PGU1 to PGU20. Where PGU1, PGU2, PGU11 and PGU12 are remain on for 24 hours. The 455 MW power output can be measured from PGU1 and PGU11 for 24 hours. PGU7, PGU8, PGU10 and PGU18 to PGU20 is totally off for 24 hours. So, no power generation can be obtained from those units. Further others unit are on for some few hours and off some few hours. Thus the optimal generation can be taken only those are in on condition.

Table-6.16b gives the optimal power scheduling of 100-uniut system with effect of PEVs by suggested hCHHO-SCA method for PGU21 to PGU40. The PGU21, PGU22, PGU31 and PGU32 are in on condition for 24 hours. And other PGU are sometimes on and sometimes off. PGU28 to PGU30 and PGU38 to PGU40 are off during 24 hours.

Table-6.16c presents the generation scheduling of 100-unit system with effect of PEVs using proposed hCHHO-SCA optimization algorithm for PGU41 to PGU60. Here, PGU41, PGU42, PGU51 and PGU52 are on for 24 hours. The 455 MW power can be generated from PGU41 and PGU51. The output power is '0' for PGU48 to PGU50 and PGU58 to PGU60. The PGU47 and PGU57 generate same power for 10^{th} to 12^{th} hours, i.e. 83.69 MW for 10^{th}, 80.196667 MW for 11^{th} and 84.585556 MW for 12^{th} hour. The other PGU are on and off for few hours and output power generation can be measured through the table.

Thable-6.16d signifies the generation scheduling of 100-generating unit by hCHHO-SCA algorithm for PGU61 to PGU80 considering the effect of PEVs. The PGU61 and PGU71 is on for 24 hours. The 455 MW power output can be shown from PGU61 and PGU71 for 24 hours. The power output from PGU66 and PGU68 to PGU68 to PGU70 and PGU78 to PGU80 is '0' for 24 hours. The PGU67 and PGU77 generate same power for 10^{th} to 12^{th} hours, i.e. 83.69 MW for 10^{th}, 80.196667 MW for 11^{th} and 84.585556 MW for 12^{th} hour.

Table-6.16c: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 41-60) with PEVs

Hour	PGU41	PGU42	PGU43	PGU44	PGU45	PGU46	PGU47	PGU48	PGU49	PGU50	PGU51	PGU52	PGU53	PGU54	PGU55	PGU56	PGU57	PGU58	PGU59	PGU60
1	455	413.73333	0	0	0	0	0	0	0	0	455	413.73333	0	0	0	0	0	0	0	0
2	455	451.91667	0	0	0	0	0	0	0	0	455	451.91667	0	0	0	0	0	0	0	0
3	455	445.20667	0	130	0	0	0	0	0	0	455	445.20667	0	130	0	0	0	0	0	0
4	455	440.39167	130	130	0	0	0	0	0	0	455	440.39167	0	130	0	0	0	0	0	0
5	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
6	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
7	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
8	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
9	455	455	0	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
10	455	455	0	130	162	0	83.69	0	0	0	455	455	130	130	162	0	83.69	0	0	0
11	455	455	0	130	162	0	80.196667	0	0	0	455	455	130	130	162	80	80.196667	0	0	0
12	455	455	0	130	162	0	84.585556	0	0	0	455	455	130	130	162	80	84.585556	0	0	0
13	455	455	0	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
14	455	455	130	130	156.39222	20	0	0	0	0	455	455	130	130	156.39222	0	0	0	0	0
15	455	455	130	130	159.83667	20	0	0	0	0	455	455	0	130	159.83667	0	0	0	0	0
16	455	442.681	130	130	0	0	0	0	0	0	455	442.681	0	0	0	0	0	0	0	0
17	455	444.48	130	0	0	0	0	0	0	0	455	444.48	0	0	0	0	0	0	0	0
18	455	455	130	0	0	0	0	0	0	0	455	455	0	0	0	75.14	0	0	0	0
19	455	455	130	0	0	70.15125	0	0	0	0	455	455	0	0	0	70.15125	0	0	0	0
20	455	455	0	0	0	75.38	0	0	0	0	455	455	130	0	0	75.38	0	0	0	0
21	455	455	0	0	0	60.855	0	0	0	0	455	455	130	130	0	0	0	0	0	0
22	455	450.256	0	0	0	0	0	0	0	0	455	450.256	130	130	0	0	0	0	0	0
23	455	421.76	0	0	0	0	0	0	0	0	455	421.76	130	130	0	0	0	0	0	0
24	455	0	0	0	0	0	0	0	0	0	455	415.93167	130	130	0	0	0	0	0	0

Table-6.16d: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 61-80) with PEVs

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
4	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
5	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
6	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
7	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
8	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
9	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
10	455	455	130	130	162	0	83.69	0	0	0	455	455	130	130	162	80	83.69	0	0	0
11	455	455	130	130	162	0	80.196667	0	0	0	455	455	130	130	162	80	80.196667	0	0	0
12	455	455	130	130	162	0	84.585556	0	0	0	455	455	130	130	162	80	84.585556	0	0	0
13	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	0	0	0
14	455	455	130	130	156.39222	0	0	0	0	0	455	455	0	130	156.39222	0	0	0	0	0
15	455	455	0	130	159.83667	0	0	0	0	0	455	455	0	130	159.83667	0	0	0	0	0
16	455	442.681	0	130	0	0	0	0	0	0	455	442.681	0	0	0	0	0	0	0	0
17	455	444.48	0	0	0	0	0	0	0	0	455	444.48	0	0	0	0	0	0	0	0
18	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
19	455	455	0	0	0	0	0	0	0	0	455	455	130	0	0	70.15125	0	0	0	0
20	455	455	0	0	0	0	0	0	0	0	455	455	130	0	0	75.38	0	0	0	0
21	455	455	0	0	0	0	0	0	0	0	455	455	130	130	0	60.855	0	0	0	0
22	455	450.256	0	130	0	0	0	0	0	0	455	450.256	130	130	0	0	0	0	0	0
23	455	421.76	0	130	0	0	0	0	0	0	455	421.76	130	130	0	0	0	0	0	0
24	455	415.93167	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0

Table-6.16e: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 81-100) with PEVs

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
4	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
5	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
6	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
7	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
8	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
9	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
10	455	455	130	130	162	80	83.69	0	0	0	455	455	130	130	162	80	83.69	0	0	0
11	455	455	130	130	162	80	80.196667	0	0	0	455	455	130	130	162	80	80.196667	0	0	0
12	455	455	130	130	162	80	84.585556	0	0	0	455	455	130	130	162	80	84.585556	0	0	0
13	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
14	455	455	130	130	156.39222	0	0	0	0	0	455	455	130	130	156.39222	0	0	0	0	0
15	455	455	0	130	159.83667	0	0	0	0	0	455	455	0	130	159.83667	0	0	0	0	0
16	455	442.681	0	0	0	0	0	0	0	0	455	442.681	0	0	0	0	0	0	0	0
17	455	444.48	0	0	0	0	0	0	0	0	455	444.48	0	0	0	0	0	0	0	0
18	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
19	455	455	0	0	0	70.15125	0	0	0	0	455	455	0	0	0	0	0	0	0	0
20	455	455	0	0	0	75.38	0	0	0	0	455	455	0	0	0	0	0	0	0	0
21	455	455	0	0	0	60.855	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	450.256	0	130	0	0	0	0	0	0	455	450.256	0	130	0	0	0	0	0	0
23	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
24	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0

Table-6.16e gives the optimal power scheduling of 100-unit system by suggested hCHHO-SCA method for PGU81 to PGU100 considering the effect of PEVs. PGU88 to PGU90 and PGU98 to PGU100 is totally off throughout the day. So, no power generation can be obtained from those units. Further others unit are on for some few hours and off some few hours. Thus the optimal generation can be taken only those are in on condition.

Table-6.17a shows the best profit of PGU1 to PGU20 for each unit for particular hours considering the effect of PEVs. The duration of total hour is 24 hours. The suggested hCHHO-SCA optimizer is tested on 100-unit system. The profit from PGU8 can be obtained for 10^{th} and 11^{th} hours, i.e. 1614.25 $ for 10^{th} and 1658.25 $ for 11^{th} hours and for the other hours it remains off.

Table-6.17b represents the hourly profit for 100-generating unit system by hCHHO-SCA optimizer for PGU21 to PGU40 with PEVs. The PGU21, PGU22, PGU31 and PGU32 are on throughout 24 hours. So, for those units the profit values are obtained in each hour. The PGU27 is on only for 10^{th} to 12^{th} hours and the profit can be obtained as 2456.3015 $ for 10^{th} hour, 2417.9295 $ for 11^{th} hour and 2677.1328 $ for 12^{th} hour and for other time period it will be off throughout the day.

The Table-6.17c is presented the hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm for units 41 to unit 60 with PEVs. The PGU41, PGU51 and PGU52 remain on for 24 hours. The PGU48 to PGU50 and PGU58 to PGU60 remain close throughout the whole day. That’s why no profit come from those units, the output is ‘0’.

The Table-6.17d and Table-6.17e is presented the hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm for PGU61 to PGU80 and PGU81 to PGU100 with PEVs. The PGU61, PGU71, PGU81 and PGU92 remain on for 24 hours. The PGU68 to PGU70 and PGU78 to PGU80 as well as PGU88 to PGU90 and PGU98 to PGU100 remain close throughout the whole day. That’s why no profit come from those units, the output is ‘0’.

Table-6.17a: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 21-40) with PEVs

Hour	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	10078.25	9164.1933	0	0	0	0	0	0	0	0	10078.25	9164.1933	0	0	0	0	0	0	0	0
2	10010	9942.1667	0	2860	0	0	0	0	0	0	10010	9942.1667	0	0	0	0	0	0	0	0
3	10510.5	10284.274	3003	3003	0	0	0	0	0	0	10510.5	10284.274	0	0	0	0	0	0	0	0
4	10305.75	9974.8713	2944.5	2944.5	0	0	0	0	0	0	10305.75	9974.8713	2944.5	2944.5	0	0	0	0	0	0
5	10578.75	10578.75	3022.5	3022.5	3324.5177	0	0	0	0	0	10578.75	10578.75	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	10442.25	2983.5	2983.5	3208.6395	0	0	0	0	0	10442.25	10442.25	2983.5	2983.5	3208.6395	0	0	0	0	0
7	10237.5	10237.5	2925	2925	3001.1625	0	0	0	0	0	10237.5	10237.5	2925	2925	3001.1625	0	0	0	0	0
8	10078.25	10078.25	2879.5	2879.5	2899.8226	0	0	0	0	0	10078.25	10078.25	2879.5	2879.5	2899.8226	0	0	0	0	0
9	10374	10374	0	2964	3438.468	0	0	0	0	0	10374	10374	0	2964	3438.468	0	0	0	0	0
10	13354.25	13354.25	0	3815.5	4754.7	2348	0	1614.25	0	0	13354.25	13354.25	0	3815.5	4754.7	2348	2456.3015	0	0	0
11	13718.25	13718.25	0	3919.5	4884.3	2412	0	1658.25	0	0	13718.25	13718.25	0	3919.5	4884.3	2412	2417.9295	0	0	0
12	14400.75	14400.75	0	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	0	4114.5	5127.3	2532	2677.1328	0	0	0
13	11193	11193	0	3198	3985.2	0	0	0	0	0	11193	11193	0	3198	3985.2	1968	0	0	0	0
14	11147.5	11147.5	3185	3185	3831.6094	0	0	0	0	0	11147.5	11147.5	3185	3185	3831.6094	0	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
16	10146.5	9871.7863	2899	2899	0	0	0	0	0	0	10146.5	9871.7863	2899	2899	0	0	0	0	0	0
17	10123.75	9889.68	2892.5	2892.5	0	0	0	0	0	0	10123.75	9889.68	2892.5	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	2866.5	2866.5	0	1656.837	0	0	0	0	10032.75	10032.75	2866.5	2866.5	0	1656.837	0	0	0	0
19	10101	10101	0	2886	0	1557.3578	0	0	0	0	10101	10101	0	2886	0	1557.3578	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	1707.357	0	0	0	0	10305.75	10305.75	0	2944.5	0	1707.357	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10333.375	0	2983.5	0	0	0	0	0	0	10442.25	10333.375	0	2983.5	0	0	0	0	0	0
23	10351.25	9595.04	0	0	0	0	0	0	0	0	10351.25	9595.04	0	0	0	0	0	0	0	0
24	10260.25	9379.2591	0	0	0	0	0	0	0	0	10260.25	9379.2591	0	0	0	0	0	0	0	0

Table-6.17b: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 21-40) with PEVs

Hour	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	10078.25	9164.1933	0	0	0	0	0	0	0	0	10078.25	9164.1933	0	0	0	0	0	0	0	0
2	10010	9942.1667	0	2860	0	0	0	0	0	0	10010	9942.1667	0	0	0	0	0	0	0	0
3	10510.5	10284.274	0	3003	0	0	0	0	0	0	10510.5	10284.274	0	3003	0	0	0	0	0	0
4	10305.75	9974.8713	2944.5	2944.5	0	0	0	0	0	0	10305.75	9974.8713	2944.5	2944.5	0	0	0	0	0	0
5	10578.75	10578.75	3022.5	3022.5	0	0	0	0	0	0	10578.75	10578.75	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	10442.25	2983.5	2983.5	3208.6395	0	0	0	0	0	10442.25	10442.25	2983.5	2983.5	3208.6395	0	0	0	0	0
7	10237.5	10237.5	2925	2925	3001.1625	0	0	0	0	0	10237.5	10237.5	2925	2925	3001.1625	0	0	0	0	0
8	10078.25	10078.25	2879.5	2879.5	2899.8226	0	0	0	0	0	10078.25	10078.25	2879.5	2879.5	2899.8226	0	0	0	0	0
9	10374	10374	0	2964	3438.468	0	0	0	0	0	10374	10374	0	2964	3438.468	0	0	0	0	0
10	13354.25	13354.25	0	3815.5	4754.7	2348	2456.3015	0	0	0	13354.25	13354.25	0	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	0	3919.5	4884.3	2412	2417.9295	0	0	0	13718.25	13718.25	0	3919.5	4884.3	2412	2417.9295	0	0	0
12	14400.75	14400.75	0	4114.5	5127.3	2532	2677.1328	0	0	0	14400.75	14400.75	0	4114.5	5127.3	2532	2677.1328	0	0	0
13	11193	11193	0	3198	3985.2	0	0	0	0	0	11193	11193	0	3198	3985.2	1968	1064.442	0	0	0
14	11147.5	11147.5	3185	3185	3831.6094	0	0	0	0	0	11147.5	11147.5	3185	3185	0	0	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
16	10146.5	9871.7863	2899	2899	0	0	0	0	0	0	10146.5	9871.7863	2899	2899	0	0	0	0	0	0
17	10123.75	9889.68	2892.5	2892.5	0	0	0	0	0	0	10123.75	9889.68	2892.5	0	0	0	0	0	0	0
18	10032.75	10032.75	2866.5	2866.5	0	1656.837	0	0	0	0	10032.75	10032.75	2866.5	0	0	0	0	0	0	0
19	10101	10101	2886	2886	0	1557.3578	0	0	0	0	10101	10101	0	0	0	1557.3578	0	0	0	0
20	10305.75	10305.75	2944.5	0	0	1707.357	0	0	0	0	10305.75	10305.75	0	0	0	1707.357	0	0	0	0
21	10510.5	10510.5	3003	0	0	0	0	0	0	0	10510.5	10510.5	0	0	0	1405.7505	0	0	0	0
22	10442.25	10333.375	0	0	0	0	0	0	0	0	10442.25	10333.375	0	2983.5	0	0	0	0	0	0
23	10351.25	9595.04	0	0	0	0	0	0	0	0	10351.25	9595.04	0	2957.5	0	0	0	0	0	0
24	10260.25	9379.2591	0	0	0	0	0	0	0	0	10260.25	9379.2591	0	2931.5	0	0	0	0	0	0

Table-6.17c: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 41-60) with PEVs

Hour	PGU41	PGU42	PGU43	PGU 44	PGU45	PGU46	PGU 47	PGU48	PGU49	PGU50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PGU56	PGU 57	PGU 58	PGU 59	PGU 60
1	10078.25	9164.1933	0	0	0	0	0	0	0	0	10078.25	9164.1933	0	0	0	0	0	0	0	0
2	10010	9942.1667	0	0	0	0	0	0	0	0	10010	9942.1667	0	0	0	0	0	0	0	0
3	10510.5	10284.274	0	3003	0	0	0	0	0	0	10510.5	10284.274	0	3003	0	0	0	0	0	0
4	10305.75	9974.8713	2944.5	2944.5	0	0	0	0	0	0	10305.75	9974.8713	0	2944.5	0	0	0	0	0	0
5	10578.75	10578.75	3022.5	3022.5	0	0	0	0	0	0	10578.75	10578.75	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	10442.25	2983.5	2983.5	0	0	0	0	0	0	10442.25	10442.25	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
8	10078.25	10078.25	2879.5	2879.5	0	0	0	0	0	0	10078.25	10078.25	2879.5	2879.5	0	0	0	0	0	0
9	10374	10374	0	2964	0	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	0	3815.5	4754.7	0	2456.3015	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	2456.3015	0	0	0
11	13718.25	13718.25	0	3919.5	4884.3	0	2417.9295	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	2417.9295	0	0	0
12	14400.75	14400.75	0	4114.5	5127.3	0	2677.1328	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2677.1328	0	0	0
13	11193	11193	0	3198	3985.2	1968	0	0	0	0	11193	11193	3198	3198	3985.2	1968	0	0	0	0
14	11147.5	11147.5	3185	3185	3831.6094	490.00001	0	0	0	0	11147.5	11147.5	3185	3185	3831.6094	0	0	0	0	0
15	10237.5	10237.5	2925	2925	3596.325	450	0	0	0	0	10237.5	10237.5	0	2925	3596.325	0	0	0	0	0
16	10146.5	9871.7863	2899	2899	0	0	0	0	0	0	10146.5	9871.7863	0	0	0	0	0	0	0	0
17	10123.75	9889.68	2892.5	0	0	0	0	0	0	0	10123.75	9889.68	0	0	0	0	0	0	0	0
18	10032.75	10032.75	2866.5	0	0	0	0	0	0	0	10032.75	10032.75	0	0	0	1656.837	0	0	0	0
19	10101	10101	2886	0	0	1557.3578	0	0	0	0	10101	10101	0	0	0	1557.3578	0	0	0	0
20	10305.75	10305.75	0	0	0	1707.357	0	0	0	0	10305.75	10305.75	2944.5	0	0	1707.357	0	0	0	0
21	10510.5	10510.5	0	0	0	1405.7505	0	0	0	0	10510.5	10510.5	3003	3003	0	0	0	0	0	0
22	10442.25	10333.375	0	0	0	0	0	0	0	0	10442.25	10333.375	2983.5	2983.5	0	0	0	0	0	0
23	10351.25	9595.04	0	0	0	0	0	0	0	0	10351.25	9595.04	2957.5	2957.5	0	0	0	0	0	0
24	10260.25	0	0	0	0	0	0	0	0	0	10260.25	9379.2591	2931.5	2931.5	0	0	0	0	0	0

Table-6.17d: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 61-80) with PEVs

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	10078.25	0	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	0	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	0	0	3003	0	0	0	0	0	0	10510.5	0	0	3003	0	0	0	0	0	0
4	10305.75	0	0	2944.5	0	0	0	0	0	0	10305.75	0	0	2944.5	0	0	0	0	0	0
5	10578.75	0	3022.5	3022.5	0	0	0	0	0	0	10578.75	0	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	0	2983.5	2983.5	0	0	0	0	0	0	10442.25	0	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	0	2925	2925	0	0	0	0	0	0	10237.5	0	2925	2925	0	0	0	0	0	0
8	10078.25	0	2879.5	2879.5	0	0	0	0	0	0	10078.25	0	2879.5	2879.5	0	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	2456.3015	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	2456.3015	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	0	2417.9295	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	2417.9295	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	0	2677.1328	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2677.1328	0	0	0
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	3985.2	1968	0	0	0	0
14	11147.5	11147.5	3185	3185	3831.6094	0	0	0	0	0	11147.5	11147.5	0	3185	3831.6094	0	0	0	0	0
15	10237.5	10237.5	0	2925	3596.325	0	0	0	0	0	10237.5	10237.5	0	2925	3596.325	0	0	0	0	0
16	10146.5	9871.7863	0	2899	0	0	0	0	0	0	10146.5	9871.7863	0	0	0	0	0	0	0	0
17	10123.75	9889.68	0	0	0	0	0	0	0	0	10123.75	9889.68	0	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	0	0	0	0	0	10032.75	10032.75	0	0	0	0	0	0	0	0
19	10101	10101	0	0	0	0	0	0	0	0	10101	10101	2886	0	0	1557.3578	0	0	0	0
20	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	2944.5	0	0	1707.357	0	0	0	0
21	10510.5	10510.5	0	0	0	0	0	0	0	0	10510.5	10510.5	3003	3003	0	1405.7505	0	0	0	0
22	10442.25	10333.375	0	2983.5	0	0	0	0	0	0	10442.25	10333.375	2983.5	2983.5	0	0	0	0	0	0
23	10351.25	9595.04	0	2957.5	0	0	0	0	0	0	10351.25	9595.04	2957.5	2957.5	0	0	0	0	0	0
24	10260.25	9379.2591	0	2931.5	0	0	0	0	0	0	10260.25	0	0	2931.5	0	0	0	0	0	0

Table-6.17e: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 81-100) with PEVs

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	10078.25	0	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	0	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	0	0	3003	0	0	0	0	0	0	10510.5	0	0	3003	0	0	0	0	0	0
4	10305.75	0	0	2944.5	0	0	0	0	0	0	10305.75	0	0	2944.5	0	0	0	0	0	0
5	10578.75	0	3022.5	3022.5	0	0	0	0	0	0	10578.75	0	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	0	2983.5	2983.5	0	0	0	0	0	0	10442.25	0	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	0	2925	2925	0	0	0	0	0	0	10237.5	0	2925	2925	0	0	0	0	0	0
8	10078.25	0	2879.5	2879.5	0	0	0	0	0	0	10078.25	0	2879.5	2879.5	0	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	2456.3015	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	2456.3015	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	2417.9295	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	2417.9295	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2677.1328	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2677.1328	0	0	0
13	11193	11193	3198	3198	3985.2	1968	0	0	0	0	11193	11193	3198	3198	3985.2	1968	0	0	0	0
14	11147.5	11147.5	3185	3185	3831.6094	0	0	0	0	0	11147.5	11147.5	3185	3185	3831.6094	0	0	0	0	0
15	10237.5	10237.5	0	2925	3596.325	0	0	0	0	0	10237.5	10237.5	0	2925	3596.325	0	0	0	0	0
16	10146.5	9871.7863	0	0	0	0	0	0	0	0	10146.5	9871.7863	0	0	0	0	0	0	0	0
17	10123.75	9889.68	0	0	0	0	0	0	0	0	10123.75	9889.68	0	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	0	0	0	0	0	10032.75	10032.75	0	0	0	0	0	0	0	0
19	10101	10101	0	0	0	1557.3578	0	0	0	0	10101	10101	0	0	0	0	0	0	0	0
20	10305.75	10305.75	0	0	0	1707.357	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
21	10510.5	10510.5	0	0	0	1405.7505	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10333.375	0	2983.5	0	0	0	0	0	0	10442.25	10333.375	0	2983.5	0	0	0	0	0	0
23	10351.25	0	0	2957.5	0	0	0	0	0	0	10351.25	0	0	2957.5	0	0	0	0	0	0
24	10260.25	0	0	2931.5	0	0	0	0	0	0	10260.25	0	0	2931.5	0	0	0	0	0	0

6.6.2 Hybrid Chaotic Slime Mould-Sine Cosine Optimization Algorithm with PEVs during Charging and Discharging

The proposed hCSMA-SCA is established to increase the penetrating capability through the entire search region. The alteration with input boundaries with chaotic map is thought about to make the hybridization SMA enhancer with SCA technique which is especially proficient to track down the ideal arrangement over the hunt locale. This technique is unrivaled as the populace based enhancers are more reasonable to tackle ongoing issue since they can ready to stay away from the caught into nearby optima and investigate the pursuit district just as take advantage of worldwide ideal arrangement more steady than the individual based analyzer. The number of populations are taken as 40 for 10 unit, 40 unit and 100 unit systems.

6.6.2.1 Ten Generating Unit System

This system contains of 10-generating unit system having a 24-hour electricity demand. The spinning reserve is not considered due to maximize the profit values. The hCSMA-SCA technique is evaluated for 100 iterations considering the effect of PEVs. The hCSMA-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.15**. The commitment status and the optimal scheduling for this unit system are shown in Table-6.18a and the hourly profit of the 10-generating unit system have been shown in Table-6.18b.

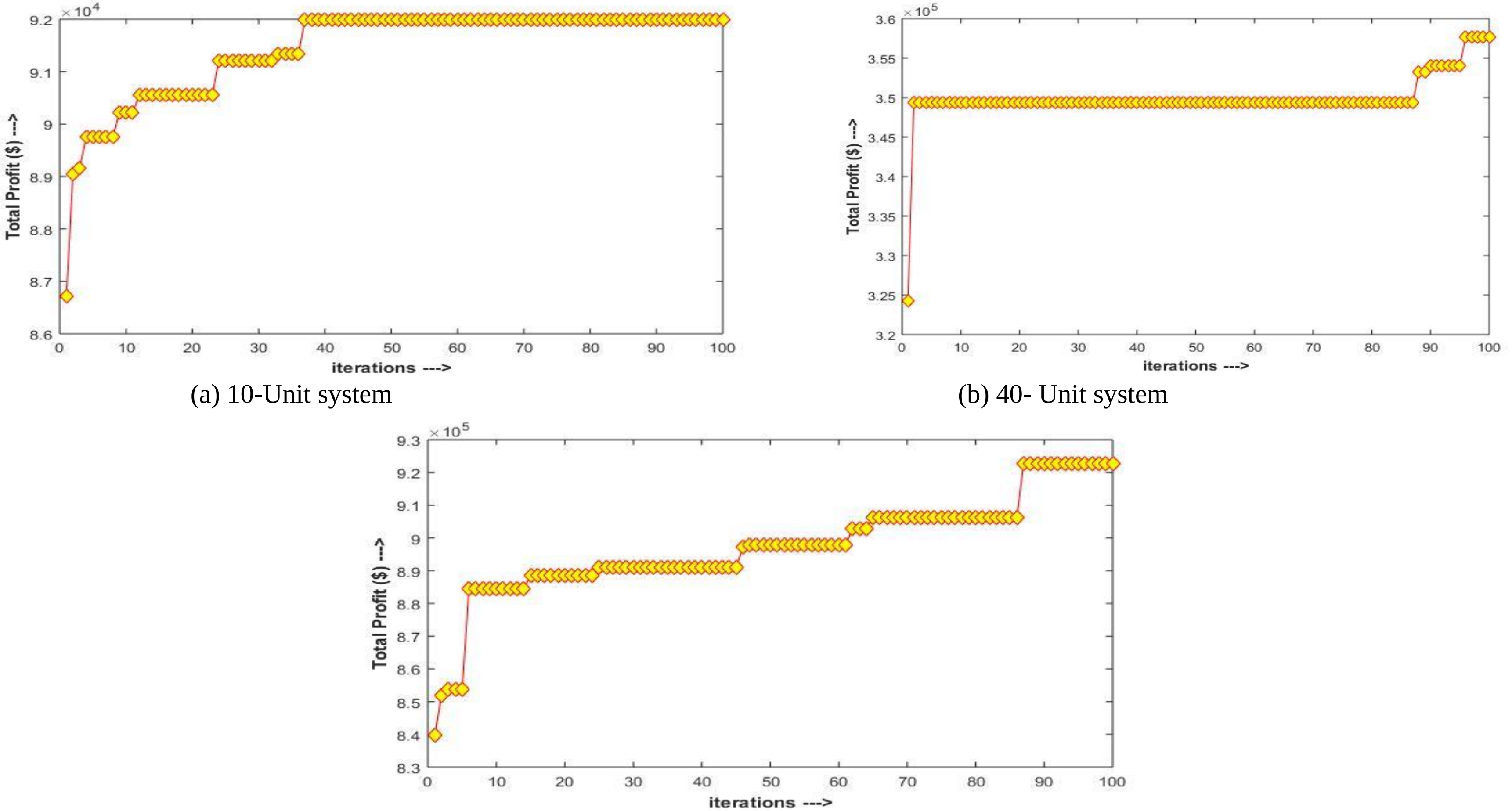
The Table-6.18a and Table-6.18b represents the commitment status with optimum scheduling and profit of the generators for 24 hours considering effect of PEVs. In this case, the PGU1 and PGU2 are on for 24 hours. From 5 to 16 hours, the PGU3 is on. For 10^{th} to 23^{rd} hours PGU4 is on, PGU5 is on for 3^{rd} to 21^{th} hours and PGU6 is on for 10^{th} to 15^{th} hours. The PGU10 is stayed off for 24 hours.

Table-6.18a: Commitment status and scheduling for 10-generating unit system using hCSMA-SCA optimization algorithm with PEVs

Commitment status of thermal units											Scheduling of the committed generating units									
HOURS	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7**	**PGU8**	**PGU9**	**PGU10**	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7**	**PGU8**	**PGU9**	**PGU10**
1	1	1	0	0	0	0	0	0	0	0	455	277.4	0	0	0	0	0	0	0	0
2	1	1	0	0	0	0	0	0	0	0	455	316.5	0	0	0	0	0	0	0	0
3	1	1	0	0	1	0	0	0	0	0	455	391.24	0	0	25	0	0	0	0	0
4	1	1	0	0	1	0	0	0	0	0	455	455	0	0	42.35	0	0	0	0	0
5	1	1	1	0	1	0	0	0	0	0	455	412.99	130	0	25	0	0	0	0	0
6	1	1	1	0	1	0	0	0	0	0	455	455	130	0	39.24	0	0	0	0	0
7	1	1	1	0	1	0	0	0	0	0	455	443.54	130	0	25	0	0	0	0	0
8	1	1	1	0	1	0	0	0	0	0	455	433.67	130	0	25	0	0	0	0	0
9	1	1	1	0	1	0	1	0	0	0	455	455	130	0	58.24	0	25	0	0	0
10	1	1	1	1	1	1	1	0	0	0	455	455	130	130	139.52	20	25	0	0	0
11	1	1	1	1	1	1	1	1	0	0	455	455	130	130	153.77	20	25	10	0	0
12	1	1	1	1	1	1	1	0	1	0	455	455	130	130	138.27	20	25	0	10	0
13	1	1	1	1	1	1	1	0	0	0	455	455	130	130	70.27	20	25	0	0	0
14	1	1	1	1	1	1	1	0	0	0	455	455	130	130	82.53	20	25	0	0	0
15	1	1	1	1	1	1	0	0	0	0	455	455	130	130	39.02	20	0	0	0	0
16	1	1	1	1	1	0	0	0	0	0	455	306.81	130	130	25	0	0	0	0	0
17	1	1	0	1	1	0	0	0	0	0	455	424.8	0	130	25	0	0	0	0	0
18	1	1	0	1	1	0	0	0	0	0	455	455	0	130	40.56	0	0	0	0	0
19	1	1	0	1	1	0	0	0	0	0	455	455	0	130	41.21	0	0	0	0	0
20	1	1	0	1	1	0	0	0	0	0	455	383.04	0	130	25	0	0	0	0	0
21	1	1	0	1	1	0	0	0	0	0	455	413.42	0	130	25	0	0	0	0	0
22	1	1	0	1	0	0	0	0	1	0	455	397.56	0	130	0	0	0	0	10	0
23	1	1	0	1	0	0	0	0	0	0	455	279.08	0	130	0	0	0	0	0	0
24	1	1	0	0	0	0	0	0	0	0	455	300.59	0	0	0	0	0	0	0	0

Table-6.18b: Hourly profit for 10-generating unit system using hCSMA-SCA optimization algorithm with PEVs

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	Start-up Cost	Hourly Profit
1	10078.25	6144.41	0	0	0	0	0	0	0	0	0	16222.66
2	10010	6963	0	0	0	0	0	0	0	0	0	16973
3	10510.5	9037.644	0	0	577.5	0	0	0	0	0	900	20125.644
4	10305.75	10305.75	0	0	959.2275	0	0	0	0	0	0	21570.7275
5	10578.75	9602.0175	3022.5	0	581.25	0	0	0	0	0	60	23784.5175
6	10442.25	10442.25	2983.5	0	900.558	0	0	0	0	0	1100	24768.558
7	10237.5	9979.65	2925	0	562.5	0	0	0	0	0	0	23704.65
8	10078.25	9605.7905	2879.5	0	553.75	0	0	0	0	0	0	23117.2905
9	10374	10374	2964	0	1327.872	0	570	0	0	0	1460	25609.872
10	13354.25	13354.25	3815.5	3815.5	4094.912	587	733.75	0	0	0	120	39755.162
11	13718.25	13718.25	3919.5	3919.5	4636.1655	603	753.75	301.5	0	0	580	41569.9155
12	14400.75	14400.75	4114.5	4114.5	4376.2455	633	791.25	0	316.5	0	30	43147.4955
13	11193	11193	3198	3198	1728.642	492	615	0	0	0	0	31617.642
14	11147.5	11147.5	3185	3185	2021.985	490	612.5	0	0	0	60	31789.485
15	10237.5	10237.5	2925	2925	877.95	450	0	0	0	0	0	27652.95
16	10146.5	6841.863	2899	2899	557.5	0	0	0	0	0	0	23343.863
17	10123.75	9451.8	0	2892.5	556.25	0	0	0	0	0	0	23024.3
18	10032.75	10032.75	0	2866.5	894.348	0	0	0	0	0	60	23826.348
19	10101	10101	0	2886	914.862	0	0	0	0	0	60	24002.862
20	10305.75	8675.856	0	2944.5	566.25	0	0	0	0	0	170	22492.356
21	10510.5	9550.002	0	3003	577.5	0	0	0	0	0	30	23641.002
22	10442.25	9124.002	0	2983.5	0	0	0	0	229.5	0	0	22779.252
23	10351.25	6349.07	0	2957.5	0	0	0	0	0	0	900	19657.82
24	10260.25	6778.3045	0	0	0	0	0	0	0	0	700	17038.5545



(a) 10-Unit system

(b) 40- Unit system

(c) 100-Unit system

Fig.6.15: Convergence curve for 10-, 40- and 100-generating unit system using hCSMA-SCA optimization algorithm with PEVs

6.6.2.2 Forty Generating Unit System

This system contains of 40-generating unit system having a 24-hour electricity demand. The hCSMA-SCA technique is evaluated for 100 iterations considering the effect of PEVs. The hCSMA-SCA algorithm is verified for 30 trial runs. The issue of electrical load fluctuations in the distribution side networks and expanding the cost of power grid cost caused by the unpredictable nature of PEVs. So, the optimum management for charging as well as discharging nature of PEVs users may provide electricity supply for power grid in case of shortage of power, alleviate balance of electricity demand as well as supply and it has a great significance to improvement of the power grid stability. The profit analysis for each generating unit during charging as well as discharging of PEVs with proper generation scheduling and status of the committed units can easily take into consideration. The convergence graph of total profit is shown in **Fig.6.15**. The profit with start-up cost and fuel cost of 24 hours are shown in Table-6.19. The optimal scheduling of 40 unit systems are shown in Table-6.20a and Table-6.20b. The hourly profit table for this system is shown in Table-6.21a and Table-6.21b respectively.

Table-6.19: Hourly profit with startup cost and fuel cost for 40-generating unit system using hCSMA-SCA optimization algorithm with PEVs

Hours	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	62737.66	5590	54353.2239	**13**	129919.242	180	109348.218
2	66473	1120	58836.493	**14**	127339.485	0	106965.392
3	79030.644	0	67619.6283	**15**	108652.95	210	97180.8249
4	83405.2275	2000	73422.6053	**16**	92919.863	640	83441.0154
5	93534.5175	0	81011.3102	**17**	89774.3	60	80630.6998
6	96372.558	2980	84604.0269	**18**	92622.348	290	84466.12
7	93904.65	750	84153.7983	**19**	93266.862	350	84477.4938
8	92225.2905	30	83980.9258	**20**	93160.356	870	82049.3546
9	105637.872	670	93123.2204	**21**	95713.002	3220	83469.8702
10	163025.162	400	118506.371	**22**	94383.252	730	83966.9842
11	169285.316	150	120584.619	**23**	81082.82	1880	71503.9785
12	177216.896	210	120213.609	**24**	71158.5545	560	62146.1181

Table-6.20a: Generation scheduling for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with PEVs

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU-10	PGU-11	PGU-12	PGU-13	PGU-14	PGU-15	PGU-16	PGU-17	PGU-18	PGU-19	PGU-20
1	455	337.46667	0	0	0	0	0	0	0	0	455	337.46667	0	0	0	0	0	0	0	0
2	455	313.83333	0	130	0	0	0	0	0	0	455	313.83333	0	130	0	0	0	0	0	0
3	455	317.08	130	130	0	0	0	0	0	0	455	317.08	0	130	0	0	0	0	0	0
4	455	317.45	130	130	0	0	0	0	0	0	455	317.45	130	130	0	0	0	0	0	0
5	455	370.99667	130	130	25	0	0	0	0	0	455	370.99667	130	130	25	0	0	0	0	0
6	455	421.41333	130	130	25	0	0	0	0	0	455	421.41333	130	130	25	0	0	0	0	0
7	455	412.84667	130	130	25	0	0	0	0	0	455	412.84667	130	130	25	0	0	0	0	0
8	455	409.55667	130	130	25	0	0	0	0	0	455	409.55667	130	130	25	0	0	0	0	0
9	455	424.56	130	130	25	0	0	0	0	0	455	424.56	130	130	25	0	0	0	0	0
10	455	455	130	130	162	24.13	25	10	0	0	455	455	130	130	162	24.13	25	0	0	0
11	455	455	130	130	162	36.6925	25	10	10	0	455	455	130	130	162	36.6925	25	0	0	0
12	455	455	130	130	162	32.8175	25	10	0	0	455	455	130	130	162	32.8175	25	10	0	0
13	455	455	130	130	117.8175	20	25	0	0	0	455	455	130	130	117.8175	20	25	0	0	0
14	455	455	130	130	103.1325	20	0	0	0	0	455	455	130	130	103.1325	20	25	0	0	0
15	455	455	130	130	37.255	0	0	0	0	0	455	455	130	130	37.255	0	0	0	0	0
16	455	326.7025	130	130	0	0	0	0	0	0	455	326.7025	130	130	0	0	0	0	0	0
17	455	352.45	130	130	0	0	25	0	0	0	455	352.45	130	130	0	0	0	0	0	0
18	455	383.89	130	130	0	0	25	0	0	0	455	383.89	130	130	0	20	0	0	0	0
19	455	384.0525	130	130	0	0	25	0	0	0	455	384.0525	130	130	0	20	0	0	0	0
20	455	395.76	0	130	0	20	0	0	0	0	455	395.76	130	130	0	20	0	0	0	0
21	455	423.355	0	130	0	20	0	0	0	0	455	423.355	130	130	0	0	25	0	0	0
22	455	0	0	130	62.52	20	0	0	0	0	455	455	130	130	62.52	0	25	0	0	0
23	455	0	0	0	59.693333	0	0	0	0	0	455	455	0	0	59.693333	0	25	0	0	0
24	455	0	0	0	25	0	0	0	0	0	455	376.86333	0	0	25	0	0	0	0	0

Table-6.20b: Generation scheduling for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with PEVs

Hour	PGU21	PGU22	PGU23	PGU 24	PGU 25	PGU 26	PGU 27	PGU 28	PGU 29	PGU 30	PGU 31	PGU32	PGU 33	PGU 34	PGU 35	PGU 36	PGU 37	PGU 38	PGU 39	PGU 40
1	455	337.46667	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	313.83333	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	317.08	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
4	455	317.45	130	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
5	455	370.99667	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
6	455	421.41333	130	130	25	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
7	455	412.84667	130	130	25	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
8	455	409.55667	130	130	25	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
9	455	424.56	130	130	25	0	0	0	0	0	455	424.56	130	130	0	0	0	0	0	0
10	455	455	130	130	162	24.13	25	10	0	0	455	455	130	130	162	24.13	25	10	0	0
11	455	455	130	130	162	36.6925	25	10	0	0	455	455	130	130	162	36.6925	25	10	0	0
12	455	455	130	130	162	32.8175	25	10	0	0	455	455	130	130	162	32.8175	25	10	0	0
13	455	455	130	130	117.8175	20	0	0	0	0	455	455	130	130	117.8175	20	0	0	0	0
14	455	455	130	130	103.1325	20	0	0	0	0	455	455	130	130	103.1325	20	0	0	0	0
15	455	455	130	130	37.255	0	0	0	0	0	455	455	130	130	37.255	0	0	0	0	0
16	455	326.7025	130	130	0	0	0	0	0	0	455	326.7025	130	130	0	0	0	0	0	0
17	455	352.45	0	130	0	0	0	0	0	0	455	352.45	0	130	0	0	0	0	0	0
18	455	383.89	0	130	0	20	0	0	0	0	455	383.89	0	130	0	0	0	0	0	0
19	455	384.0525	0	130	0	20	0	0	0	0	455	384.0525	0	130	0	0	0	0	0	0
20	455	395.76	0	130	0	20	0	0	0	0	455	395.76	0	130	0	0	0	0	0	0
21	455	423.355	0	0	0	20	25	0	0	0	455	423.355	0	130	0	20	0	0	0	0
22	455	455	0	0	62.52	0	25	0	0	0	455	455	130	130	0	20	0	0	0	0
23	455	455	0	0	59.693333	0	25	0	0	0	455	455	130	0	0	20	0	0	0	0
24	455	376.86333	0	0	25	0	0	0	0	0	455	376.86333	130	0	0	0	0	0	0	0

Table-6.20a shows the optimal scheduling of PGU1 to PGU20 for 40-generating unit test system considering the effect of PEVs using hCSMA-SCA optimizer. The PGU10 and PGU20 is off for 24 hours. The PGU1, PGU2, PGU11 and PGU12 is always remain on throughout the whole day. PGU9 gives 10 MW power only for 11th hour and PGU18 gives 10 MW power only for 12th hour as it have been on for that particular hour only. Further, the PGU are sometimes remain on and off condition for optimum power generation scheduling.

In Table-6.20b represents the power scheduling of 21 to 40 unit for 40-unit system with PEVs using hCSMA-SCA optimizer. The PGU21, PGU22 and PGU31 is continuing on for 24 hours. The PGU29, PGU30, PGU39 to PGU40 remain off throughout the whole day. The PGU28 and PGU38 is on for 10th and 13th hour only. For this the output is 10 MW for 10th hour to 13th hour. The PGU27 is on for 10th to 12th hour and 21st to 23rd hour. The power output from that us is 25 MW for that particular hours.

The hourly profit for 40-test system is presented in Table-6.21a and Table-6.21b using hCSMA-SCA optimizer. The Table-6.21a shows the hourly profit for PGU20 for whole day. The maximum number of profit can be obtained from the PGU1, PGU2, PGU11 and PGU12 as it was remain on for all hours. PGU9 gives 301.5 $ for 11 hour and PGU18 gives 316.5 $ for 12th hour. The other units are gives several amount of profit for that particular hour when it was on.

Table-6.21b shows that the hourly profit for PGU21 to PGU40 for this test system for 24 hours. The PGU21, PGU22 and PGU31 are on for 24 hours, so that the profit from these units are maximum. Moreover for the others hours as it remain off, no profit come from that hour when the generating unit remain off. The PGU28 and PGU38 gives 293.5 $ profit for 10th hour, 301.5 $ for 11th hour and 316.5 $ for 12th hour.

Table-6.21a: Hourly profit for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with PEVs

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	GPU16	PGU17	PGU 18	PGU19	PGU 20
1	10078.25	7474.88667	0	0	0	0	0	0	0	0	10078.25	7474.88667	0	0	0	0	0	0	0	0
2	10010	6904.33333	0	2860	0	0	0	0	0	0	10010	6904.33333	0	2860	0	0	0	0	0	0
3	10510.5	7324.548	3003	3003	0	0	0	0	0	0	10510.5	7324.548	0	3003	0	0	0	0	0	0
4	10305.75	7190.2425	2944.5	2944.5	0	0	0	0	0	0	10305.75	7190.2425	2944.5	2944.5	0	0	0	0	0	0
5	10578.75	8625.6725	3022.5	3022.5	581.25	0	0	0	0	0	10578.75	8625.6725	3022.5	3022.5	581.25	0	0	0	0	0
6	10442.25	9671.436	2983.5	2983.5	573.75	0	0	0	0	0	10442.25	9671.436	2983.5	2983.5	573.75	0	0	0	0	0
7	10237.5	9289.05	2925	2925	562.5	0	0	0	0	0	10237.5	9289.05	2925	2925	562.5	0	0	0	0	0
8	10078.25	9071.68017	2879.5	2879.5	553.75	0	0	0	0	0	10078.25	9071.68017	2879.5	2879.5	553.75	0	0	0	0	0
9	10374	9679.968	2964	2964	570	0	0	0	0	0	10374	9679.968	2964	2964	570	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	708.2155	733.75	293.5	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	708.2155	733.75	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	1106.27887	753.75	301.5	301.5	0	13718.25	13718.25	3919.5	3919.5	4884.3	1106.27887	753.75	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	1038.67388	791.25	316.5	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	1038.67388	791.25	316.5	0	0
13	11193	11193	3198	3198	2898.3105	492	615	0	0	0	11193	11193	3198	3198	2898.3105	492	615	0	0	0
14	11147.5	11147.5	3185	3185	2526.74625	490	0	0	0	0	11147.5	11147.5	3185	3185	2526.74625	490	612.5	0	0	0
15	10237.5	10237.5	2925	2925	838.2375	0	0	0	0	0	10237.5	10237.5	2925	2925	838.2375	0	0	0	0	0
16	10146.5	7285.46575	2899	2899	0	0	0	0	0	0	10146.5	7285.46575	2899	2899	0	0	0	0	0	0
17	10123.75	7842.0125	2892.5	2892.5	0	0	556.25	0	0	0	10123.75	7842.0125	2892.5	2892.5	0	0	0	0	0	0
18	10032.75	8464.7745	2866.5	2866.5	0	0	551.25	0	0	0	10032.75	8464.7745	2866.5	2866.5	0	441	0	0	0	0
19	10101	8525.9655	2886	2886	0	0	555	0	0	0	10101	8525.9655	2886	2886	0	444	0	0	0	0
20	10305.75	8963.964	0	2944.5	0	453	0	0	0	0	10305.75	8963.964	2944.5	2944.5	0	453	0	0	0	0
21	10510.5	9779.5005	0	3003	0	462	0	0	0	0	10510.5	9779.5005	3003	3003	0	0	577.5	0	0	0
22	10442.25	0	0	2983.5	1434.834	459	0	0	0	0	10442.25	10442.25	2983.5	2983.5	1434.834	0	573.75	0	0	0
23	10351.25	0	0	0	1358.02333	0	0	0	0	0	10351.25	10351.25	0	0	1358.02333	0	568.75	0	0	0
24	10260.25	0	0	0	563.75	0	0	0	0	0	10260.25	8498.26817	0	0	563.75	0	0	0	0	0

Table-6.21b: Hourly profit for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with PEVs

HOURS	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PG34	PGU35	GPU36	PGU37	PGU 38	PGU39	PGU 40
1	10078.25	7474.88667	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	6904.33333	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	7324.548	0	3003	0	0	0	0	0	0	10510.5	0	0	3003	0	0	0	0	0	0
4	10305.75	7190.2425	2944.5	2944.5	0	0	0	0	0	0	10305.75	0	0	2944.5	0	0	0	0	0	0
5	10578.75	8625.6725	3022.5	3022.5	0	0	0	0	0	0	10578.75	0	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	9671.436	2983.5	2983.5	573.75	0	0	0	0	0	10442.25	0	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	9289.05	2925	2925	562.5	0	0	0	0	0	10237.5	0	2925	2925	0	0	0	0	0	0
8	10078.25	9071.68017	2879.5	2879.5	553.75	0	0	0	0	0	10078.25	0	2879.5	2879.5	0	0	0	0	0	0
9	10374	9679.968	2964	2964	570	0	0	0	0	0	10374	9679.968	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	708.2155	733.75	293.5	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	708.2155	733.75	293.5	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	1106.27887	753.75	301.5	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	1106.27887	753.75	301.5	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	1038.67388	791.25	316.5	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	1038.67388	791.25	316.5	0	0
13	11193	11193	3198	3198	2898.3105	492	0	0	0	0	11193	11193	3198	3198	2898.3105	492	0	0	0	0
14	11147.5	11147.5	3185	3185	2526.74625	490	0	0	0	0	11147.5	11147.5	3185	3185	2526.74625	490	0	0	0	0
15	10237.5	10237.5	2925	2925	838.2375	0	0	0	0	0	10237.5	10237.5	2925	2925	838.2375	0	0	0	0	0
16	10146.5	7285.46575	2899	2899	0	0	0	0	0	0	10146.5	7285.46575	2899	2899	0	0	0	0	0	0
17	10123.75	7842.0125	0	2892.5	0	0	0	0	0	0	10123.75	7842.0125	0	2892.5	0	0	0	0	0	0
18	10032.75	8464.7745	0	2866.5	0	441	0	0	0	0	10032.75	8464.7745	0	2866.5	0	0	0	0	0	0
19	10101	8525.9655	0	2886	0	444	0	0	0	0	10101	8525.9655	0	2886	0	0	0	0	0	0
20	10305.75	8963.964	0	2944.5	0	453	0	0	0	0	10305.75	8963.964	0	2944.5	0	0	0	0	0	0
21	10510.5	9779.5005	0	0	0	462	577.5	0	0	0	10510.5	9779.5005	0	3003	0	462	0	0	0	0
22	10442.25	10442.25	0	0	1434.834	0	573.75	0	0	0	10442.25	10442.25	2983.5	2983.5	0	459	0	0	0	0
23	10351.25	10351.25	0	0	1358.02333	0	568.75	0	0	0	10351.25	10351.25	2957.5	0	0	455	0	0	0	0
24	10260.25	8498.26817	0	0	563.75	0	0	0	0	0	10260.25	8498.26817	2931.5	0	0	0	0	0	0	0

6.6.2.3 Hundred Generating Unit System

This system contains of 100-generating unit system having a 24-hour electricity demand. The hCSMA-SCA technique is evaluated for 100 iterations considering the effect of PEVs. The hCSMA-SCA algorithmis verified for 30 trial runs. The Table-22 shows the hourly profit with start-up cost and fuel cost for 100-generating unit system using hCSMA-SCA optimization algorithm with PEVs. The profit analysis for each generating unit during charging as well as discharging of PEVs with proper generation scheduling and status of the committed units can easily take into consideration. The convergence graph of total profit is shown in **Fig.6.15**.The optimal scheduling of 100-generating unit systems are shown in Table-6.23a to Table-6.23e. The hourly profit table for this system is shown in Table-6.24a to Table-6.24e respectively.

Table-6.22: Hourly profit with start-up cost and fuel cost for 100-generating unit system using hCSMA-SCA optimization algorithm with PEVs

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	155767.66	11550	135503.234	**13**	326522.442	270	275476.012
2	165473	5580	144636.041	**14**	318439.485	480	267665.722
3	196840.644	6300	167531.478	**15**	270652.95	590	242082.367
4	207074.228	1190	181392.465	**16**	232071.863	1300	206960.888
5	233034.518	270	200786.43	**17**	223274.3	1360	198710.638
6	239580.558	1400	209670.511	**18**	230214.348	640	209046.726
7	234304.65	610	209220.652	**19**	231794.862	2250	209058.103
8	230441.291	530	208463.216	**20**	234496.356	1690	206898.487
9	265693.872	1450	233709.036	**21**	239857.002	3220	207409.346
10	409565.162	3390	299677.681	**22**	237591.252	5570	206083.502
11	424716.116	1540	304127.44	**23**	203932.82	5850	177567.444
12	445355.696	360	303752.645	**24**	179398.555	3470	155567.104

Table-6.23a: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with PEVs

HOUR	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	455	310.3	0	0	0	0	0	0	0	0	455	310.3	0	0	0	0	0	0	0	0
2	455	355.1875	0	0	0	0	0	0	0	0	455	355.1875	0	130	0	0	0	0	0	0
3	455	333.905	130	0	0	0	0	0	0	0	455	333.905	130	130	0	0	0	0	0	0
4	455	330.29375	130	130	0	0	0	0	0	0	455	330.29375	130	130	0	0	0	0	0	0
5	455	365.99875	130	130	25	0	0	0	0	0	455	365.99875	130	130	25	0	0	0	0	0
6	455	395.53	130	130	25	0	0	0	0	0	455	395.53	130	130	25	0	0	0	0	0
7	455	392.3175	130	130	25	0	0	0	0	0	455	392.3175	130	130	25	0	0	0	0	0
8	455	407.33375	130	130	25	0	0	0	0	0	455	407.33375	130	130	25	0	0	0	0	0
9	455	443.324	130	130	25	0	0	0	0	0	455	443.324	130	130	25	0	0	0	0	0
10	455	455	130	130	162	41.452	25	10	10	0	455	455	130	130	162	41.452	25	10	0	0
11	455	455	130	130	162	52.677	25	10	10	0	455	455	130	130	162	52.677	25	10	10	0
12	455	455	130	130	162	51.127	25	10	0	0	455	455	130	130	162	51.127	25	10	10	0
13	455	455	130	130	122.327	20	25	0	0	0	455	455	130	130	122.327	20	25	0	0	0
14	455	455	130	130	103.753	20	25	0	0	0	455	455	130	130	103.753	20	25	0	0	0
15	455	455	130	130	32.902	0	0	0	0	0	455	455	130	130	32.902	0	0	0	0	0
16	455	372.681	130	130	0	0	0	0	0	0	455	372.681	130	130	25	0	0	0	0	0
17	455	363.98	130	130	0	0	0	0	0	0	455	363.98	130	130	25	0	0	0	0	0
18	455	391.056	130	130	0	20	0	0	0	0	455	391.056	130	130	0	20	0	0	0	0
19	455	391.121	130	130	0	20	0	0	0	0	455	391.121	130	130	0	20	0	0	0	0
20	455	395.304	130	130	0	20	0	0	0	0	455	395.304	130	130	0	20	0	0	0	0
21	455	367.342	130	130	0	20	0	0	0	0	455	367.342	130	130	0	0	0	0	0	0
22	455	357.256	0	130	0	0	0	0	0	0	455	357.256	130	130	0	0	0	0	0	0
23	455	338.01	0	130	0	0	0	0	0	0	455	338.01	130	130	0	0	0	0	0	0
24	455	337.94143	0	130	0	0	0	0	0	0	455	337.94143	0	0	0	0	0	0	0	0

Table-6.23b: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with PEVs

HOUR	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	310.3	0	0	0	0	0	0	0	0	455	310.3	0	0	0	0	0	0	0	0
2	455	355.1875	0	0	0	0	0	0	0	0	455	355.1875	0	0	0	0	0	0	0	0
3	455	333.905	130	130	0	0	0	0	0	0	455	333.905	130	0	0	0	0	0	0	0
4	455	330.29375	130	130	0	0	0	0	0	0	455	330.29375	130	130	0	0	0	0	0	0
5	455	365.99875	130	130	25	0	0	0	0	0	455	365.99875	130	130	0	0	0	0	0	0
6	455	395.53	130	130	25	0	0	0	0	0	455	395.53	130	130	0	0	0	0	0	0
7	455	392.3175	130	130	25	0	0	0	0	0	455	392.3175	130	130	0	0	0	0	0	0
8	455	407.33375	130	130	25	0	0	0	0	0	455	407.33375	130	130	0	0	0	0	0	0
9	455	443.324	130	130	25	0	0	0	0	0	455	443.324	130	130	25	0	0	0	0	0
10	455	455	130	130	162	41.452	25	10	10	0	455	455	130	130	162	41.452	25	10	0	0
11	455	455	130	130	162	52.677	25	10	10	0	455	455	130	130	162	52.677	25	10	10	0
12	455	455	130	130	162	51.127	25	10	0	0	455	455	130	130	162	51.127	25	10	10	0
13	455	455	130	130	122.327	20	25	0	0	0	455	455	130	130	122.327	20	25	0	0	0
14	455	455	130	130	103.753	20	25	0	0	0	455	455	130	130	103.753	20	0	0	0	0
15	455	455	130	130	32.902	0	0	0	0	0	455	455	130	130	32.902	0	0	0	0	0
16	455	372.681	130	130	25	0	0	0	0	0	455	372.681	130	130	0	0	0	0	0	0
17	455	363.98	130	130	0	0	0	0	0	0	455	363.98	130	130	0	0	0	0	0	0
18	455	391.056	130	130	0	20	0	0	0	0	455	391.056	130	130	0	20	0	0	0	0
19	455	391.121	130	130	0	20	0	0	0	0	455	391.121	130	130	0	20	0	0	0	0
20	455	395.304	130	130	0	20	0	0	0	0	455	395.304	0	130	0	20	0	0	0	0
21	455	367.342	130	130	0	20	0	0	0	0	455	367.342	0	130	0	0	0	0	0	0
22	455	357.256	130	130	0	0	0	0	0	0	455	357.256	0	130	0	0	0	0	0	0
23	455	338.01	0	0	0	0	0	0	0	0	455	338.01	0	130	0	0	0	0	0	0
24	455	337.94143	0	0	0	0	0	0	0	0	455	337.94143	0	130	0	0	0	0	0	0

The Table-6.23a is given as the power scheduling of 100-unit test system using hCSMA-SCA optimizer for PGU1 to PGU20 with PEVs. The PGU10 and PGU20 is off for 24 hours. The PGU1, PGU2, PGU11 and PGU12 is always remain on throughout the whole day. PGU8 and PGU18 gives 10 MW power only for 10^{th} to 12^{th} hour and PGU19 gives 10 MW power for 11^{th} and 12^{th} hour as it have been on for that particular hour only. For PGU7 and PGU17, 25 MW power can be obtained only for 10^{th} to 14^{th} hour. Further, the PGU are sometimes remain on and off condition for optimum power generation scheduling.

In Table-6.23b represents the power scheduling of 21 to 40 unit for 100-unit system using hCSMA-SCA optimizer considering the effect of PEVs. The PGU21, PGU22, PGU31 and PGU32 is continuous on for 24 hours. The PGU30 and PGU40 remain off throughout the whole day. The PGU29 is on for 10^{th} and 11^{th}hour, gives 10MW power and PGU38 is on for 10^{th} to 12^{th} hour only and is 10 MW for that particular hour.

In Table-6.23c represents the power scheduling of 41 to 60 unit for 100-unit system using hCSMA-SCA optimizer with PEVs. The PGU41, PGU42, PGU51 and PGU52 is continuous on for 24 hours. The PGU50 and PGU60 remain off throughout the whole day. The PGU49 is on only for 12^{th} hour. For this the output is 10 MW for 12^{th} hour. The PGU58 is on for 11^{th} and 12^{th} hour. The power output from that us is 10 MW for that particular hours.

Table-6.23d represents the power scheduling of 61 to 80 unit for 100-unit system using hCSMA-SCA optimizer considering the effect of PEVs. The PGU61 and PGU71 is always on and the output power is 455 MW for 24 hours. The PGU69, PGU70, PGU79 and PGU80 is off for the whole day.

Table-6.23e represents the power scheduling of 81 to 100 unit for 100-unit system using hCSMA-SCA optimizer considering the effect of PEVs. The PGU81 and PGU91 is always on and the output power is 455 MW for 24 hours. The PGU89, PGU90, PGU99 and PGU100 is off for the whole day.

Table-6.23c: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 41-60) with PEVs

Hour	PG U41	PGU42	PGU 43	PGU 44	PGU45	PGU46	PGU 47	PGU 48	PGU49	PGU50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PGU56	PGU57	PGU58	PGU59	PGU60
1	455	310.3	0	0	0	0	0	0	0	0	455	310.3	0	0	0	0	0	0	0	0
2	455	355.1875	0	0	0	0	0	0	0	0	455	355.1875	0	0	0	0	0	0	0	0
3	455	333.905	0	130	0	0	0	0	0	0	455	333.905	0	0	0	0	0	0	0	0
4	455	330.29375	130	130	0	0	0	0	0	0	455	330.29375	130	0	0	0	0	0	0	0
5	455	365.99875	130	130	0	0	0	0	0	0	455	365.99875	130	0	0	0	0	0	0	0
6	455	395.53	130	130	25	0	0	0	0	0	455	395.53	130	130	25	0	0	0	0	0
7	455	392.3175	130	130	25	0	0	0	0	0	455	392.3175	130	130	25	0	0	0	0	0
8	455	407.33375	130	130	25	0	0	0	0	0	455	407.33375	130	130	25	0	0	0	0	0
9	455	443.324	130	130	25	0	0	0	0	0	455	443.324	130	130	25	0	0	0	0	0
10	455	455	130	130	162	41.452	25	10	0	0	455	455	130	130	162	41.452	25	0	0	0
11	455	455	130	130	162	52.677	25	10	0	0	455	455	130	130	162	52.677	25	10	0	0
12	455	455	130	130	162	51.127	25	10	10	0	455	455	130	130	162	51.127	25	10	0	0
13	455	455	130	130	122.327	20	0	0	0	0	455	455	130	130	122.327	20	25	0	0	0
14	455	455	130	130	103.753	20	0	0	0	0	455	455	130	130	103.753	20	25	0	0	0
15	455	455	130	130	32.902	0	0	0	0	0	455	455	130	130	32.902	0	0	0	0	0
16	455	372.681	130	130	0	0	0	0	0	0	455	372.681	0	130	0	0	0	0	0	0
17	455	363.98	0	130	0	0	0	0	0	0	455	363.98	0	130	0	0	0	0	0	0
18	455	391.056	0	130	0	0	0	0	0	0	455	391.056	0	130	0	20	0	0	0	0
19	455	391.121	0	130	0	0	0	0	0	0	455	391.121	0	130	0	20	0	0	0	0
20	455	395.304	0	130	0	0	0	0	0	0	455	395.304	0	130	0	20	0	0	0	0
21	455	367.342	0	130	0	20	0	0	0	0	455	367.342	130	130	0	20	0	0	0	0
22	455	357.256	130	130	0	20	0	0	0	0	455	357.256	130	130	0	0	0	0	0	0
23	455	338.01	130	0	0	20	0	0	0	0	455	338.01	130	130	0	0	0	0	0	0
24	455	337.94143	130	0	0	0	0	0	0	0	455	0	130	0	0	0	0	0	0	0

Table-6.23d: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 61-80) with PEVs

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	455	310.3	0	0	0	0	0	0	0	0	455	310.3	0	0	0	0	0	0	0	0
2	455	355.1875	0	0	0	0	0	0	0	0	455	355.1875	0	0	0	0	0	0	0	0
3	455	333.905	0	0	0	0	0	0	0	0	455	333.905	0	130	0	0	0	0	0	0
4	455	330.29375	0	130	0	0	0	0	0	0	455	330.29375	0	130	0	0	0	0	0	0
5	455	365.99875	130	130	0	0	0	0	0	0	455	365.99875	130	130	0	0	0	0	0	0
6	455	395.53	130	130	0	0	0	0	0	0	455	395.53	130	130	0	0	0	0	0	0
7	455	392.3175	130	130	0	0	0	0	0	0	455	392.3175	130	130	0	0	0	0	0	0
8	455	407.33375	130	130	0	0	0	0	0	0	455	407.33375	130	130	0	0	0	0	0	0
9	455	443.324	130	130	25	0	0	0	0	0	455	443.324	130	130	25	0	0	0	0	0
10	455	455	130	130	162	41.452	25	10	0	0	455	455	130	130	162	41.452	25	10	0	0
11	455	455	130	130	162	52.677	25	10	0	0	455	455	130	130	162	52.677	25	0	0	0
12	455	455	130	130	162	51.127	25	10	0	0	455	455	130	130	162	51.127	25	10	0	0
13	455	455	130	130	122.327	20	25	0	0	0	455	455	130	130	122.327	20	0	0	0	0
14	455	455	130	130	103.753	20	0	0	0	0	455	455	130	130	103.753	20	0	0	0	0
15	455	455	130	130	32.902	0	0	0	0	0	455	455	130	130	32.902	0	0	0	0	0
16	455	372.681	130	130	0	0	0	0	0	0	455	372.681	0	130	0	0	0	0	0	0
17	455	363.98	0	130	0	0	0	0	0	0	455	363.98	0	130	0	0	0	0	0	0
18	455	391.056	0	130	0	20	0	0	0	0	455	391.056	0	130	0	20	0	0	0	0
19	455	391.121	0	130	0	20	0	0	0	0	455	391.121	0	130	0	20	0	0	0	0
20	455	395.304	0	130	0	20	0	0	0	0	455	395.304	0	130	0	20	0	0	0	0
21	455	367.342	0	130	0	0	0	0	0	0	455	367.342	0	130	0	0	0	0	0	0
22	455	357.256	0	130	0	0	0	0	0	0	455	357.256	130	130	0	0	0	0	0	0
23	455	0	0	130	0	0	0	0	0	0	455	338.01	130	0	0	0	0	0	0	0
24	455	0	0	130	0	0	0	0	0	0	455	337.94143	130	0	0	0	0	0	0	0

Table-6.23e: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 81-100) with PEVs

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
4	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
5	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
6	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
7	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
8	455	0	130	0	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
9	455	443.324	130	0	0	0	0	0	0	0	455	443.324	130	130	0	0	0	0	0	0
10	455	455	130	0	162	41.452	25	0	0	0	455	455	130	130	162	41.452	25	10	0	0
11	455	455	130	0	162	52.677	25	10	0	0	455	455	130	130	162	52.677	25	0	0	0
12	455	455	130	0	162	51.127	25	10	0	0	455	455	130	130	162	51.127	25	0	0	0
13	455	455	130	130	122.327	20	0	0	0	0	455	455	130	130	122.327	20	0	0	0	0
14	455	455	130	130	103.753	0	0	0	0	0	455	455	130	130	103.753	0	0	0	0	0
15	455	455	130	130	32.902	0	0	0	0	0	455	455	130	130	32.902	0	0	0	0	0
16	455	372.681	0	130	0	0	0	0	0	0	455	372.681	0	130	0	0	0	0	0	0
17	455	363.98	0	130	0	0	0	0	0	0	455	363.98	0	130	0	0	0	0	0	0
18	455	391.056	0	130	0	20	0	0	0	0	455	391.056	0	130	0	0	0	0	0	0
19	455	391.121	0	130	0	20	0	0	0	0	455	391.121	0	130	0	0	0	0	0	0
20	455	395.304	0	130	0	20	0	0	0	0	455	395.304	0	130	0	0	0	0	0	0
21	455	367.342	130	130	0	0	0	0	0	0	455	367.342	130	130	0	0	0	0	0	0
22	455	357.256	130	130	0	0	0	0	0	0	455	357.256	130	130	0	0	0	0	0	0
23	455	338.01	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
24	455	337.94143	130	0	0	0	0	0	0	0	455	0	130	0	0	0	0	0	0	0

The Table-6.24a is presented the hourly profit for 100-generating unit system using proposed hCSMA-SCA optimization algorithm with PEVs. From 100 numbers of power generating units, this table shows the hourly profit of PGU1 to PGU20 for 24 hours. The PGU1, PGU2, PGU11 and PGU12 are on for every hours, while PGU3 and PGU4 have been off for some hours. The PGU9 is on only for 10th and 11th hour and 293.5 $ and 301.5 $ profit can be obtained.

The Table-6.24b is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm for units 21 to unit 40 considering effect of PEVs. In this table, the PGU21, PGU22, PGU31 and PGU32 are on for 24 hours and maximum profit are obtained. The PGU30 and PGU40 is off throughout the whole day. Others PGU are remained on for some hours and off for few hours. From those units, the profit can be measured for that particular hour when it was on. The 293.5 $ profit can be obtained from PGU29 in 10th hour and 301.5 $ profit from 11th hour, while 301.5 $ profit can also obtain for PGU39 in 11th hour. For this unit 316.5 $ profit can be measured from 12th hour.

The Table-6.24c is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm considering effect of PEVs for PGU41 to PGU60. The PGU41, PGU42, PGU51 and PGU52 remain on for 24 hours. The PGU50, PGU59 and PGU60 remain close throughout the whole day. Other units are remained on sometime and off for few times. The PGU47 and PGU48 is remain on from 10th to 12th hours. The profit for PGU47 is 733.75 $ for 10th and 11th hour and 791.25 $ is for 12th hour. However the profit for PGU48 is 293.5 $ in 10th hour, 301.5 $ is for 11th hour and 316.5 $ is for 12th hour. Further PGU49 is on only for 12th hour, so the profit for that unit is 316.5 $ only for that particular hour.

Table-6.24a: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with PEVs

Hour	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	10078.25	6873.145	0	0	0	0	0	0	0	0	10078.25	6873.145	0	0	0	0	0	0	0	0
2	10010	7814.125	0	0	0	0	0	0	0	0	10010	7814.125	0	2860	0	0	0	0	0	0
3	10510.5	7713.2055	3003	0	0	0	0	0	0	0	10510.5	7713.2055	3003	3003	0	0	0	0	0	0
4	10305.75	7481.153438	2944.5	2944.5	0	0	0	0	0	0	10305.75	7481.153438	2944.5	2944.5	0	0	0	0	0	0
5	10578.75	8509.470937	3022.5	3022.5	581.25	0	0	0	0	0	10578.75	8509.470937	3022.5	3022.5	581.25	0	0	0	0	0
6	10442.25	9077.4135	2983.5	2983.5	573.75	0	0	0	0	0	10442.25	9077.4135	2983.5	2983.5	573.75	0	0	0	0	0
7	10237.5	8827.14375	2925	2925	562.5	0	0	0	0	0	10237.5	8827.14375	2925	2925	562.5	0	0	0	0	0
8	10078.25	9022.442562	2879.5	2879.5	553.75	0	0	0	0	0	10078.25	9022.442562	2879.5	2879.5	553.75	0	0	0	0	0
9	10374	10107.7872	2964	2964	570	0	0	0	0	0	10374	10107.7872	2964	2964	570	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	1216.6162	733.75	293.5	293.5	0	13354.25	13354.25	3815.5	3815.5	4754.7	1216.6162	733.75	293.5	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	1588.21155	753.75	301.5	301.5	0	13718.25	13718.25	3919.5	3919.5	4884.3	1588.21155	753.75	301.5	301.5	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	1618.16955	791.25	316.5	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	1618.16955	791.25	316.5	316.5	0
13	11193	11193	3198	3198	3009.2442	492	615	0	0	0	11193	11193	3198	3198	3009.2442	492	615	0	0	0
14	11147.5	11147.5	3185	3185	2541.9485	490	612.5	0	0	0	11147.5	11147.5	3185	3185	2541.9485	490	612.5	0	0	0
15	10237.5	10237.5	2925	2925	740.295	0	0	0	0	0	10237.5	10237.5	2925	2925	740.295	0	0	0	0	0
16	10146.5	8310.7863	2899	2899	0	0	0	0	0	0	10146.5	8310.7863	2899	2899	557.5	0	0	0	0	0
17	10123.75	8098.555	2892.5	2892.5	0	0	0	0	0	0	10123.75	8098.555	2892.5	2892.5	556.25	0	0	0	0	0
18	10032.75	8622.7848	2866.5	2866.5	0	441	0	0	0	0	10032.75	8622.7848	2866.5	2866.5	0	441	0	0	0	0
19	10101	8682.8862	2886	2886	0	444	0	0	0	0	10101	8682.8862	2886	2886	0	444	0	0	0	0
20	10305.75	8953.6356	2944.5	2944.5	0	453	0	0	0	0	10305.75	8953.6356	2944.5	2944.5	0	453	0	0	0	0
21	10510.5	8485.6002	3003	3003	0	462	0	0	0	0	10510.5	8485.6002	3003	3003	0	0	0	0	0	0
22	10442.25	8199.0252	0	2983.5	0	0	0	0	0	0	10442.25	8199.0252	2983.5	2983.5	0	0	0	0	0	0
23	10351.25	7689.7275	0	2957.5	0	0	0	0	0	0	10351.25	7689.7275	2957.5	2957.5	0	0	0	0	0	0
24	10260.25	7620.579214	0	2931.5	0	0	0	0	0	0	10260.25	7620.579214	0	0	0	0	0	0	0	0

Table-6.24b: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with PEVs

Hour	PGU21	PGU22	PGU23	PGU 24	PGU25	PGU26	PGU27	PGU2 8	PGU29	PG U 30	PGU31	PGU32	PGU 33	PGU 34	PGU35	PGU36	PGU37	PGU 38	PGU39	PG U 40
1	10078.25	6873.145	0	0	0	0	0	0	0	0	10078.25	6873.145	0	0	0	0	0	0	0	0
2	10010	7814.125	0	0	0	0	0	0	0	0	10010	7814.125	0	0	0	0	0	0	0	0
3	10510.5	7713.2055	3003	3003	0	0	0	0	0	0	10510.5	7713.2055	3003	0	0	0	0	0	0	0
4	10305.75	7481.153438	2944.5	2944.5	0	0	0	0	0	0	10305.75	7481.153438	2944.5	2944.5	0	0	0	0	0	0
5	10578.75	8509.470937	3022.5	3022.5	581.25	0	0	0	0	0	10578.75	8509.470937	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	9077.4135	2983.5	2983.5	573.75	0	0	0	0	0	10442.25	9077.4135	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	8827.14375	2925	2925	562.5	0	0	0	0	0	10237.5	8827.14375	2925	2925	0	0	0	0	0	0
8	10078.25	9022.442562	2879.5	2879.5	553.75	0	0	0	0	0	10078.25	9022.442562	2879.5	2879.5	0	0	0	0	0	0
9	10374	10107.7872	2964	2964	570	0	0	0	0	0	10374	10107.7872	2964	2964	570	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	1216.6162	733.75	293.5	293.5	0	13354.25	13354.25	3815.5	3815.5	4754.7	1216.6162	733.75	293.5	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	1588.21155	753.75	301.5	301.5	0	13718.25	13718.25	3919.5	3919.5	4884.3	1588.21155	753.75	301.5	301.5	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	1618.16955	791.25	316.5	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	1618.16955	791.25	316.5	316.5	0
13	11193	11193	3198	3198	3009.2442	492	615	0	0	0	11193	11193	3198	3198	3009.2442	492	615	0	0	0
14	11147.5	11147.5	3185	3185	2541.9485	490	612.5	0	0	0	11147.5	11147.5	3185	3185	2541.9485	490	0	0	0	0
15	10237.5	10237.5	2925	2925	740.295	0	0	0	0	0	10237.5	10237.5	2925	2925	740.295	0	0	0	0	0
16	10146.5	8310.7863	2899	2899	557.5	0	0	0	0	0	10146.5	8310.7863	2899	2899	0	0	0	0	0	0
17	10123.75	8098.555	2892.5	2892.5	0	0	0	0	0	0	10123.75	8098.555	2892.5	2892.5	0	0	0	0	0	0
18	10032.75	8622.7848	2866.5	2866.5	0	441	0	0	0	0	10032.75	8622.7848	2866.5	2866.5	0	441	0	0	0	0
19	10101	8682.8862	2886	2886	0	444	0	0	0	0	10101	8682.8862	2886	2886	0	444	0	0	0	0
20	10305.75	8953.6356	2944.5	2944.5	0	453	0	0	0	0	10305.75	8953.6356	0	2944.5	0	453	0	0	0	0
21	10510.5	8485.6002	3003	3003	0	462	0	0	0	0	10510.5	8485.6002	0	3003	0	0	0	0	0	0
22	10442.25	8199.0252	2983.5	2983.5	0	0	0	0	0	0	10442.25	8199.0252	0	2983.5	0	0	0	0	0	0
23	10351.25	7689.7275	0	0	0	0	0	0	0	0	10351.25	7689.7275	0	2957.5	0	0	0	0	0	0
24	10260.25	7620.579214	0	0	0	0	0	0	0	0	10260.25	7620.579214	0	2931.5	0	0	0	0	0	0

Table-6.24c: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 41-60) with PEVs

Hour	PGU41	PGU42	PGU43	PGU 44	PGU45	PGU46	PGU 47	PGU48	PGU 49	PGU 50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PGU56	PGU57	PGU 58	PGU 59	PGU 60
1	10078.25	6873.145	0	0	0	0	0	0	0	0	10078.25	6873.145	0	0	0	0	0	0	0	0
2	10010	7814.125	0	0	0	0	0	0	0	0	10010	7814.125	0	0	0	0	0	0	0	0
3	10510.5	7713.2055	0	3003	0	0	0	0	0	0	10510.5	7713.2055	0	0	0	0	0	0	0	0
4	10305.75	7481.153438	2944.5	2944.5	0	0	0	0	0	0	10305.75	7481.153438	2944.5	0	0	0	0	0	0	0
5	10578.75	8509.470937	3022.5	3022.5	0	0	0	0	0	0	10578.75	8509.470937	3022.5	0	0	0	0	0	0	0
6	10442.25	9077.4135	2983.5	2983.5	573.75	0	0	0	0	0	10442.25	9077.4135	2983.5	2983.5	573.75	0	0	0	0	0
7	10237.5	8827.14375	2925	2925	562.5	0	0	0	0	0	10237.5	8827.14375	2925	2925	562.5	0	0	0	0	0
8	10078.25	9022.442562	2879.5	2879.5	553.75	0	0	0	0	0	10078.25	9022.442562	2879.5	2879.5	553.75	0	0	0	0	0
9	10374	10107.7872	2964	2964	570	0	0	0	0	0	10374	10107.7872	2964	2964	570	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	1216.6162	733.75	293.5	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	1216.6162	733.75	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	1588.21155	753.75	301.5	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	1588.21155	753.75	301.5	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	1618.16955	791.25	316.5	316.5	0	14400.75	14400.75	4114.5	4114.5	5127.3	1618.16955	791.25	316.5	0	0
13	11193	11193	3198	3198	3009.2442	492	0	0	0	0	11193	11193	3198	3198	3009.2442	492	615	0	0	0
14	11147.5	11147.5	3185	3185	2541.9485	490	0	0	0	0	11147.5	11147.5	3185	3185	2541.9485	490	612.5	0	0	0
15	10237.5	10237.5	2925	2925	740.295	0	0	0	0	0	10237.5	10237.5	2925	2925	740.295	0	0	0	0	0
16	10146.5	8310.7863	2899	2899	0	0	0	0	0	0	10146.5	8310.7863	0	2899	0	0	0	0	0	0
17	10123.75	8098.555	0	2892.5	0	0	0	0	0	0	10123.75	8098.555	0	2892.5	0	0	0	0	0	0
18	10032.75	8622.7848	0	2866.5	0	0	0	0	0	0	10032.75	8622.7848	0	2866.5	0	441	0	0	0	0
19	10101	8682.8862	0	2886	0	0	0	0	0	0	10101	8682.8862	0	2886	0	444	0	0	0	0
20	10305.75	8953.6356	0	2944.5	0	0	0	0	0	0	10305.75	8953.6356	0	2944.5	0	453	0	0	0	0
21	10510.5	8485.6002	0	3003	0	462	0	0	0	0	10510.5	8485.6002	3003	3003	0	462	0	0	0	0
22	10442.25	8199.0252	2983.5	2983.5	0	459	0	0	0	0	10442.25	8199.0252	2983.5	2983.5	0	0	0	0	0	0
23	10351.25	7689.7275	2957.5	0	0	455	0	0	0	0	10351.25	7689.7275	2957.5	2957.5	0	0	0	0	0	0
24	10260.25	7620.579214	2931.5	0	0	0	0	0	0	0	10260.25	0	2931.5	0	0	0	0	0	0	0

Table-6.24d: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 61-80) with PEVs

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	10078.25	6873.145	0	0	0	0	0	0	0	0	10078.25	6873.145	0	0	0	0	0	0	0	0
2	10010	7814.125	0	0	0	0	0	0	0	0	10010	7814.125	0	0	0	0	0	0	0	0
3	10510.5	7713.2055	0	0	0	0	0	0	0	0	10510.5	7713.2055	0	3003	0	0	0	0	0	0
4	10305.75	7481.153438	0	2944.5	0	0	0	0	0	0	10305.75	7481.153438	0	2944.5	0	0	0	0	0	0
5	10578.75	8509.470937	3022.5	3022.5	0	0	0	0	0	0	10578.75	8509.470937	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	9077.4135	2983.5	2983.5	0	0	0	0	0	0	10442.25	9077.4135	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	8827.14375	2925	2925	0	0	0	0	0	0	10237.5	8827.14375	2925	2925	0	0	0	0	0	0
8	10078.25	9022.442562	2879.5	2879.5	0	0	0	0	0	0	10078.25	9022.442562	2879.5	2879.5	0	0	0	0	0	0
9	10374	10107.7872	2964	2964	570	0	0	0	0	0	10374	10107.7872	2964	2964	570	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	1216.6162	733.75	293.5	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	1216.6162	733.75	293.5	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	1588.21155	753.75	301.5	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	1588.21155	753.75	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	1618.16955	791.25	316.5	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	1618.16955	791.25	316.5	0	0
13	11193	11193	3198	3198	3009.2442	492	615	0	0	0	11193	11193	3198	3198	3009.2442	492	0	0	0	0
14	11147.5	11147.5	3185	3185	2541.9485	490	0	0	0	0	11147.5	11147.5	3185	3185	2541.9485	490	0	0	0	0
15	10237.5	10237.5	2925	2925	740.295	0	0	0	0	0	10237.5	10237.5	2925	2925	740.295	0	0	0	0	0
16	10146.5	8310.7863	2899	2899	0	0	0	0	0	0	10146.5	8310.7863	0	2899	0	0	0	0	0	0
17	10123.75	8098.555	0	2892.5	0	0	0	0	0	0	10123.75	8098.555	0	2892.5	0	0	0	0	0	0
18	10032.75	8622.7848	0	2866.5	0	441	0	0	0	0	10032.75	8622.7848	0	2866.5	0	441	0	0	0	0
19	10101	8682.8862	0	2886	0	444	0	0	0	0	10101	8682.8862	0	2886	0	444	0	0	0	0
20	10305.75	8953.6356	0	2944.5	0	453	0	0	0	0	10305.75	8953.6356	0	2944.5	0	453	0	0	0	0
21	10510.5	8485.6002	0	3003	0	0	0	0	0	0	10510.5	8485.6002	0	3003	0	0	0	0	0	0
22	10442.25	8199.0252	0	2983.5	0	0	0	0	0	0	10442.25	8199.0252	2983.5	2983.5	0	0	0	0	0	0
23	10351.25	0	0	2957.5	0	0	0	0	0	0	10351.25	7689.7275	2957.5	0	0	0	0	0	0	0
24	10260.25	0	0	2931.5	0	0	0	0	0	0	10260.25	7620.579214	2931.5	0	0	0	0	0	0	0

Table-6.24e: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 81-100) with PEVs

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	10078.25	0	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	0	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	0	0	3003	0	0	0	0	0	0	10510.5	0	0	3003	0	0	0	0	0	0
4	10305.75	0	0	2944.5	0	0	0	0	0	0	10305.75	0	0	2944.5	0	0	0	0	0	0
5	10578.75	0	3022.5	3022.5	0	0	0	0	0	0	10578.75	0	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	0	2983.5	2983.5	0	0	0	0	0	0	10442.25	0	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	0	2925	2925	0	0	0	0	0	0	10237.5	0	2925	2925	0	0	0	0	0	0
8	10078.25	0	2879.5	0	0	0	0	0	0	0	10078.25	0	2879.5	2879.5	0	0	0	0	0	0
9	10374	10107.7872	2964	0	0	0	0	0	0	0	10374	10107.7872	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	0	4754.7	1216.6162	733.75	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	1216.6162	733.75	293.5	0	0
11	13718.25	13718.25	3919.5	0	4884.3	1588.21155	753.75	301.5	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	1588.21155	753.75	0	0	0
12	14400.75	14400.75	4114.5	0	5127.3	1618.16955	791.25	316.5	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	1618.16955	791.25	0	0	0
13	11193	11193	3198	3198	3009.2442	492	0	0	0	0	11193	11193	3198	3198	3009.2442	492	0	0	0	0
14	11147.5	11147.5	3185	3185	2541.9485	0	0	0	0	0	11147.5	11147.5	3185	3185	2541.9485	0	0	0	0	0
15	10237.5	10237.5	2925	2925	740.295	0	0	0	0	0	10237.5	10237.5	2925	2925	740.295	0	0	0	0	0
16	10146.5	8310.7863	0	2899	0	0	0	0	0	0	10146.5	8310.7863	0	2899	0	0	0	0	0	0
17	10123.75	8098.555	0	2892.5	0	0	0	0	0	0	10123.75	8098.555	0	2892.5	0	0	0	0	0	0
18	10032.75	8622.7848	0	2866.5	0	441	0	0	0	0	10032.75	8622.7848	0	2866.5	0	0	0	0	0	0
19	10101	8682.8862	0	2886	0	444	0	0	0	0	10101	8682.8862	0	2886	0	0	0	0	0	0
20	10305.75	8953.6356	0	2944.5	0	453	0	0	0	0	10305.75	8953.6356	0	2944.5	0	0	0	0	0	0
21	10510.5	8485.6002	3003	3003	0	0	0	0	0	0	10510.5	8485.6002	3003	3003	0	0	0	0	0	0
22	10442.25	8199.0252	2983.5	2983.5	0	0	0	0	0	0	10442.25	8199.0252	2983.5	2983.5	0	0	0	0	0	0
23	10351.25	7689.7275	2957.5	2957.5	0	0	0	0	0	0	10351.25	0	2957.5	2957.5	0	0	0	0	0	0
24	10260.25	7620.579214	2931.5	0	0	0	0	0	0	0	10260.25	0	2931.5	0	0	0	0	0	0	0

The Table-6.24d is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm considering effect of PEVs for units 61 to unit 80. The PGU61, PGU71 and PGU72 are continuously on for 24 hours. Further PGU69, PGU70, PGU79 and PGU80 is off for 24 hours. The profit for PGU68 is 293.5 \$ in 10^{th} hour, 301.5 \$ is for 11^{th} hour and 316.5 \$ is for 12^{th} hour. Further, PGU78 give 293.5 \$ profit and 316.5 \$ profit for 10^{th} and 12^{th} hour respectively. For PGU67 and PGU77, the profit for 10^{th} hour is 733.75 \$, profit for 11^{th} hour is 753.75 \$, profit for 12^{th} hour is 791.25 \$ and the profit for 13^{th} hour is 615 \$ only for PGU67.

The Table-6.24e is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm considering effect of PEVs for units 81 to unit 100. The PGU81 and PGU91 has been on for 24 hours. PGU89, PGU90, PGU99 and PGU100 have been off for through the whole day. The PGU98 gives 293.5 \$ profit only for 10^{th} hour. The profit for PGU87 and PGU97 are same for 10^{th} to 12^{th} hours. For 10^{th} hour the profit is 733.75 \$, for 11^{th} hour the profit is 753.75 \$ and for 12^{th} hour the profit is 791.25 \$. For PGU88 the profit is 301.5 \$ in 11^{th} hour and 316.5 \$ is for 12^{th} hour. The PGU95 is kept on from 10^{th} to 15^{th} hours. So, the profit value can be varies from 740.295 \$ to 5127.3 \$ during this particular time period.

6.6.3 Hybrid Chaotic Harris Hawks-Sine Cosine Optimization Algorithm with solar PV during Summer

A new hybrid algorithm hCHHO-SCA is established to solve PBUCP with considering the uncertainty of solar energy in summer days. This is one of the gradient-free with consideration of inhabitants based calculations for the new optimization strategy, which will be helpful to detail on any kinds of optimization issues. The optimizer hCHHO-SCA have certain major performances in the phases of explorations phases of exploitations. The number of populations are 40 for 10-, 40- and 100-generating unit systems.

6.6.3.1 Ten Generating Unit System

This test system is used to check the efficiency of the proposed hCHHO-SCA optimizer. The system contains of 10-generating unit system having a 24-hour electricity demand. The hCHHO-SCA technique is evaluated for 100 iterations solar energy as solar PV in summer. The hCHHO- SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.16**. The commitment status, the optimal scheduling and the profit table of the 10-generating units have been shown in Table-6.25a and Table-6.25b respectively.

The Table-6.25a presents the commitment status and optimum scheduling of the generators during 24 hours considering solar PV in summer using hCHHO-SCA optimizer. In this case, the PGU1 and PGU2 are on for 24 hours. PGU1 generates 455 MW of power for 24 hours. Further, displays The PGU3 generates 130 MW of power for 10th to 15th hours. The PGU4 is remain off for 1 to 4th hours and 23rd and 24th hour. It is on only for 5th hour to 22nd hour. In those time, for which the PGU4 is on, it generates 130 MW power for each hour.

The Table-6.25b shows the hourly profit of 10-unit system considering solar PV in summer using hCHHO-SCA optimizer. For PGU1 and PGU2 maximum profit can be obtained because it is on for the whole day. For PGU3 the profit value differs from 2925 $ to 4114.5 $ only for 10th hour to 15th hour. For PGU7 to PGU10 no profit will be gained as it is not committed.

Table-6.25a: Commitment status and scheduling for 10-generating unit system using hCHHO-SCA optimization algorithm with solar during summer

Commitment status of thermal units								Scheduling of the committed generating units						
HOURS	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**
1	1	1	0	0	0	0	0	455	245	0	0	0	0	0
2	1	1	0	0	0	0	0	455	295	0	0	0	0	0
3	1	1	0	0	0	0	0	455	395	0	0	0	0	0
4	1	1	0	0	0	0	0	455	455	0	0	0	0	0
5	1	1	0	1	0	0	0	455	415	0	130	0	0	0
6	1	1	0	1	0	0	0	455	455	0	130	0	0	0
7	1	1	0	1	0	0	0	455	455	0	130	0	0	0
8	1	1	0	1	0	0	0	455	450.45	0	130	0	0	0
9	1	1	0	1	1	0	0	455	455	0	130	114.33	0	0
10	1	1	1	1	1	1	0	455	455	130	130	162	40.6600002	0
11	1	1	1	1	1	1	0	455	455	130	130	162	42.83	0
12	1	1	1	1	1	1	0	455	455	130	130	162	33.94	0
13	1	1	1	1	1	0	0	455	455	130	130	110.14	0	0
14	1	1	1	1	1	0	0	455	455	130	130	75.53	0	0
15	1	1	1	1	0	0	0	455	440.41	130	130	0	0	0
16	1	1	0	1	0	0	0	455	406.14	0	130	0	0	0
17	1	1	0	1	0	0	0	455	377.16	0	130	0	0	0
18	1	1	0	1	0	0	0	455	421.4	0	130	0	0	0
19	1	1	0	1	0	0	0	455	435.41	0	130	0	0	0
20	1	1	0	1	0	0	0	455	448.49	0	130	0	0	0
21	1	1	0	1	0	0	0	455	454.84	0	130	0	0	0
22	1	1	0	1	0	0	0	455	455	0	130	0	0	0
23	1	1	0	0	0	0	0	455	445	0	0	0	0	0
24	1	1	0	0	0	0	0	455	345	0	0	0	0	0

Table-6.25b: Hourly profit for 10-generating unit system using hCHHO-SCA optimization algorithm with solar during summer

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7 to PG10	Start-up Cost	Hourly Profit
1	10078.25	5426.75	0	0	0	0	0	0	15505
2	10010	6490	0	0	0	0	0	0	16500
3	10510.5	9124.5	0	0	0	0	0	1680	19635
4	10305.75	10305.75	0	0	0	0	0	560	20611.5
5	10578.75	9648.75	0	3022.5	0	0	0	520	23250
6	10442.25	10442.25	0	2983.5	0	0	0	0	23868
7	10237.5	10237.5	0	2925	0	0	0	0	23400
8	10078.25	9977.4675	0	2879.5	0	0	0	0	22935.2175
9	10374	10374	0	2964	2606.724	0	0	120	26318.724
10	13354.25	13354.25	3815.5	3815.5	4754.7	1193.37101	0	60	40287.571
11	13718.25	13718.25	3919.5	3919.5	4884.3	1291.3245	0	170	41451.1245
12	14400.75	14400.75	4114.5	4114.5	5127.3	1074.201	0	260	43232.001
13	11193	11193	3198	3198	2709.444	0	0	0	31491.444
14	11147.5	11147.5	3185	3185	1850.485	0	0	0	30515.485
15	10237.5	9909.22501	2925	2925	0	0	0	0	25996.725
16	10146.5	9056.922	0	2899	0	0	0	0	22102.422
17	10123.75	8391.81	0	2892.5	0	0	0	60	21408.06
18	10032.75	9291.87	0	2866.5	0	0	0	0	22191.12
19	10101	9666.102	0	2886	0	0	0	0	22653.102
20	10305.75	10158.2985	0	2944.5	0	0	0	0	23408.5485
21	10510.5	10506.804	0	3003	0	0	0	900	24020.304
22	10442.25	10442.25	0	2983.5	0	0	0	0	23868
23	10351.25	10123.75	0	0	0	0	0	0	20475
24	10260.25	7779.75	0	0	0	0	0	0	18040

6.6.3.2 Forty Generating Unit System

The proposed hCHHO-SCA algorithm is used to find optimal scheduling and profit considering solar PV in summer. The solar energy have been taken into consideration. The forty generating unit system is tested on 30 runs. The best profit has been recorded for 100 iterations. The profit with start-up costand fuel cost of 24 hours are shown in Table-6.26. The optimal scheduling of 40-generating unit systems are shown in Table-6.27a and Table-6.27b. The hourly profit for this system is given in Table-6.28a and Table-6.28b respectively. The convergence graph of total profit is shown in **Fig.6.16**.

Table-6.26: Hourly profit with startup cost and fuel cost for 40-generating unit system using hCHHO-SCA optimization algorithm with solar during summer

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	62020	2540	53787.3293	**13**	129793.044	2660	102905.826
2	66000	1980	57283.9693	**14**	126065.485	1800	99701.8277
3	78540	2150	65457.854	**15**	106996.725	120	92283.8666
4	82446	6340	70578.81	**16**	91678.422	900	79499.5794
5	93000	5000	77802.3628	**17**	88158.06	560	75971.4783
6	95472	0	80603.6428	**18**	90987.12	900	79432.2875
7	93600	1120	80603.6428	**19**	91917.102	750	79677.8932
8	92043.2175	0	79941.5826	**20**	94076.5485	750	79907.2172
9	106346.724	10000	90104.7047	**21**	96092.304	290	80018.5558
10	163557.571	5000	107519.601	**22**	95472	10000	80021.3612
11	169166.525	560	108769.819	**23**	81900	770	68711.639
12	177301.401	340	108613.948	**24**	72160	1600	61709.679

Table-6.27a: Generation scheduling for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with solar during summer

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5-PGU-10	PGU-11	PGU-12	PGU-13	PGU-14	PGU-15-PGU-20
1	455	326.6666667	326.6666667	0	0	455	0	326.6666667	0	0
2	455	393.3333333	393.3333333	0	0	455	0	393.3333333	0	0
3	455	440	440	129.9999999	0	455	0	440	129.9999999	0
4	455	390.0000002	390.0000002	129.9999996	0	455	0	390.0000002	129.9999996	0
5	455	384.0000002	384.0000002	129.9999995	0	455	0	384.0000002	129.9999995	0
6	455	416	416	130	0	455	0	416	130	0
7	455	416	416	130	0	455	0	416	130	0
8	455	441.09	441.09	130	0	455	0	441.09	0	0
9	455	406.3328571	406.3328571	0	0	455	406.3328571	406.3328571	0	0
10	455	452.8325	452.8325	0	0	455	452.8325	452.8325	0	0
11	455	441.35375	441.35375	0	0	455	441.35375	441.35375	0	0
12	455	440.2425	440.2425	0	0	455	440.2425	440.2425	0	0
13	455	399.5175001	399.5175001	0	0	455	399.5175001	399.5175001	0	0
14	455	437.9328571	437.9328571	0	0	455	437.9328571	437.9328571	0	0
15	455	400.7728572	400.7728572	0	0	455	400.7728572	400.7728572	0	0
16	454.9999999	381.8566667	381.8566667	0	0	454.9999999	381.8566667	381.8566667	0	0
17	455	428.432	428.432	0	0	455	428.432	428.432	0	0
18	455	435.28	435.28	130	0	455	435.28	435.28	0	0
19	455	438.082	438.082	130	0	455	438.082	438.082	0	0
20	455	440.698	440.698	130	0	455	440.698	440.698	0	0
21	455	441.968	441.968	130	0	455	441.968	441.968	0	0
22	455	442	442	130	0	455	442	442	0	0
23	455	445	445	0	0	455	0	445	0	0
24	455	345	0	0	0	455	0	345	0	0

The optimal power generation scheduling for 40-generating unit system using hCHHO-SCA optimizer have been shown in Table-6.27a. Out of 40-generating units Table-6.30a represent PGU1 to PGU20 for 24 hours considering RES in summer. The optimal scheduling have been obtained from PGU1, PGU2, PGU3 and PGU13 for 24 hours. The PGU5 to PGU10 and PGU15 to PGU20 remain off during 24 hours. So, the output power is became ‘0’. The PGU4 and PGU12 have been on for few hours. Thus the optimum scheduling can be obtain for that particular hour. The generation scheduling for PGU11 is 455 MW that meets the 24 hours power demand.

Table-6.27b: Generation scheduling for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40) with solar during summer

HOURS	PGU21	PGU22	PGU23	PGU24	PGU25-PGU-30	PGU31	PGU32	PGU33	PGU34	PGU35-PGU-40
1	455	0	0	0	0	455	0	0	0	0
2	455	0	0	0	0	455	0	0	0	0
3	455	0	0	0	0	455	0	0	0	0
4	455	0	390.0000002	0	0	455	0	0	0	0
5	455	0	384.0000002	0	0	455	0	384.0000002	0	0
6	455	0	416	0	0	455	0	416	0	0
7	455	0	416	0	0	455	0	416	0	0
8	455	0	441.09	0	0	455	0	441.09	0	0
9	455	0	406.3328571	0	0	455	406.3328571	406.3328571	0	0
10	455	452.8325	452.832	130	0	455	452.8325	452.8325	0	0
11	455	441.35375	441.353	130	0	455	441.35375	441.35375	130	0
12	455	440.2425	440.242	130	0	455	440.2425	440.2425	130	0
13	455	399.51750	399.517	129.99	0	455	399.517500	399.5175001	129.9	0
14	455	437.93285	437.932	130	0	455	437.932857	0	130	0
15	455	400.7728	400.772	0	0	455	400.77285	0	129.9	0
16	454.99	381.85666	0	0	0	454.999	381.85666	0	0	0
17	455	428.432	0	0	0	455	0	0	0	0
18	455	435.28	0	0	0	455	0	0	0	0
19	455	438.082	0	0	0	455	0	0	0	0
20	455	440.698	0	0	0	455	0	0	0	0
21	455	441.968	0	0	0	455	0	0	0	0
22	455	442	0	0	0	455	0	0	0	0
23	455	445	0	0	0	455	0	0	0	0
24	455	345	345	0	0	455	0	0	0	0

The suggested hCHHO-SCA optimization algorithm is used to solve PBUCP for 40-unit test system with solar PV in summer. The Table-6.27b represents the optimum scheduling of PGU21 to PGU40. The power scheduling for PGU21 and PGU31 is 455 MW for 24 hours. Further, PGU25 to PGU30 and PGU35 to PGU40 has been off throughout the 24 hours. For 10th, 11th, 12th, 13th and 14th hours, the PGU24 have been on. The optimal power generation is 130 MW for 10th, 11th, 12th and 14th hours and 129.99 MW for 13th hour. The PGU22, PGU23 and PGU32, PGU33 are kept on for some few hours. Further PGU34 has been remained on only for 11th hour to 15th hour.

Table-6.28a and Table-6.28b represents the hourly profit for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with solar PV during summer.

Table-6.28a: Hourly profit for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with solar during summer

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	GPU16	PGU17	PGU 18	PGU19	PGU 20
1	10078.25	7235.66667	7235.66667	0	0	0	0	0	0	0	10078.25	0	7235.66667	0	0	0	0	0	0	0
2	10010	8653.33333	8653.33333	0	0	0	0	0	0	0	10010	0	8653.33333	0	0	0	0	0	0	0
3	10510.5	10164	10164	3003	0	0	0	0	0	0	10510.5	0	10164	3003	0	0	0	0	0	0
4	10305.75	8833.5	8833.5	2944.49999	0	0	0	0	0	0	10305.75	0	8833.5	2944.49999	0	0	0	0	0	0
5	10578.75	8928.00001	8928.00001	3022.49999	0	0	0	0	0	0	10578.75	0	8928.00001	3022.49999	0	0	0	0	0	0
6	10442.25	9547.2	9547.2	2983.5	0	0	0	0	0	0	10442.25	0	9547.2	2983.5	0	0	0	0	0	0
7	10237.5	9360	9360	2925	0	0	0	0	0	0	10237.5	0	9360	2925	0	0	0	0	0	0
8	10078.25	9770.1435	9770.1435	2879.5	0	0	0	0	0	0	10078.25	0	9770.1435	0	0	0	0	0	0	0
9	10374	9264.38914	9264.38914	0	0	0	0	0	0	0	10374	9264.38914	9264.38914	0	0	0	0	0	0	0
10	13354.25	13290.6339	13290.6339	0	0	0	0	0	0	0	13354.25	13290.6339	13290.6339	0	0	0	0	0	0	0
11	13718.25	13306.8156	13306.8156	0	0	0	0	0	0	0	13718.25	13306.8156	13306.8156	0	0	0	0	0	0	0
12	14400.75	13933.6751	13933.6751	0	0	0	0	0	0	0	14400.75	13933.6751	13933.6751	0	0	0	0	0	0	0
13	11193	9828.1305	9828.1305	0	0	0	0	0	0	0	11193	9828.1305	9828.1305	0	0	0	0	0	0	0
14	11147.5	10729.355	10729.355	0	0	0	0	0	0	0	11147.5	10729.355	10729.355	0	0	0	0	0	0	0
15	10237.5	9017.38929	9017.38929	0	0	0	0	0	0	0	10237.5	9017.38929	9017.38929	0	0	0	0	0	0	0
16	10146.5	8515.40367	8515.40367	0	0	0	0	0	0	0	10146.5	8515.40367	8515.40367	0	0	0	0	0	0	0
17	10123.75	9532.612	9532.612	0	0	0	0	0	0	0	10123.75	9532.612	9532.612	0	0	0	0	0	0	0
18	10032.75	9597.924	9597.924	2866.5	0	0	0	0	0	0	10032.75	9597.924	9597.924	0	0	0	0	0	0	0
19	10101	9725.4204	9725.4204	2886	0	0	0	0	0	0	10101	9725.4204	9725.4204	0	0	0	0	0	0	0
20	10305.75	9981.8097	9981.8097	2944.5	0	0	0	0	0	0	10305.75	9981.8097	9981.8097	0	0	0	0	0	0	0
21	10510.5	10209.4608	10209.4608	3003	0	0	0	0	0	0	10510.5	10209.4608	10209.4608	0	0	0	0	0	0	0
22	10442.25	10143.9	10143.9	2983.5	0	0	0	0	0	0	10442.25	10143.9	10143.9	0	0	0	0	0	0	0
23	10351.25	10123.75	10123.75	0	0	0	0	0	0	0	10351.25	0	10123.75	0	0	0	0	0	0	0
24	10260.25	7779.75	0	0	0	0	0	0	0	0	10260.25	0	7779.75	0	0	0	0	0	0	0

Table-6.28b: Hourly profit for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40) with solar during summer

HOURS	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PG34	PGU35	GPU36	PGU37	PGU 38	PGU39	PGU 40
1	10078.25	0	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	0	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	0	0	0	0	0	0	0	0	0	10510.5	0	0	0	0	0	0	0	0	0
4	10305.75	0	8833.5	0	0	0	0	0	0	0	10305.75	0	0	0	0	0	0	0	0	0
5	10578.75	0	8928.00001	0	0	0	0	0	0	0	10578.75	0	8928.00001	0	0	0	0	0	0	0
6	10442.25	0	9547.2	0	0	0	0	0	0	0	10442.25	0	9547.2	0	0	0	0	0	0	0
7	10237.5	0	9360	0	0	0	0	0	0	0	10237.5	0	9360	0	0	0	0	0	0	0
8	10078.25	0	9770.1435	0	0	0	0	0	0	0	10078.25	0	9770.1435	0	0	0	0	0	0	0
9	10374	0	9264.38914	0	0	0	0	0	0	0	10374	9264.38914	9264.38914	0	0	0	0	0	0	0
10	13354.25	13290.6339	13290.6339	3815.5	0	0	0	0	0	0	13354.25	13290.6339	13290.6339	0	0	0	0	0	0	0
11	13718.25	13306.8156	13306.8156	3919.5	0	0	0	0	0	0	13718.25	13306.8156	13306.8156	3919.5	0	0	0	0	0	0
12	14400.75	13933.6751	13933.6751	4114.5	0	0	0	0	0	0	14400.75	13933.6751	13933.6751	4114.5	0	0	0	0	0	0
13	11193	9828.1305	9828.1305	3197.99999	0	0	0	0	0	0	11193	9828.1305	9828.1305	3197.99999	0	0	0	0	0	0
14	11147.5	10729.355	10729.355	3185	0	0	0	0	0	0	11147.5	10729.355	0	3185	0	0	0	0	0	0
15	10237.5	9017.38929	9017.38929	0	0	0	0	0	0	0	10237.5	9017.38929	0	2924.99999	0	0	0	0	0	0
16	10146.5	8515.40367	0	0	0	0	0	0	0	0	10146.5	8515.40367	0	0	0	0	0	0	0	0
17	10123.75	9532.612	0	0	0	0	0	0	0	0	10123.75	0	0	0	0	0	0	0	0	0
18	10032.75	9597.924	0	0	0	0	0	0	0	0	10032.75	0	0	0	0	0	0	0	0	0
19	10101	9725.4204	0	0	0	0	0	0	0	0	10101	0	0	0	0	0	0	0	0	0
20	10305.75	9981.8097	0	0	0	0	0	0	0	0	10305.75	0	0	0	0	0	0	0	0	0
21	10510.5	10209.4608	0	0	0	0	0	0	0	0	10510.5	0	0	0	0	0	0	0	0	0
22	10442.25	10143.9	0	0	0	0	0	0	0	0	10442.25	0	0	0	0	0	0	0	0	0
23	10351.25	10123.75	0	0	0	0	0	0	0	0	10351.25	0	0	0	0	0	0	0	0	0
24	10260.25	7779.75	7779.75	0	0	0	0	0	0	0	10260.25	0	0	0	0	0	0	0	0	0

6.6.3.3 Hundred Generating Unit System

This test system is used to check the efficiency of the proposed hCHHO-SCA optimizer. The system contains of 100-generating unit system having a 24-hour electricity demand. The hCHHO-SCA technique is evaluated for 100 iterations solar energy as solar PV in summer. The solar PV in electricity generation based distributed energy supply innovation has become the improvement center in the power sector. However, the intermittence and fluctuations of the wind as well as solar energy and other environmentally friendly power sources progressively logically inconsistency in-between new electrical energy and the power grid framework. The nature of solar PV is very uncertain as well as it must be difficult for static analysis in the field of optimizations to optimize uncertain no stationary distributed power sources in hybrid systems. A profit based analysis on this stochastic method for optimization of hourly profit, fuel costs, startup costs are formulated by minimizing the total operating costs including the uncertainty of solar PV during summer for the proposed hybrid system. The hCHHO- SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.16**. Table-6.29 shows the hourly profit with start-up cost and fuel cost for100-generating unit system using hCHHO-SCA optimization algorithm with solar PV during summer. The optimal scheduling of 100-generating unit systems are shown in Table-6.30a to Table-6.30e. The hourly profit table for this system is shown in Table-6.31a to Table-6.31e respectively.

Table-6.29: Hourly profit with start-up cost and fuel cost for100-generating unit system using hCHHO-SCA optimization algorithm with solar during summer

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	155050	6220	137074.14	**13**	326396.24	470	272503.14
2	165000	10530	147430.92	**14**	317165.49	1720	262129.85
3	196350	4490	165405.74	**15**	268996.73	1850	240643.47
4	206115	3510	176424.66	**16**	230830.42	240	202188.15
5	232500	1090	198131.71	**17**	221658.06	1830	193981.38
6	238680	120	207009.27	**18**	228579.12	4730	205069.3
7	234000	3100	207169.23	**19**	230445.1	860	207679.45
8	230259.22	840	207001.71	**20**	235412.55	4780	209939.67
9	266402.72	11200	235160.62	**21**	240236.3	3370	206357.64
10	410097.57	960	287588.05	**22**	238680	5590	205734.41
11	424597.32	2320	289952.96	**23**	204750	1290	177322.38
12	445440.2	830	290212.87	**24**	180400	7710	158931.94

Table-6.30a: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with solar during summer

HOUR	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	455	243.33333	0	0	0	0	0	0	0	0	455	243.33333	0	0	0	0	0	0	0	0
2	455	278.88889	130	0	0	0	0	0	0	0	455	278.88889	0	0	0	0	0	0	0	0
3	455	387.22222	130	0	0	0	0	0	0	0	455	387.22222	0	0	0	0	0	0	0	0
4	455	451.11111	130	0	0	0	0	0	0	0	455	451.11111	0	0	25	0	0	0	0	0
5	455	455	130	0	0	0	0	0	0	0	455	455	0	0	123.33333	0	0	0	0	0
6	455	455	130	0	0	0	0	0	0	0	455	455	0	0	144.28571	0	0	0	0	0
7	455	455	130	0	0	0	0	0	0	0	455	455	0	130	125.71429	0	0	0	0	0
8	455	455	130	0	0	0	25	0	0	0	455	455	0	130	107.20714	0	0	0	0	0
9	455	455	130	130	0	0	25	0	0	0	455	455	0	130	96.16625	0	0	0	0	0
10	455	455	130	130	162	80	37.66	0	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	154.23778	20	0	10	0	0	455	455	130	130	154.23778	0	0	0	0	0
14	455	455	130	130	162	0	0	55	0	0	455	455	130	130	162	0	0	0	0	0
15	455	455	130	130	162	0	0	0	0	40.705	455	455	130	130	0	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
17	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	10	0	0
18	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
19	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	78.082	0	0	0
20	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	82.415	0	55	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	0	0	0	65.46	0	0	0
22	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
23	455	455	130	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
24	455	455	130	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0

Table-6.30b: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40) with solar during summer

HOUR	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	243.33333	0	0	0	0	0	0	0	0	455	243.33333	0	0	0	0	0	0	0	0
2	455	278.88889	0	0	25	0	0	0	0	0	455	278.88889	0	0	25	0	0	0	0	0
3	455	387.22222	0	0	25	0	0	0	0	0	455	387.22222	0	0	25	0	0	0	0	0
4	455	451.11111	0	0	25	0	0	0	0	0	455	451.11111	0	0	25	0	0	0	0	0
5	455	455	0	0	123.33333	0	0	0	0	0	455	455	0	0	123.33333	0	25	0	0	0
6	455	455	0	0	144.28571	0	0	0	0	0	455	455	130	0	144.28571	0	25	0	0	0
7	455	455	0	0	125.71429	0	0	0	0	0	455	455	130	0	125.71429	0	25	0	0	0
8	455	455	0	0	107.20714	20	0	0	0	0	455	455	130	0	107.20714	20	0	0	0	0
9	455	455	0	130	96.16625	20	0	0	0	0	455	455	130	130	96.16625	20	0	0	0	0
10	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	42.83	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	56.97	0	0	0
13	455	455	130	130	154.23778	0	0	0	0	0	455	455	130	130	154.23778	0	25	0	0	0
14	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
17	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
18	455	455	0	130	0	80	0	0	0	0	455	455	0	130	0	0	0	0	0	0
19	455	455	0	130	0	80	0	0	0	0	455	455	0	130	0	0	0	0	0	0
20	455	455	0	0	0	80	0	0	0	0	455	455	0	0	0	0	0	0	0	0
21	455	455	0	0	162	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
22	455	455	130	0	162	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
23	455	455	130	0	158	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
24	455	455	130	0	162	0	0	0	0	0	455	0	130	0	0	0	0	0	0	0

The Table-6.30a represents the generation scheduling of 100-generating unit system with effect of solar PV using hCHHO-SCA optimization algorithm in summer for PGU1 to PGU20. Where PGU1, PGU2, PGU11 and PGU12 are remain on for 24 hours. The 455 MW power output can be measured from PGU1 and PGU11 for 24 hours. PGU9 and PGU20 is totally off for 24 hours. So, no power generation can be obtained from those units. Further others unit are on for some few hours and off some few hours. Thus the optimal generation can be taken only those are in on condition.

Table-6.30b gives the optimal power scheduling of 100-uniut system with effect of solar PV by suggested hCHHO-SCA method in summer for PGU21 to PGU40. The PGU21, PGU22, PGU31 and PGU32 are in on condition for 24 hours. And other PGU are sometimes on and sometimes off. PGU27 to PGU30 and PGU36 to PGU40 are off during 24 hours.

Table-6.30c presents the generation scheduling of 100-unit system with effect of solar PV using proposed hCHHO-SCA optimization algorithm in summer for PGU41 to PGU60. Here, PGU41, PGU42, PGU51 and PGU52 are on for 24 hours. The 455 MW power can be generated from PGU41 and PGU51. The output power is ‘0’ for PGU49 to PGU50 and PGU57 to PGU60. The PGU47 generate power for 18th to 20th hours, i.e. 83.2 MW for 18th, 78.082 MW for 19th and 82.415 MW for 20th hour. The other PGU are on and off for few hours and output power generation can be measured through the table.

Thable-6.30d signifies the generation scheduling of 100-generating unit by hCHHO-SCA algorithm for PGU61 to PGU80 considering the effect of solar PV in summer. The PGU61 and PGU71 is on for 24 hours. The 455 MW power output can be shown from PGU61 and PGU71 for 24 hours. The power output from PGU68 to PGU70 and PGU78 to PGU80 is ‘0’ for 24 hours. The PGU67 generate same power for 20th to 22th hours, i.e. 82.415 MW for 20th, 65.46 MW for 21th and 85 MW for 22th hour.

Table-6.30c: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 41-60) with solar during summer

Hour	PGU41	PGU42	PGU43	PGU44	PGU45	PGU46	PGU47	PGU48	PGU49	PGU50	PGU51	PGU52	PGU53	PGU54	PGU55	PGU56	PGU57	PGU58	PGU59	PGU60
1	455	243.33333	0	0	0	0	0	0	0	0	455	243.33333	0	0	0	0	0	0	0	0
2	455	278.88889	0	0	0	0	0	0	0	0	455	278.88889	0	0	0	0	0	0	0	0
3	455	387.22222	0	0	0	0	0	0	0	0	455	387.22222	0	0	0	0	0	0	0	0
4	455	451.11111	0	0	0	0	0	0	0	0	455	451.11111	0	0	0	0	0	0	0	0
5	455	455	0	0	0	0	0	0	0	0	455	455	0	0	123.33333	20	0	0	0	0
6	455	455	0	0	144.28571	0	0	0	0	0	455	455	0	0	144.28571	20	0	0	0	0
7	455	455	0	0	125.71429	0	0	0	0	0	455	455	0	0	125.71429	20	0	0	0	0
8	455	455	0	0	107.20714	0	0	0	0	0	455	455	0	0	107.20714	0	0	0	0	0
9	455	455	0	130	96.16625	0	0	0	0	0	455	455	0	130	96.16625	0	0	0	0	0
10	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
11	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	154.23778	20	0	10	0	0	455	455	130	130	154.23778	20	0	0	0	0
14	455	455	130	130	0	80	0	0	0	0	455	455	130	130	0	80	0	0	0	0
15	455	455	130	130	0	0	0	55	0	0	455	455	130	130	0	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
17	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
18	455	455	0	130	0	80	83.2	0	0	0	455	455	0	130	0	0	0	0	0	0
19	455	455	0	130	0	80	78.082	0	0	0	455	455	0	0	0	0	0	0	0	0
20	455	455	0	0	162	80	82.415	0	0	0	455	455	0	0	0	0	0	0	0	0
21	455	455	0	0	162	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
22	455	455	130	0	162	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
23	455	455	130	0	158	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
24	455	0	130	0	162	0	0	0	0	0	455	0	130	0	0	0	0	0	0	0

Table-6.30d: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 61-80) with solar during summer

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	455	243.33333	0	130	0	0	0	0	0	0	455	243.33333	0	0	0	0	0	0	0	0
2	455	278.88889	0	130	0	0	0	0	0	0	455	278.88889	0	0	0	0	0	0	0	0
3	455	387.22222	0	130	0	0	0	0	0	0	455	387.22222	0	0	0	0	0	0	0	0
4	455	451.11111	0	130	0	0	0	0	0	0	455	451.11111	0	0	0	0	0	0	0	0
5	455	455	0	130	0	0	25	0	0	0	455	455	130	0	123.33333	0	0	0	0	0
6	455	455	0	130	0	0	25	0	0	0	455	455	130	0	144.28571	0	0	0	0	0
7	455	455	0	130	0	0	25	0	0	0	455	455	130	0	125.71429	0	0	0	0	0
8	455	455	0	130	0	0	25	0	0	0	455	455	130	0	107.20714	0	0	0	0	0
9	455	455	0	130	96.16625	0	0	0	0	0	455	455	130	0	96.16625	20	0	0	0	0
10	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	154.23778	20	0	0	0	0	455	455	130	130	154.23778	20	0	0	0	0
14	455	455	130	130	162	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
17	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	36.08	0	0	0	0
18	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	80	0	0	0	0
19	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	80	78.082	0	0	0
20	455	455	0	0	0	0	82.415	0	0	0	455	455	0	0	0	0	82.415	0	0	0
21	455	455	0	0	162	0	65.46	0	0	0	455	455	130	0	0	0	65.46	0	0	0
22	455	455	0	0	162	0	85	0	0	0	455	455	130	130	0	0	0	0	0	0
23	455	0	0	0	158	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
24	455	0	0	0	162	0	0	0	0	0	455	0	130	130	162	0	0	0	0	0

Table-6.30e: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 81-100) with solar during summer

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	455	243.33333	0	0	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
2	455	278.88889	0	0	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
3	455	387.22222	0	0	25	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
4	455	451.11111	0	0	25	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
5	455	455	0	0	123.33333	0	25	0	0	0	455	0	0	130	0	0	0	0	0	0
6	455	455	0	0	144.28571	0	25	0	0	0	455	0	0	130	0	0	0	0	0	0
7	455	455	0	0	125.71429	0	25	0	0	0	455	0	0	130	0	0	0	0	0	0
8	455	455	0	130	107.20714	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
9	455	455	130	130	96.16625	20	0	0	0	0	455	455	0	130	0	20	0	0	0	0
10	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	55	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	0	56.97	0	0	0	455	455	130	130	162	0	0	0	0	0
13	455	455	130	130	0	0	25	0	0	0	455	455	130	130	154.23778	0	0	10	0	0
14	455	455	130	130	0	0	58.530001	0	0	0	455	455	130	130	162	0	0	0	0	0
15	455	455	0	130	0	0	0	0	55	40.705	455	455	0	130	162	0	0	0	0	0
16	455	455	0	130	0	71.14	0	0	0	0	455	455	0	0	0	0	0	10	0	0
17	455	455	0	0	0	36.08	0	0	0	0	455	455	0	0	0	0	0	0	0	0
18	455	455	0	0	0	80	0	0	0	0	455	455	0	0	0	0	83.2	0	0	0
19	455	455	0	0	0	0	78.082	0	0	0	455	455	0	0	0	0	78.082	0	0	0
20	455	455	0	0	162	0	82.415	0	0	0	455	455	0	0	0	0	82.415	0	0	0
21	455	455	0	0	162	0	65.46	0	0	0	455	455	0	0	0	0	0	0	0	0
22	455	455	130	0	162	0	0	0	0	0	455	0	0	0	162	80	0	0	0	0
23	455	0	130	0	158	0	0	0	0	0	455	0	0	0	158	20	0	0	0	0
24	455	0	130	0	162	0	0	0	0	0	455	0	0	0	162	73	0	0	0	0

Table-6.30e gives the optimal power scheduling of 100-uniut system by suggested hCHHO-SCA method for PGU81 to PGU100 considering the effect of solar PV in summer. PGU88 and PGU100 is totally off throughout the day. So, no power generation can be obtained from those units. Further others unit are on for some few hours and off some few hours. Thus the optimal generation can be taken only those are in on condition.

Table-6.31a shows the best profit of PGU1 to PGU20 for each unit for particular hours considering the effect of solar PV in summer. The duration of total hour is 24 hours. The suggested hCHHO-SCA optimizer is tested on 100-unit system. The profit from PGU8 can be obtained for 13^{th} and 14^{th} hours, i.e. 246 $ for 13^{th} and 1347.5 $ for 14^{th} hours and for the other hours it remains off.

Table-6.31b represents the hourly profit for 100-generating unit system by hCHHO-SCA optimizer for PGU21 to PGU40 considering the effect of solar PV in summer. The PGU21, PGU22, PGU31 and PGU32 are on throughout 24 hours. So, for those units the profit values are obtained in each hour. The PGU27 to PGU30 and PGU98 to PGU40 is off during 24 hours.

The Table-6.31c is presented the hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm for units 41 to unit 60 with solar PV in summer. The PGU41 and PGU51 remain on for 24 hours. The PGU49 to PGU50 and PGU57 to PGU60 remain close throughout the whole day. That’s why no profit come from those units, the output is ‘0’.

The Table-6.31d and Table-6.31e is presented the hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm for PGU61 to PGU80 and PGU81 to PGU100 with solar PV in summer. The PGU61, PGU71, PGU81 and PGU91 remain on for 24 hours. The PGU68 to PGU70 and PGU78 to PGU80 as well as PGU88 and PGU100 remain close throughout the whole day. That’s why no profit come from those units, the output is ‘0’.

Table-6.31a: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 1-20) with solar during summer

Hour	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	10078.25	5389.8333	0	0	0	0	0	0	0	0	10078.25	5389.8333	0	0	0	0	0	0	0	0
2	10010	6135.5556	2860	0	0	0	0	0	0	0	10010	6135.5556	0	0	0	0	0	0	0	0
3	10510.5	8944.8333	3003	0	0	0	0	0	0	0	10510.5	8944.8333	0	0	0	0	0	0	0	0
4	10305.75	10217.667	2944.5	0	0	0	0	0	0	0	10305.75	10217.667	0	0	566.25	0	0	0	0	0
5	10578.75	10578.75	3022.5	0	0	0	0	0	0	0	10578.75	10578.75	0	0	2867.5	0	0	0	0	0
6	10442.25	10442.25	2983.5	0	0	0	0	0	0	0	10442.25	10442.25	0	0	3311.3571	0	0	0	0	0
7	10237.5	10237.5	2925	0	0	0	0	0	0	0	10237.5	10237.5	0	2925	2828.5714	0	0	0	0	0
8	10078.25	10078.25	2879.5	0	0	0	553.75	0	0	0	10078.25	10078.25	0	2879.5	2374.6382	0	0	0	0	0
9	10374	10374	2964	2964	0	0	570	0	0	0	10374	10374	0	2964	2192.5905	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	1105.321	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3794.2493	492	0	246	0	0	11193	11193	3198	3198	3794.2493	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	1347.5	0	0	11147.5	11147.5	3185	3185	3969	0	0	0	0	0
15	10237.5	10237.5	2925	2925	3645	0	0	0	0	915.8625	10237.5	10237.5	2925	2925	0	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	10123.75	0	2892.5	0	0	0	0	0	0	10123.75	10123.75	0	2892.5	0	0	0	222.5	0	0
18	10032.75	10032.75	0	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	0	0	0	0
19	10101	10101	0	2886	0	0	0	0	0	0	10101	10101	0	2886	0	0	1733.4204	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	1866.6998	0	1245.75	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	0	0	0	1512.126	0	0	0
22	10442.25	10442.25	0	0	0	0	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	10351.25	2957.5	0	0	0	0	0	0	0	10351.25	10351.25	0	0	0	0	0	0	0	0
24	10260.25	10260.25	2931.5	0	0	0	0	0	0	0	10260.25	10260.25	0	0	0	0	0	0	0	0

Table-6.31b: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 21-40) with solar during summer

Hour	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU 29	PGU 30	PGU31	PGU32	PGU33	PGU 34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	10078.25	5389.8333	0	0	0	0	0	0	0	0	10078.25	5389.8333	0	0	0	0	0	0	0	0
2	10010	6135.5556	0	0	550	0	0	0	0	0	10010	6135.5556	0	0	550	0	0	0	0	0
3	10510.5	8944.8333	0	0	577.5	0	0	0	0	0	10510.5	8944.8333	0	0	577.5	0	0	0	0	0
4	10305.75	10217.667	0	0	566.25	0	0	0	0	0	10305.75	10217.667	0	0	566.25	0	0	0	0	0
5	10578.75	10578.75	0	0	2867.5	0	0	0	0	0	10578.75	10578.75	0	0	2867.5	0	581.25	0	0	0
6	10442.25	10442.25	0	0	3311.3571	0	0	0	0	0	10442.25	10442.25	2983.5	0	3311.3571	0	573.75	0	0	0
7	10237.5	10237.5	0	0	2828.5714	0	0	0	0	0	10237.5	10237.5	2925	0	2828.5714	0	562.5	0	0	0
8	10078.25	10078.25	0	0	2374.6382	443	0	0	0	0	10078.25	10078.25	2879.5	0	2374.6382	443	0	0	0	0
9	10374	10374	0	2964	2192.5905	456	0	0	0	0	10374	10374	2964	2964	2192.5905	456	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	1291.3245	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	1803.1005	0	0	0
13	11193	11193	3198	3198	3794.2493	0	0	0	0	0	11193	11193	3198	3198	3794.2493	0	615	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	0	0	0	11147.5	11147.5	3185	3185	3969	0	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	10123.75	0	2892.5	0	0	0	0	0	0	10123.75	10123.75	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	1764	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	0	0	0	0
19	10101	10101	0	2886	0	1776	0	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	0	0	0	1812	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
21	10510.5	10510.5	0	0	3742.2	0	0	0	0	0	10510.5	10510.5	0	0	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	0	3717.9	0	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	10351.25	2957.5	0	3594.5	0	0	0	0	0	10351.25	10351.25	0	0	0	0	0	0	0	0
24	10260.25	10260.25	2931.5	0	3653.1	0	0	0	0	0	10260.25	0	2931.5	0	0	0	0	0	0	0

Table-6.31c: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 41-60) with solar during summer

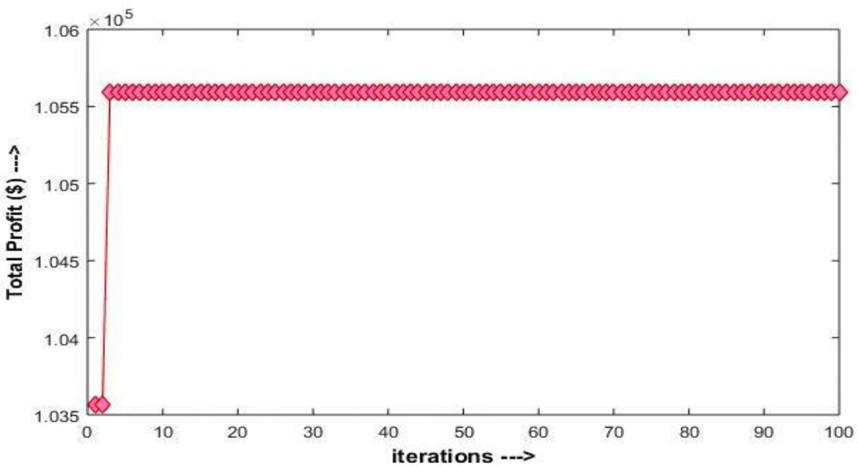
Hour	PGU41	PGU42	PGU43	PGU 44	PGU45	PGU46	PGU 47	PGU48	PGU49	PGU50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PGU56	PGU57	PGU 58	PGU 59	PGU 60
1	10078.25	5389.8333	0	0	0	0	0	0	0	0	10078.25	5389.8333	0	0	0	0	0	0	0	0
2	10010	6135.5556	0	0	0	0	0	0	0	0	10010	6135.5556	0	0	0	0	0	0	0	0
3	10510.5	8944.8333	0	0	0	0	0	0	0	0	10510.5	8944.8333	0	0	0	0	0	0	0	0
4	10305.75	10217.667	0	0	0	0	0	0	0	0	10305.75	10217.667	0	0	0	0	0	0	0	0
5	10578.75	10578.75	0	0	0	0	0	0	0	0	10578.75	10578.75	0	0	2867.5	465.00001	0	0	0	0
6	10442.25	10442.25	0	0	3311.3571	0	0	0	0	0	10442.25	10442.25	0	0	3311.3571	459.00001	0	0	0	0
7	10237.5	10237.5	0	0	2828.5714	0	0	0	0	0	10237.5	10237.5	0	0	2828.5714	450	0	0	0	0
8	10078.25	10078.25	0	0	2374.6382	0	0	0	0	0	10078.25	10078.25	0	0	2374.6382	0	0	0	0	0
9	10374	10374	0	2964	2192.5905	0	0	0	0	0	10374	10374	0	2964	2192.5905	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3794.2493	492	0	246	0	0	11193	11193	3198	3198	3794.2493	492	0	0	0	0
14	11147.5	11147.5	3185	3185	0	1960	0	0	0	0	11147.5	11147.5	3185	3185	0	1960	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	1237.5	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	10123.75	0	2892.5	0	0	0	0	0	0	10123.75	10123.75	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	1764	1834.56	0	0	0	10032.75	10032.75	0	2866.5	0	0	0	0	0	0
19	10101	10101	0	2886	0	1776	1733.420 4	0	0	0	10101	10101	0	0	0	0	0	0	0	0
20	10305.75	10305.75	0	0	3669.3	1812	1866.699 8	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
21	10510.5	10510.5	0	0	3742.2	0	0	0	0	0	10510.5	10510.5	3003	0	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	0	3717.9	0	0	0	0	0	10442.25	10442.25	2983.5	0	0	0	0	0	0	0
23	10351.25	10351.25	2957.5	0	3594.5	0	0	0	0	0	10351.25	10351.25	2957.5	0	0	0	0	0	0	0
24	10260.25	0	2931.5	0	3653.1	0	0	0	0	0	10260.25	0	2931.5	0	0	0	0	0	0	0

Table-6.31d: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 61-80) with solar during summer

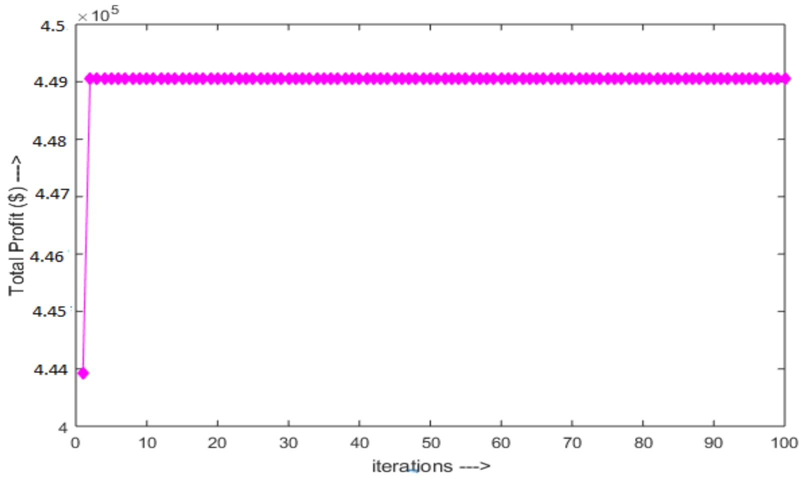
Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	10078.25	5389.8333	0	2879.5	0	0	0	0	0	0	10078.25	5389.8333	0	0	0	0	0	0	0	0
2	10010	6135.5556	0	2860	0	0	0	0	0	0	10010	6135.5556	0	0	0	0	0	0	0	0
3	10510.5	8944.8333	0	3003	0	0	0	0	0	0	10510.5	8944.8333	0	0	0	0	0	0	0	0
4	10305.75	10217.667	0	2944.5	0	0	0	0	0	0	10305.75	10217.667	0	0	0	0	0	0	0	0
5	10578.75	10578.75	0	3022.5	0	0	581.25	0	0	0	10578.75	10578.75	3022.5	0	2867.5	0	0	0	0	0
6	10442.25	10442.25	0	2983.5	0	0	573.75	0	0	0	10442.25	10442.25	2983.5	0	3311.3571	0	0	0	0	0
7	10237.5	10237.5	0	2925	0	0	562.5	0	0	0	10237.5	10237.5	2925	0	2828.5714	0	0	0	0	0
8	10078.25	10078.25	0	2879.5	0	0	553.75	0	0	0	10078.25	10078.25	2879.5	0	2374.6382	0	0	0	0	0
9	10374	10374	0	2964	2192.5905	0	0	0	0	0	10374	10374	2964	0	2192.5905	456	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3794.2493	492	0	0	0	0	11193	11193	3198	3198	3794.2493	492	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	0	0	0	11147.5	11147.5	3185	3185	0	0	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	10123.75	0	0	0	0	0	0	0	0	10123.75	10123.75	0	0	0	802.78	0	0	0	0
18	10032.75	10032.75	0	0	0	0	0	0	0	0	10032.75	10032.75	0	0	0	1764	0	0	0	0
19	10101	10101	0	0	0	0	0	0	0	0	10101	10101	0	0	0	1776	1733.4204	0	0	0
20	10305.75	10305.75	0	0	0	0	1866.6998	0	0	0	10305.75	10305.75	0	0	0	0	1866.6998	0	0	0
21	10510.5	10510.5	0	0	3742.2	0	1512.126	0	0	0	10510.5	10510.5	3003	0	0	0	1512.126	0	0	0
22	10442.25	10442.25	0	0	3717.9	0	1950.75	0	0	0	10442.25	10442.25	2983.5	2983.5	0	0	0	0	0	0
23	10351.25	0	0	0	3594.5	0	0	0	0	0	10351.25	0	2957.5	2957.5	0	0	0	0	0	0
24	10260.25	0	0	0	3653.1	0	0	0	0	0	10260.25	0	2931.5	2931.5	3653.1	0	0	0	0	0

Table-6.31e: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 81-100) with solar during summer

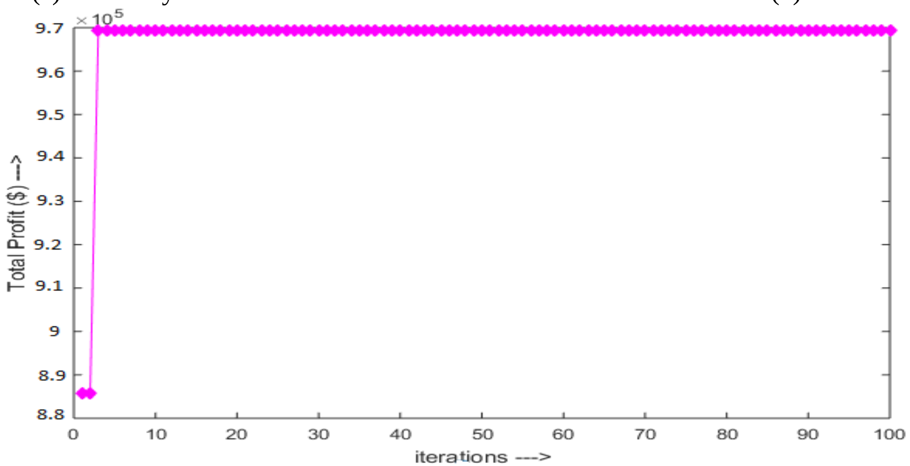
Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	10078.25	5389.8333	0	0	0	0	0	0	0	0	10078.25	0	0	2879.5	0	0	0	0	0	0
2	10010	6135.5556	0	0	0	0	0	0	0	0	10010	0	0	2860	0	0	0	0	0	0
3	10510.5	8944.8333	0	0	577.5	0	0	0	0	0	10510.5	0	0	3003	0	0	0	0	0	0
4	10305.75	10217.667	0	0	566.25	0	0	0	0	0	10305.75	0	0	2944.5	0	0	0	0	0	0
5	10578.75	10578.75	0	0	2867.5	0	581.25	0	0	0	10578.75	0	0	3022.5	0	0	0	0	0	0
6	10442.25	10442.25	0	0	3311.3571	0	573.75	0	0	0	10442.25	0	0	2983.5	0	0	0	0	0	0
7	10237.5	10237.5	0	0	2828.5714	0	562.5	0	0	0	10237.5	0	0	2925	0	0	0	0	0	0
8	10078.25	10078.25	0	2879.5	2374.6382	0	0	0	0	0	10078.25	0	0	2879.5	0	0	0	0	0	0
9	10374	10374	2964	2964	2192.5905	456	0	0	0	0	10374	10374	0	2964	0	456	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	1614.25	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	0	1803.1005	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0
13	11193	11193	3198	3198	0	0	615	0	0	0	11193	11193	3198	3198	3794.2493	0	0	246	0	0
14	11147.5	11147.5	3185	3185	0	0	1433.985	0	0	0	11147.5	11147.5	3185	3185	3969	0	0	0	0	0
15	10237.5	10237.5	0	2925	0	0	0	0	1237.5	915.8625	10237.5	10237.5	0	2925	3645	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	1586.422	0	0	0	0	10146.5	10146.5	0	0	0	0	0	223	0	0
17	10123.75	10123.75	0	0	0	802.78	0	0	0	0	10123.75	10123.75	0	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	1764	0	0	0	0	10032.75	10032.75	0	0	0	0	1834.56	0	0	0
19	10101	10101	0	0	0	0	1733.4204	0	0	0	10101	10101	0	0	0	0	1733.4204	0	0	0
20	10305.75	10305.75	0	0	3669.3	0	1866.6998	0	0	0	10305.75	10305.75	0	0	0	0	1866.6998	0	0	0
21	10510.5	10510.5	0	0	3742.2	0	1512.126	0	0	0	10510.5	10510.5	0	0	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	0	3717.9	0	0	0	0	0	10442.25	0	0	0	3717.9	1836	0	0	0	0
23	10351.25	0	2957.5	0	3594.5	0	0	0	0	0	10351.25	0	0	0	3594.5	455	0	0	0	0
24	10260.25	0	2931.5	0	3653.1	0	0	0	0	0	10260.25	0	0	0	3653.1	1646.15	0	0	0	0



(a) 10-unit system



(b) 40-Unit system



(c) 100-Unit system

Fig.6.16: Convergence curve for 10-, 40- and 100-generating unit system using hCHHO-SCA optimization algorithm with solar during summer

6.6.4 Hybrid Chaotic Slime Mould-Sine Cosine Optimization Algorithm with solar PV during summer

The proposed hybrid algorithm hCSMA-SCA is established to increase the penetrating capability through the entire search region. The alteration with input boundaries with chaotic map is thought about to make the hybridization SMA enhancer with SCA technique which is especially proficient to track down the ideal arrangement over the hunt locale. This technique is unrivaled as the populace based enhancers are more reasonable to tackle ongoing issue since they can ready to stay away from the caught into nearby optima and investigate the pursuit district just as take advantage of worldwide ideal arrangement more steady than the individual based analyzer. The number of populations are taken as 40 for 10-, 40- and 100-generating unit systems.

6.6.4.1 Ten Generating Unit System

This system contains of 10-generating unit system having a 24-hour electricity demand.The hCSMA-SCA technique is evaluated for 100 iterations solar energy as solar PV in summer. The hCSMA-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.17**. Thecommitment status and the optimal scheduling for this unit system are shown in Table-6.32a and the hourly profit of the 10-generating unit system have been shown in Table.6.32b.

The Table-6.32a represents the commitment status with optimum scheduling and profit of the generators for 24 hours considering effect of solar PV in summer. In this case, the PGU1 and PGU2 are on for 24 hours. From 9 to 22 hours, the PGU3 is on. For 5^{th} to 23^{rd} hours PGU4 is on, PGU5 is on for 3^{rd} to 15^{th} hours and PGU6 is on for 10^{th} to 14^{th} hours. PGU7 and PGU8 is on for 10^{th} to 13^{th} hours. From PGU9 and PGU10 have been remain off for 24 hours.

Table-6.32b represent the hourly profit table with start-up cost for 10-generating unit system using hCSMA-SCA optimization algorithm with solar PV during summer.

Table-6.32a: Commitment status and scheduling for 10-generating unit system using hCSMA-SCA optimization algorithm with solar during summer

Commitment status of thermal units										Scheduling of the committed generating units								
HOURS	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7**	**PGU8**	**PGU9 to PG10**	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7**	**PGU8**	**PGU9 to PG10**
1	1	1	0	0	0	0	0	0	0	455	245	0	0	0	0	0	0	0
2	1	1	0	0	0	0	0	0	0	455	295	0	0	0	0	0	0	0
3	1	1	0	0	1	0	0	0	0	455	370	0	0	25	0	0	0	0
4	1	1	0	0	1	0	0	0	0	455	430	0	0	25	0	0	0	0
5	1	1	0	1	1	0	0	0	0	455	390	0	130	25	0	0	0	0
6	1	1	0	1	1	0	0	0	0	455	430	0	130	25	0	0	0	0
7	1	1	0	1	1	0	0	0	0	455	430	0	130	25	0	0	0	0
8	1	1	0	1	1	0	0	0	0	455	425.45	0	130	25	0	0	0	0
9	1	1	1	1	1	0	0	0	0	455	414.33	130	130	25	0	0	0	0
10	1	1	1	1	1	1	1	1	0	455	455	130	130	147.66	20	25	10	0
11	1	1	1	1	1	1	1	1	0	455	455	130	130	149.83	20	25	10	0
12	1	1	1	1	1	1	1	1	0	455	455	130	130	140.94	20	25	10	0
13	1	1	1	1	1	1	0	0	0	455	455	130	130	90.14	20	0	0	0
14	1	1	1	1	1	1	0	0	0	455	455	130	130	55.53	20	0	0	0
15	1	1	1	1	1	0	0	0	0	455	415.41	130	130	25	0	0	0	0
16	1	1	1	1	0	0	0	0	0	455	276.14	130	130	0	0	0	0	0
17	1	1	1	1	0	0	0	0	0	455	247.16	130	130	0	0	0	0	0
18	1	1	1	1	0	0	0	0	0	455	291.4	130	130	0	0	0	0	0
19	1	1	1	1	0	0	0	0	0	455	305.41	130	130	0	0	0	0	0
20	1	1	1	1	0	0	0	0	0	455	318.49	130	130	0	0	0	0	0
21	1	1	1	1	0	0	0	0	0	455	324.84	130	130	0	0	0	0	0
22	1	1	1	1	0	0	0	0	0	455	325	130	130	0	0	0	0	0
23	1	1	0	1	0	0	0	0	0	455	315	0	130	0	0	0	0	0
24	1	1	0	0	0	0	0	0	0	455	345	0	0	0	0	0	0	0

Table-6.32b: Hourly profit for 10-generating unit system using hCSMA-SCA optimization algorithm with solar during summer

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9 to PG10	Start-up Cost	Hourly Profit
1	10078.25	5426.75	0	0	0	0	0	0	0	870	15505
2	10010	6490	0	0	0	0	0	0	0	730	16500
3	10510.5	8547	0	0	577.5	0	0	0	0	900	19635
4	10305.75	9739.5	0	0	566.25	0	0	0	0	60	20611.5
5	10578.75	9067.5	0	3022.5	581.25	0	0	0	0	0	23250
6	10442.25	9868.5	0	2983.5	573.75	0	0	0	0	0	23868
7	10237.5	9675	0	2925	562.5	0	0	0	0	0	23400
8	10078.25	9423.7175	0	2879.5	553.75	0	0	0	0	0	22935.2175
9	10374	9446.724	2964	2964	570	0	0	0	0	170	26318.724
10	13354.25	13354.25	3815.5	3815.5	4333.821	587	733.75	293.5	0	580	40287.571
11	13718.25	13718.25	3919.5	3919.5	4517.3745	603	753.75	301.5	0	60	41451.1245
12	14400.75	14400.75	4114.5	4114.5	4460.751	633	791.25	316.5	0	60	43232.001
13	11193	11193	3198	3198	2217.444	492	0	0	0	0	31491.444
14	11147.5	11147.5	3185	3185	1360.485	490	0	0	0	0	30515.485
15	10237.5	9346.725	2925	2925	562.5	0	0	0	0	120	25996.725
16	10146.5	6157.922	2899	2899	0	0	0	0	0	260	22102.422
17	10123.75	5499.31	2892.5	2892.5	0	0	0	0	0	0	21408.06
18	10032.75	6425.37	2866.5	2866.5	0	0	0	0	0	0	22191.12
19	10101	6780.102	2886	2886	0	0	0	0	0	170	22653.102
20	10305.75	7213.7985	2944.5	2944.5	0	0	0	0	0	60	23408.5485
21	10510.5	7503.804	3003	3003	0	0	0	0	0	610	24020.304
22	10442.25	7458.75	2983.5	2983.5	0	0	0	0	0	60	23868
23	10351.25	7166.25	0	2957.5	0	0	0	0	0	0	20475
24	10260.25	7779.75	0	0	0	0	0	0	0	0	18040

6.6.4.2 Forty Generating Unit System

This test system contains of 40-generating unit system having a 24-hour electricity demand.The hCSMA-SCA technique is evaluated for 100 iterations considering solar as solar PV in summer days. The hCSMA-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.17**. Table-6.33 present the hourly profit with startup cost and fuel cost for 40-generating unit system using hCSMA-SCA optimization algorithm with solar PV during summer. The optimal scheduling of 40 unit systems are shown in Table-6.34a and Table-6.34b. The hourly profit table for this system is shown in Table-6.35a and Table-6.35b respectively.

Table-6.33: Hourly profit with startup cost and fuel cost for 40-generating unit system using hCSMA-SCA optimization algorithm with solar during summer

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	62020	3210	53787.3293	**13**	129793.044	1490	102905.826
2	66000	3400	57283.9693	**14**	126065.485	900	99701.8277
3	78540	0	65457.854	**15**	106996.725	0	92283.8666
4	82446	10000	70578.81	**16**	91678.422	1800	79499.5794
5	93000	700	77802.3628	**17**	88158.06	1010	75971.4783
6	95472	1860	80603.6428	**18**	90987.12	780	80596.5984
7	93600	340	80603.6428	**19**	91917.102	2750	82671.5243
8	92043.2175	560	79941.5826	**20**	94076.5485	90	82972.5644
9	106346.724	14500	90104.7047	**21**	96092.304	5120	86462.9438
10	163557.571	10810	107519.601	**22**	95472	5200	84634.442
11	169166.525	170	108769.819	**23**	81900	5000	73268.1951
12	177301.401	560	108613.948	**24**	72160	5900	72435.3078

Table-6.34a: Generation scheduling for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with solar during summer

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU-10	PGU-11	PGU-12	PGU-13	PGU-14	PGU-15	PGU-16	PGU-17	PGU-18	PGU-19	PGU-20
1	455	0	326.6666667	0	0	0	0	0	0	0	455	326.6666667	326.6666667	0	0	0	0	0	0	0
2	455	0	393.3333333	0	0	0	0	0	0	0	455	393.3333333	393.3333333	0	0	0	0	0	0	0
3	455	0	440	130	0	0	0	0	0	0	455	440	440	130	0	0	0	0	0	0
4	455	0	390	130	0	0	0	0	0	0	455	390	390	130	0	0	0	0	0	0
5	455	0	384	130	0	0	0	0	0	0	455	384	384	130	0	0	0	0	0	0
6	455	0	416	130	0	0	0	0	0	0	455	416	416	130	0	0	0	0	0	0
7	455	0	416	130	0	0	0	0	0	0	455	416	416	130	0	0	0	0	0	0
8	455	0	441.09	130	0	0	0	0	0	0	455	441.09	441.09	0	0	0	0	0	0	0
9	455	406.3328571	406.3328571	0	0	0	0	0	0	0	455	406.3328571	406.3328571	0	0	0	0	0	0	0
10	455	452.8325	452.8325	0	0	0	0	0	0	0	455	452.8325	452.8325	0	0	0	0	0	0	0
11	455	441.35375	441.35375	0	0	0	0	0	0	0	455	441.35375	441.35375	0	0	0	0	0	0	0
12	455	440.2425	440.2425	0	0	0	0	0	0	0	455	440.2425	440.2425	0	0	0	0	0	0	0
13	455	399.5175	399.5175	0	0	0	0	0	0	0	455	399.5175	399.5175	0	0	0	0	0	0	0
14	455	437.9328571	437.9328571	0	0	0	0	0	0	0	455	437.9328571	437.9328571	0	0	0	0	0	0	0
15	455	400.7728571	400.7728571	0	0	0	0	0	0	0	455	400.7728571	400.7728571	0	0	0	0	0	0	0
16	455	381.8566667	381.8566667	0	0	0	0	0	0	0	455	381.8566667	381.8566667	0	0	0	0	0	0	0
17	455	428.432	428.432	0	0	0	0	0	0	0	455	428.432	428.432	0	0	0	0	0	0	0
18	455	455	455	130	113.2	0	0	0	0	0	455	0	455	130	113.2	0	0	0	0	0
19	455	455	455	130	162	47.41	0	0	0	0	455	0	0	130	162	0	0	0	0	0
20	455	455	455	130	162	60.49	0	0	0	0	455	0	0	130	162	0	0	0	0	0
21	455	455	0	130	162	80	71.84	0	0	0	455	0	0	130	162	80	0	0	0	0
22	455	455	0	130	125	0	25	0	0	0	455	0	0	130	125	20	0	0	0	0
23	455	455	0	0	162	0	25	0	0	0	455	0	0	0	162	22.3333333	0	0	0	0
24	0	0	0	0	162	0	0	55	0	0	455	0	0	0	162	80	71	55	0	0

Table-6.34b: Generation scheduling for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with solar during summer

Hour	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
4	455	0	390	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
5	455	0	384	0	0	0	0	0	0	0	455	0	384	0	0	0	0	0	0	0
6	455	0	416	0	0	0	0	0	0	0	455	0	416	0	0	0	0	0	0	0
7	455	0	416	0	0	0	0	0	0	0	455	0	416	0	0	0	0	0	0	0
8	455	0	441.09	0	0	0	0	0	0	0	455	0	441.09	0	0	0	0	0	0	0
9	455	406.3328571	406.3328571	0	0	0	0	0	0	0	455	0	406.3328571	0	0	0	0	0	0	0
10	455	452.8325	452.8325	130	0	0	0	0	0	0	455	452.8325	452.8325	0	0	0	0	0	0	0
11	455	441.35375	441.35375	130	0	0	0	0	0	0	455	441.35375	441.35375	130	0	0	0	0	0	0
12	455	440.2425	440.2425	130	0	0	0	0	0	0	455	440.2425	440.2425	130	0	0	0	0	0	0
13	455	399.5175	399.5175	130	0	0	0	0	0	0	455	399.5175	399.5175	130	0	0	0	0	0	0
14	455	437.9328571	437.9328571	130	0	0	0	0	0	0	455	437.9328571	0	130	0	0	0	0	0	0
15	455	400.7728571	400.7728571	0	0	0	0	0	0	0	455	400.7728571	0	130	0	0	0	0	0	0
16	455	381.8566667	0	0	0	0	0	0	0	0	455	381.8566667	0	0	0	0	0	0	0	0
17	455	0	0	0	0	0	0	0	0	0	455	428.432	0	0	0	0	0	0	0	0
18	455	0	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
19	455	0	0	0	162	0	0	0	0	0	455	455	0	0	162	0	0	0	0	0
20	455	0	0	0	162	0	0	0	0	0	455	455	0	0	162	0	0	0	0	0
21	455	0	0	0	162	80	0	0	0	0	455	455	0	130	162	80	0	0	0	0
22	455	0	0	0	125	20	0	0	0	0	455	455	455	130	125	20	0	0	0	0
23	455	0	0	0	162	22.333333	0	0	0	0	455	0	455	130	162	22.333333	0	0	0	0
24	455	0	455	0	162	80	71	55	0	0	0	0	455	130	162	80	0	55	0	0

Table-6.34a shows the optimal scheduling of PGU1 to PGU20 for 40-generating unit test system considering the effect of solar PV in summer using hCSMA-SCA optimizer. The PGU9, PGU10, PGU19 and PGU20 is off for 24 hours. The PGU1 and PGU11 is always remain on throughout the whole day. PGU8 and PGU18 gives 55 MW power only for 24th hour. PGU17 gives 71 MW power only for 24th hour as it have been on for that particular hour only. Further, the PGU are sometimes remain on and off condition for optimum power generation scheduling.

In Table-6.34b represents the power scheduling of 21 to 40 unit for 40-unit system with solar PV in summer using hCSMA-SCA optimizer. The PGU21 is continuing on for 24 hours, PGU22 is on only for 9th to 16th hours. The PGU27 and PGU31 is off only for 24th hours. The PGU29, PGU30, PGU39 to PGU40 remain off throughout the whole day. The PGU28 and PGU38 is on for 23th hour only. For this the output is 55 MW for that hour.

The hourly profit for 40-test system is presented in Table-6.35a and Table-6.39b using hCSMA-SCA optimizer with solar PV in summer. The Table-6.35a shows the hourly profit for PGU1 to PGU20 for whole day. The maximum number of profit can be obtained from the PGU1 and PGU11 as it was remain on for all hours. PGU8 and PGU18 gives 1240.25 $ for 24 hour and PGU17 gives 1601.05 $ for 24th hour. The other units are gives several amount of profit for that particular hour when it was on.

Table-6.35b shows that the hourly profit for PGU21 to PGU40 for this test system for 24 hours. The PGU21 is on for 24 hours, so that the profit from this units are maximum. Moreover for the others hours as it remain off, no profit come from that hour when the generating unit remain off.

Table-6.35a: Hourly profit for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with solar during summer

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	GPU16	PGU17	PGU 18	PGU19	PGU 20
1	10078.25	0	7235.66667	0	0	0	0	0	0	0	10078.25	7235.66667	7235.66667	0	0	0	0	0	0	0
2	10010	0	8653.33333	0	0	0	0	0	0	0	10010	8653.33333	8653.33333	0	0	0	0	0	0	0
3	10510.5	0	10164	3003	0	0	0	0	0	0	10510.5	10164	10164	3003	0	0	0	0	0	0
4	10305.75	0	8833.5	2944.5	0	0	0	0	0	0	10305.75	8833.5	8833.5	2944.5	0	0	0	0	0	0
5	10578.75	0	8928	3022.5	0	0	0	0	0	0	10578.75	8928	8928	3022.5	0	0	0	0	0	0
6	10442.25	0	9547.2	2983.5	0	0	0	0	0	0	10442.25	9547.2	9547.2	2983.5	0	0	0	0	0	0
7	10237.5	0	9360	2925	0	0	0	0	0	0	10237.5	9360	9360	2925	0	0	0	0	0	0
8	10078.25	0	9770.1435	2879.5	0	0	0	0	0	0	10078.25	9770.1435	9770.1435	0	0	0	0	0	0	0
9	10374	9264.38914	9264.38914	0	0	0	0	0	0	0	10374	9264.38914	9264.38914	0	0	0	0	0	0	0
10	13354.25	13290.6339	13290.6339	0	0	0	0	0	0	0	13354.25	13290.6339	13290.6339	0	0	0	0	0	0	0
11	13718.25	13306.8156	13306.8156	0	0	0	0	0	0	0	13718.25	13306.8156	13306.8156	0	0	0	0	0	0	0
12	14400.75	13933.6751	13933.6751	0	0	0	0	0	0	0	14400.75	13933.6751	13933.6751	0	0	0	0	0	0	0
13	11193	9828.1305	9828.1305	0	0	0	0	0	0	0	11193	9828.1305	9828.1305	0	0	0	0	0	0	0
14	11147.5	10729.355	10729.355	0	0	0	0	0	0	0	11147.5	10729.355	10729.355	0	0	0	0	0	0	0
15	10237.5	9017.38929	9017.38929	0	0	0	0	0	0	0	10237.5	9017.38929	9017.38929	0	0	0	0	0	0	0
16	10146.5	8515.40367	8515.40367	0	0	0	0	0	0	0	10146.5	8515.40367	8515.40367	0	0	0	0	0	0	0
17	10123.75	9532.612	9532.612	0	0	0	0	0	0	0	10123.75	9532.612	9532.612	0	0	0	0	0	0	0
18	10032.75	10032.75	10032.75	2866.5	2496.06	0	0	0	0	0	10032.75	0	10032.75	2866.5	2496.06	0	0	0	0	0
19	10101	10101	10101	2886	3596.4	1052.502	0	0	0	0	10101	0	0	2886	3596.4	0	0	0	0	0
20	10305.75	10305.75	10305.75	2944.5	3669.3	1370.0985	0	0	0	0	10305.75	0	0	2944.5	3669.3	0	0	0	0	0
21	10510.5	10510.5	0	3003	3742.2	1848	1659.504	0	0	0	10510.5	0	0	3003	3742.2	1848	0	0	0	0
22	10442.25	10442.25	0	2983.5	2868.75	0	573.75	0	0	0	10442.25	0	0	2983.5	2868.75	459	0	0	0	0
23	10351.25	10351.25	0	0	3685.5	0	568.75	0	0	0	10351.25	0	0	0	3685.5	508.083333	0	0	0	0
24	0	0	0	0	3653.1	0	0	1240.25	0	0	10260.25	0	0	0	3653.1	1804	1601.05	1240.25	0	0

Table-6.35b: Hourly profit for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with solar during summer

HOURS	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PG34	PGU35	GPU36	PGU37	PGU 38	PGU39	PGU 40
1	10078.25	0	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	0	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	0	0	0	0	0	0	0	0	0	10510.5	0	0	0	0	0	0	0	0	0
4	10305.75	0	8833.5	0	0	0	0	0	0	0	10305.75	0	0	0	0	0	0	0	0	0
5	10578.75	0	8928	0	0	0	0	0	0	0	10578.75	0	8928	0	0	0	0	0	0	0
6	10442.25	0	9547.2	0	0	0	0	0	0	0	10442.25	0	9547.2	0	0	0	0	0	0	0
7	10237.5	0	9360	0	0	0	0	0	0	0	10237.5	0	9360	0	0	0	0	0	0	0
8	10078.25	0	9770.1435	0	0	0	0	0	0	0	10078.25	0	9770.1435	0	0	0	0	0	0	0
9	10374	9264.38914	9264.38914	0	0	0	0	0	0	0	10374	0	9264.3891	0	0	0	0	0	0	0
10	13354.25	13290.6339	13290.6339	3815.5	0	0	0	0	0	0	13354.25	13290.6339	13290.633	0	0	0	0	0	0	0
11	13718.25	13306.8156	13306.8156	3919.5	0	0	0	0	0	0	13718.25	13306.8156	13306.815	3919.5	0	0	0	0	0	0
12	14400.75	13933.6751	13933.6751	4114.5	0	0	0	0	0	0	14400.75	13933.6751	13933.675	4114.5	0	0	0	0	0	0
13	11193	9828.1305	9828.1305	3198	0	0	0	0	0	0	11193	9828.1305	9828.1305	3198	0	0	0	0	0	0
14	11147.5	10729.355	10729.355	3185	0	0	0	0	0	0	11147.5	10729.355	0	3185	0	0	0	0	0	0
15	10237.5	9017.38929	9017.38929	0	0	0	0	0	0	0	10237.5	9017.38929	0	2925	0	0	0	0	0	0
16	10146.5	8515.40367	0	0	0	0	0	0	0	0	10146.5	8515.40367	0	0	0	0	0	0	0	0
17	10123.75	0	0	0	0	0	0	0	0	0	10123.75	9532.612	0	0	0	0	0	0	0	0
18	10032.75	0	0	0	0	0	0	0	0	0	10032.75	10032.75	0	0	0	0	0	0	0	0
19	10101	0	0	0	3596.4	0	0	0	0	0	10101	10101	0	0	3596.4	0	0	0	0	0
20	10305.75	0	0	0	3669.3	0	0	0	0	0	10305.75	10305.75	0	0	3669.3	0	0	0	0	0
21	10510.5	0	0	0	3742.2	1848	0	0	0	0	10510.5	10510.5	0	3003	3742.2	1848	0	0	0	0
22	10442.25	0	0	0	2868.75	459	0	0	0	0	10442.25	10442.25	10442.25	2983.5	2868.75	459	0	0	0	0
23	10351.25	0	0	0	3685.5	508.083333	0	0	0	0	10351.25	0	10351.25	2957.5	3685.5	508.083333	0	0	0	0
24	10260.25	0	10260.25	0	3653.1	1804	1601.05	1240.25	0	0	0	0	10260.25	2931.5	3653.1	1804	0	1240.25	0	0

6.6.4.3 Hundred Generating Unit System

The system contains of 100-generating unit system having a 24-hour electricity demand. The hCSMA-SCA technique is evaluated for 100 iterations considering solar as solar PV in summer. The hCSMA-SCA algorithmis verified for 30 trial runs. Table-6.36 hourly profit with start-up cost and fuel cost for 100-generating unit system using hCSMA-SCA optimization algorithm with solar PV during summer. The convergence graph of total profit is shown in **Fig.6.17**.The optimal scheduling of 100 unit systems are shown in Table-6.37a to Table-6.37e. The hourly profit table for this system is shown in Table-6.38a to Table-6.38e respectively.

Table-6.36: Hourly profit with start-up cost and fuel cost for 100-generating unit system using hCSMA-SCA optimization algorithm with solar during summer

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	8240	136089.9752	155050	**13**	700	271913.35	326396.244
2	4950	146507.665	165000	**14**	1830	265131.92	317165.485
3	5450	167890.6885	196350	**15**	1200	243807.251	268996.725
4	3120	187640.593	206115	**16**	3050	208385.842	230830.422
5	2990	207032.5301	232500	**17**	3150	196821.028	221658.06
6	460	213667.8142	238680	**18**	490	210505.037	228579.12
7	1580	212233.989	234000	**19**	2930	207496.206	230445.102
8	2530	210822.389	230259.218	**20**	4240	206778.597	235412.5485
9	16030	237061.118	266402.724	**21**	3700	204094.042	240236.304
10	6210	288693.0248	410097.571	**22**	1870	208967.217	238680
11	1050	292311.407	424597.325	**23**	1540	185358.667	204750
12	380	294438.0778	445440.201	**24**	3820	164275.693	180400

Table-6.37a: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with solar during summer

HOUR	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	455	401.66667	0	0	0	0	0	10	10	0	455	401.66667	0	0	0	0	0	0	0	0
2	455	400	0	130	0	0	0	0	10	10	455	400	0	0	0	0	0	0	0	10
3	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
4	455	454.16667	0	130	0	0	0	0	0	0	455	454.16667	130	130	0	0	0	0	10	0
5	455	455	0	130	0	0	25	0	0	0	455	455	130	130	0	0	0	0	0	0
6	455	455	130	130	0	20	25	0	0	0	455	455	130	130	0	0	0	0	0	0
7	455	455	130	130	0	20	25	0	0	0	455	455	130	130	0	0	25	0	0	0
8	455	455	130	130	0	20	0	0	0	0	455	455	130	130	0	20	25	0	0	0
9	455	445.433	130	130	25	0	0	0	0	0	455	445.433	130	130	25	20	25	0	0	0
10	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	55	55	0
11	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	0	55	0
12	455	455	130	130	162	80	73.985	0	0	0	455	455	130	130	162	0	0	55	0	0
13	455	455	130	130	162	80	69.035	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	162	80	75.6325	0	0	0	455	455	130	130	162	0	0	0	0	0
15	455	455	130	130	0	0	75.082	55	0	0	455	455	130	130	0	80	75.082	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	80	84.067257	0	0	0
17	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	80	42.16	0	0	0
18	455	455	0	130	0	80	0	55	0	0	455	455	0	130	0	0	0	0	0	0
19	455	455	0	130	0	66.63	0	0	0	0	455	455	0	130	0	0	0	0	0	0
20	455	455	0	130	0	38.8725	0	0	0	0	455	455	0	130	0	0	0	0	0	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	25	0	0	0
22	455	455	130	130	162	0	0	55	0	0	455	455	0	0	162	0	80.5	0	0	0
23	455	455	130	0	162	0	68	0	0	0	455	455	0	0	162	80	68	0	0	0
24	455	0	130	0	162	0	79.5	0	0	0	455	455	130	0	162	80	0	0	0	0

Table-6.37b: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with solar during summer

HOUR	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	401.666667	0	0	0	0	0	0	0	0	455	401.666667	0	0	0	0	0	0	0	0
2	455	400	0	0	0	0	0	0	0	0	455	400	130	0	0	0	0	0	0	0
3	455	455	0	0	42.5	0	0	0	0	0	455	455	130	0	42.5	0	25	0	0	0
4	455	454.166667	0	0	25	20	0	0	0	0	455	454.166667	130	130	25	0	25	0	0	0
5	455	455	130	0	83.5714286	20	25	0	0	0	455	455	130	130	83.5714286	0	25	0	0	0
6	455	455	130	0	114.285714	20	25	0	0	0	455	455	130	130	114.285714	0	0	0	0	0
7	455	455	130	0	89.2857143	0	25	0	0	0	455	455	130	130	89.2857143	20	0	0	0	0
8	455	455	130	0	86.30625	0	0	0	0	0	455	455	130	130	86.30625	20	0	0	0	0
9	455	445.433	130	0	25	0	0	0	0	0	455	445.433	130	130	25	20	0	0	0	0
10	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	0	0	0	55	0	455	455	130	130	162	0	0	0	0	0
12	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	55	0
13	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	75.6325	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	75.082	0	0	0
16	455	455	0	130	0	80	0	0	0	0	455	455	0	0	0	0	84.0672571	0	0	23.9382287
17	455	455	0	130	0	80	0	0	0	0	455	455	0	0	0	0	0	0	0	0
18	455	455	0	130	0	80	0	55	0	0	455	455	0	0	0	0	0	55	0	0
19	455	455	0	130	0	66.63	0	0	0	0	455	455	0	0	0	66.63	0	0	0	0
20	455	455	0	130	0	0	0	0	0	0	455	455	0	0	0	38.8725	0	0	0	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	0	0	74.84	0	0	0	0
22	455	455	0	130	0	0	0	0	0	0	455	455	0	0	0	80	0	0	0	0
23	455	455	0	0	0	80	0	0	0	0	455	455	0	0	162	0	0	0	0	0
24	455	0	130	0	0	80	0	0	0	0	455	0	0	0	162	0	0	0	0	0

The Table-6.37a is given as the power scheduling of 100-unit test system using hCSMA-SCA optimizer for PGU1 to PGU20 with solar PV in summer. The PGU10 and PGU20 is on for 2nd hours. The PGU1, PGU2, PGU11 and PGU12 is always remain on throughout the whole day. PGU18 and PGU19 gives 55 MW power only for 10th and for 11th hour PGU19 gives 55 MW and for 12th hour and PGU18 gives 55 MW power as it have been on for that particular hour only.

In Table-6.37b represents the power scheduling of 21 to 40 unit for 100-unit system using hCSMA-SCA optimizer with solar PV in summer. The PGU21 and PGU31 have been continuous on for 24 hours. The PGU30 remain off throughout the whole day. The PGU29 and PGU39 is on for 11th and 12thhour respectively, gives 55 MW power and PGU40 is on for 16th hour only and output power is 23.9382287 MW for that particular hour.

In Table-6.37c represents the power scheduling of 41 to 60 unit for 100-unit system using hCSMA-SCA optimizer with solar PV in summer. The PGU41 and PGU51 is continuous on for 24 hours. The PGU49, PGU50 and PGU60 remain off throughout the whole day. The PGU48 is on only for 15th and 18th hour. For this the output is 55 MW for that hour. The PGU58 is on for 12th and 16th hour. The power output from that us is 55 MW for that particular hours.

Table-6.37d represents the power scheduling of 61 to 80 unit for 100-unit system using hCSMA-SCA optimizer with solar PV in summer. The PGU61 and PGU71 is always on and the output power is 455 MW for 24 hours. The PGU70, PGU79 and PGU80 is off for the whole day.

Table-6.37e represents the power scheduling of 81 to 100 unit for 100-unit system using hCSMA-SCA optimizer with solar PV in summer. The PGU81 and PGU91 is always on and the output power is 455 MW for 24 hours. The PGU90, PGU99 and PGU100 is off for the whole day.

Table-6.37c: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 41-60) with solar during summer

Hour	PGU41	PGU42	PGU43	PGU44	PGU45	PGU46	PGU47	PGU48	PGU49	PGU50	PGU51	PGU52	PGU53	PGU54	PGU55	PGU56	PGU57	PGU58	PGU59	PGU60
1	455	401.666667	0	0	0	0	0	0	0	0	455	401.666667	0	0	0	0	0	0	0	0
2	455	400	0	0	0	0	0	0	0	0	455	400	0	130	0	0	0	0	0	0
3	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
4	455	454.166667	130	130	25	20	0	0	0	0	455	454.166667	130	130	0	20	25	0	0	0
5	455	455	130	130	83.5714286	20	0	0	0	0	455	455	130	130	83.5714286	20	25	0	0	0
6	455	455	130	130	114.285714	20	0	0	0	0	455	455	130	130	114.285714	20	25	0	0	0
7	455	455	130	130	89.2857143	0	0	0	0	0	455	455	130	130	89.2857143	20	0	0	0	0
8	455	455	130	130	86.30625	0	0	0	0	0	455	455	130	130	86.30625	0	0	0	0	0
9	455	445.433	130	130	25	0	0	0	0	0	455	445.433	130	130	25	0	0	0	0	0
10	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
11	455	455	130	130	162	0	84.2766667	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	0	73.985	0	0	0	455	455	130	130	162	80	0	55	55	0
13	455	455	130	130	162	80	69.035	0	0	0	455	455	130	130	0	80	0	0	0	0
14	455	455	130	130	0	80	0	0	0	0	455	455	130	130	0	80	75.6325	0	0	0
15	455	455	130	130	0	80	0	55	0	0	455	455	130	130	0	0	75.082	0	0	0
16	455	455	0	0	0	0	0	0	0	0	455	455	0	130	0	0	84.0672571	55	0	0
17	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	55	0
18	455	455	0	0	0	0	44.1	55	0	0	455	455	0	0	0	0	0	0	0	0
19	455	455	0	0	0	0	25	0	0	0	455	455	0	0	162	0	0	0	0	0
20	455	455	0	0	162	0	25	0	0	0	455	455	0	0	162	0	0	0	0	0
21	455	455	0	0	162	0	0	0	0	0	455	455	0	0	162	0	0	0	0	0
22	455	455	0	0	162	0	0	0	0	0	455	455	0	0	162	0	0	0	0	0
23	455	0	0	0	162	0	0	0	0	0	455	0	0	0	162	0	0	0	0	0
24	455	0	0	0	162	0	0	0	0	0	455	0	0	0	162	0	0	0	0	0

Table-6.37d: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 61-80) with solar during summer

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	10	0	0
2	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	25	0	0	0
4	455	0	0	130	0	20	25	0	0	0	455	0	0	0	0	20	25	0	0	0
5	455	0	0	130	0	20	25	0	0	0	455	0	130	0	83.5714286	20	25	0	0	0
6	455	0	0	130	0	20	25	0	0	0	455	0	130	130	114.285714	20	0	0	0	0
7	455	0	0	130	0	0	0	0	0	0	455	0	130	130	89.2857143	0	0	0	0	0
8	455	0	0	130	86.30625	0	0	0	0	0	455	0	130	130	86.30625	0	0	0	0	0
9	455	445.433	0	130	25	0	0	0	0	0	455	445.433	130	130	25	0	25	0	0	0
10	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	71.33	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	84.2766667	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	73.985	0	0	0
13	455	455	130	130	162	0	0	0	0	0	455	455	130	130	0	80	0	0	0	0
14	455	455	130	130	0	0	0	0	55	0	455	455	130	130	0	0	0	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
16	455	455	0	0	0	0	0	55	0	0	455	455	0	130	0	0	0	0	0	0
17	455	455	0	0	0	80	0	55	0	0	455	455	0	0	0	0	0	0	0	0
18	455	455	0	0	0	80	44.1	0	0	0	455	455	0	0	0	80	44.1	0	0	0
19	455	455	0	0	0	66.63	25	0	0	0	455	455	0	0	0	66.63	25	0	0	0
20	455	455	0	0	0	0	25	0	0	0	455	455	0	0	162	38.8725	25	0	0	0
21	455	455	0	0	162	0	0	0	0	0	455	455	0	0	162	0	0	0	0	0
22	455	455	130	0	162	0	0	0	0	0	455	0	0	0	162	0	0	0	0	0
23	455	0	130	0	162	0	0	0	0	0	455	0	130	130	162	0	0	55	0	0
24	455	0	130	130	162	0	0	0	0	0	455	0	130	130	162	0	0	0	0	0

Table-6.37e: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 81-100) with solar during summer

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	455	0	0	0	0	0	0	0	10	0	455	0	0	0	0	0	0	0	0	0
2	455	0	0	0	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
3	455	0	0	0	0	0	25	0	0	0	455	0	0	130	0	20	0	0	0	0
4	455	0	0	0	0	20	25	10	0	0	455	0	0	130	25	20	0	10	0	0
5	455	0	0	130	83.5714286	20	25	0	0	0	455	0	0	130	83.5714286	20	0	0	0	0
6	455	0	0	130	114.285714	20	0	0	0	0	455	0	0	130	114.285714	0	0	0	0	0
7	455	0	130	130	89.2857143	20	0	0	0	0	455	0	130	130	89.2857143	0	0	0	0	0
8	455	0	130	130	86.30625	0	0	0	0	0	455	0	130	130	86.30625	0	0	0	0	0
9	455	445.433	130	130	25	0	0	0	0	0	455	445.433	130	130	25	0	0	0	0	0
10	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	71.33	0	0	0
11	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	84.2766667	0	0	0
12	455	455	130	130	0	0	0	0	0	0	455	455	130	130	162	80	73.985	0	0	0
13	455	455	130	130	0	0	69.035	0	0	0	455	455	130	130	0	0	69.035	0	0	0
14	455	455	130	130	0	0	75.6325	0	0	0	455	455	130	130	0	0	0	0	0	0
15	455	455	0	130	0	0	75.082	0	0	0	455	455	0	130	0	0	0	0	0	0
16	455	455	0	0	0	0	0	0	55	0	455	455	0	0	0	0	0	0	0	0
17	455	455	0	0	0	80	0	0	0	0	455	455	0	0	0	0	0	0	0	0
18	455	455	0	0	0	80	0	0	0	0	455	455	0	0	0	80	44.1	0	0	0
19	455	455	0	0	162	66.63	0	0	0	0	455	455	0	0	0	66.63	25	0	0	0
20	455	455	0	0	162	0	0	0	0	0	455	455	0	0	0	38.8725	25	0	0	0
21	455	455	0	0	162	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
22	455	455	0	130	162	0	80.5	0	0	0	455	0	130	0	0	0	0	0	0	0
23	455	0	0	130	162	80	68	0	0	0	455	0	130	0	0	0	0	55	0	0
24	455	0	0	130	162	80	79.5	0	0	0	455	0	130	130	0	0	0	0	0	0

The Table-6.38a is presented the hourly profit for 100-generating unit system using proposed hCSMA-SCA optimization algorithm with solar PV in summer. From 100 numbers of power generating units, this table shows the hourly profit of PGU1 to PGU20 for 24 hours. The PGU1, PGU2, PGU11 and PGU12 are on for every hours, while PGU3 and PGU4 have been off for some hours. The PGU9 is on only for 1th and 2nd hour and 221.5 $ and 220 $ profit can be obtained.

The Table-6.38b is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm for units 21 to unit 40 considering effect of solar PV in summer. In this table, the PGU21 and PGU31 are on for 24 hours and maximum profit are obtained. The PGU30 is off throughout the whole day. Others PGU are remained on for some hours and off for few hours. From those units, the profit can be measured for that particular hour when it was on.

The Table-6.38c is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm considering effect of solar PV in summer for PGU41 to PGU60. The PGU41 and PGU51 remain on for 24 hours. The PGU49, PGU50 and PGU60 remain close throughout the whole day. Other units are remained on sometime and off for few times.

The Table-6.38d is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm considering effect of solar PV in summer for units 61 to unit 80. The PGU61 and PGU71 are continuously on for 24 hours. Further PGU70, PGU79 and PGU80 is off for 24 hours.

The Table-6.38e is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm considering effect of solar PV in summer for units 81 to unit 100. The PGU81 and PGU91 has been on for 24 hours. PGU90, PGU99 and PGU100 have been off for through the whole day. The PGU98 gives 226.5 $ profit only for 4th hour and 1251.25 $ for 23 hours, for others time it remains off.

Table-6.38a: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with solar during summer

Hour	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	10078.25	8896.9167	0	0	0	0	0	221.5	221.5	0	10078.25	8896.91667	0	0	0	0	0	0	0	0
2	10010	8800	0	2860	0	0	0	0	220	220	10010	8800	0	0	0	0	0	0	0	220
3	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
4	10305.75	10286.875	0	2944.5	0	0	0	0	0	0	10305.75	10286.875	2944.5	2944.5	0	0	0	0	226.5	0
5	10578.75	10578.75	0	3022.5	0	0	581.25	0	0	0	10578.75	10578.75	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	10442.25	2983.5	2983.5	0	459	573.75	0	0	0	10442.25	10442.25	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	10237.5	2925	2925	0	450	562.5	0	0	0	10237.5	10237.5	2925	2925	0	0	562.5	0	0	0
8	10078.25	10078.25	2879.5	2879.5	0	443	0	0	0	0	10078.25	10078.25	2879.5	2879.5	0	443	553.75	0	0	0
9	10374	10155.872	2964	2964	570	0	0	0	0	0	10374	10155.8724	2964	2964	570	456	570	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	1614.25	1614.25	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	1658.25	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2341.6252	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	1740.75	0	0
13	11193	11193	3198	3198	3985.2	1968	1698.261	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	1960	1852.9963	0	0	0	11147.5	11147.5	3185	3185	3969	0	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	1689.345	1237.5	0	0	10237.5	10237.5	2925	2925	0	1800	1689.345	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	1784	1874.69983	0	0	0
17	10123.75	10123.75	0	2892.5	0	0	0	0	0	0	10123.75	10123.75	0	2892.5	0	1780	938.06	0	0	0
18	10032.75	10032.75	0	2866.5	0	1764	0	1212.75	0	0	10032.75	10032.75	0	2866.5	0	0	0	0	0	0
19	10101	10101	0	2886	0	1479.186	0	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	880.46213	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	577.5	0	0	0
22	10442.25	10442.25	2983.5	2983.5	3717.9	0	0	1262.25	0	0	10442.25	10442.25	0	0	3717.9	0	1847.475	0	0	0
23	10351.25	10351.25	2957.5	0	3685.5	0	1547	0	0	0	10351.25	10351.25	0	0	3685.5	1820	1547	0	0	0
24	10260.25	0	2931.5	0	3653.1	0	1792.725	0	0	0	10260.25	10260.25	2931.5	0	3653.1	1804	0	0	0	0

Table-6.38b: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with solar during summer

Hour	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	10078.25	8896.916667	0	0	0	0	0	0	0	0	10078.25	8896.916667	0	0	0	0	0	0	0	0
2	10010	8800	0	0	0	0	0	0	0	0	10010	8800	2860	0	0	0	0	0	0	0
3	10510.5	10510.5	0	0	981.75	0	0	0	0	0	10510.5	10510.5	3003	0	981.75	0	577.5	0	0	0
4	10305.75	10286.875	0	0	566.25	453	0	0	0	0	10305.75	10286.875	2944.5	2944.5	566.25	0	566.25	0	0	0
5	10578.75	10578.75	3022.5	0	1943.03571	465	581.25	0	0	0	10578.75	10578.75	3022.5	3022.5	1943.035714	0	581.25	0	0	0
6	10442.25	10442.25	2983.5	0	2622.85714	459	573.75	0	0	0	10442.25	10442.25	2983.5	2983.5	2622.857143	0	0	0	0	0
7	10237.5	10237.5	2925	0	2008.92857	0	562.5	0	0	0	10237.5	10237.5	2925	2925	2008.928571	450	0	0	0	0
8	10078.25	10078.25	2879.5	0	1911.68344	0	0	0	0	0	10078.25	10078.25	2879.5	2879.5	1911.683437	443	0	0	0	0
9	10374	10155.8724	2964	0	570	0	0	0	0	0	10374	10155.8724	2964	2964	570	456	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	1658.25	0	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	1740.75	0
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	0	0	0	11147.5	11147.5	3185	3185	3969	0	1852.99625	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	1689.345	0	0	0
16	10146.5	10146.5	0	2899	0	1784	0	0	0	0	10146.5	10146.5	0	0	0	0	1874.699833	0	0	533.822501
17	10123.75	10123.75	0	2892.5	0	1780	0	0	0	0	10123.75	10123.75	0	0	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	1764	0	1212.75	0	0	10032.75	10032.75	0	0	0	0	0	1212.75	0	0
19	10101	10101	0	2886	0	1479.186	0	0	0	0	10101	10101	0	0	0	1479.186	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	0	0	0	0	10305.75	10305.75	0	0	0	880.462125	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	0	0	1728.804	0	0	0	0
22	10442.25	10442.25	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	0	0	1836	0	0	0	0
23	10351.25	10351.25	0	0	0	1820	0	0	0	0	10351.25	10351.25	0	0	3685.5	0	0	0	0	0
24	10260.25	0	2931.5	0	0	1804	0	0	0	0	10260.25	0	0	0	3653.1	0	0	0	0	0

Table-6.38c: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 41-60) with solar during summer

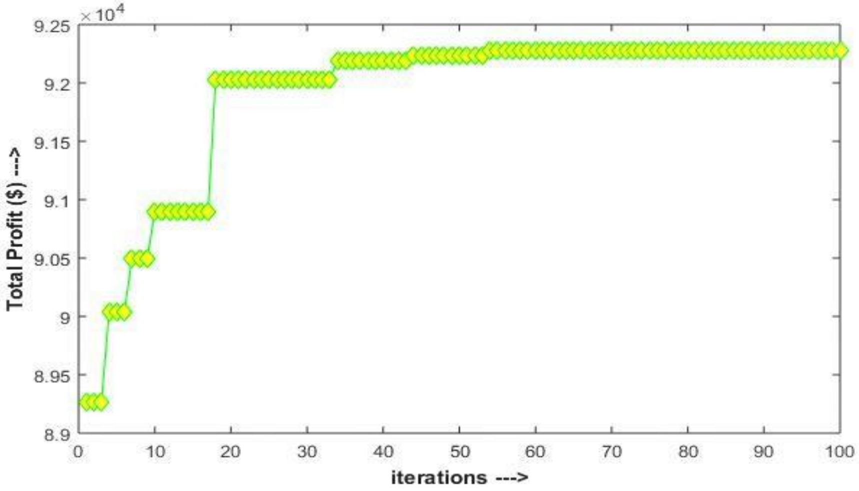
Hour	PGU41	PGU42	PGU43	PGU 44	PGU45	PGU46	PGU 47	PGU4 8	PGU 49	PGU 50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PG U56	PGU57	PGU 58	PGU 59	PGU 60
1	10078.25	8896.916667	0	0	0	0	0	0	0	0	10078.25	8896.916667	0	0	0	0	0	0	0	0
2	10010	8800	0	0	0	0	0	0	0	0	10010	8800	0	2860	0	0	0	0	0	0
3	10510.5	10510.5	3003	3003	0	0	0	0	0	0	10510.5	10510.5	3003	3003	0	0	0	0	0	0
4	10305.75	10286.875	2944.5	2944.5	566.25	453	0	0	0	0	10305.75	10286.875	2944.5	2944.5	0	453	566.25	0	0	0
5	10578.75	10578.75	3022.5	3022.5	1943.035714	465	0	0	0	0	10578.75	10578.75	3022.5	3022.5	1943.035714	465	581.25	0	0	0
6	10442.25	10442.25	2983.5	2983.5	2622.857143	459	0	0	0	0	10442.25	10442.25	2983.5	2983.5	2622.857143	459	573.75	0	0	0
7	10237.5	10237.5	2925	2925	2008.928571	0	0	0	0	0	10237.5	10237.5	2925	2925	2008.928571	450	0	0	0	0
8	10078.25	10078.25	2879.5	2879.5	1911.683437	0	0	0	0	0	10078.25	10078.25	2879.5	2879.5	1911.683437	0	0	0	0	0
9	10374	10155.8724	2964	2964	570	0	0	0	0	0	10374	10155.8724	2964	2964	570	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	0	2540.9415	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	0	2341.62525	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	1740.75	1740.75	0
13	11193	11193	3198	3198	3985.2	1968	1698.261	0	0	0	11193	11193	3198	3198	0	1968	0	0	0	0
14	11147.5	11147.5	3185	3185	0	1960	0	0	0	0	11147.5	11147.5	3185	3185	0	1960	1852.99625	0	0	0
15	10237.5	10237.5	2925	2925	0	1800	0	1237.5	0	0	10237.5	10237.5	2925	2925	0	0	1689.345	0	0	0
16	10146.5	10146.5	0	0	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	1874.699833	1226.5	0	0
17	10123.75	10123.75	0	0	0	0	0	0	0	0	10123.75	10123.75	0	0	0	0	0	0	1223.75	0
18	10032.75	10032.75	0	0	0	0	972.405	1212.75	0	0	10032.75	10032.75	0	0	0	0	0	0	0	0
19	10101	10101	0	0	0	0	555	0	0	0	10101	10101	0	0	3596.4	0	0	0	0	0
20	10305.75	10305.75	0	0	3669.3	0	566.25	0	0	0	10305.75	10305.75	0	0	3669.3	0	0	0	0	0
21	10510.5	10510.5	0	0	3742.2	0	0	0	0	0	10510.5	10510.5	0	0	3742.2	0	0	0	0	0
22	10442.25	10442.25	0	0	3717.9	0	0	0	0	0	10442.25	10442.25	0	0	3717.9	0	0	0	0	0
23	10351.25	0	0	0	3685.5	0	0	0	0	0	10351.25	0	0	0	3685.5	0	0	0	0	0
24	10260.25	0	0	0	3653.1	0	0	0	0	0	10260.25	0	0	0	3653.1	0	0	0	0	0

Table-6.38d: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 61-80) with solar during summer

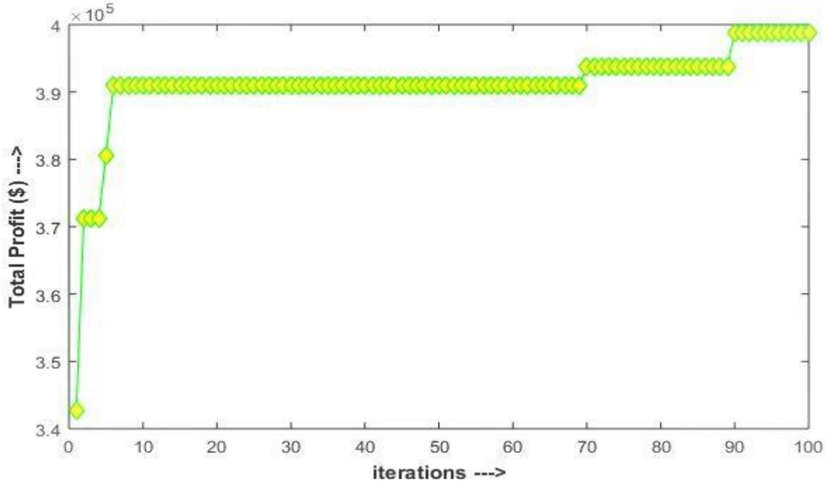
Hour	**PGU61**	**PGU62**	**PGU63**	**PGU64**	**PGU65**	**PGU66**	**PGU67**	**PGU68**	**PGU69**	**PGU70**	**PGU71**	**PGU72**	**PGU73**	**PGU74**	**PGU75**	**PGU76**	**PGU77**	**PGU78**	**PGU79**	**PGU80**
1	10078.25	0	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	221.5	0	0
2	10010	0	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	0	0	0	0	0	0	0	0	0	10510.5	0	0	0	0	0	577.5	0	0	0
4	10305.75	0	0	2944.5	0	453	566.25	0	0	0	10305.75	0	0	0	0	453	566.25	0	0	0
5	10578.75	0	0	3022.5	0	465	581.25	0	0	0	10578.75	0	3022.5	0	1943.035714	465	581.25	0	0	0
6	10442.25	0	0	2983.5	0	459	573.75	0	0	0	10442.25	0	2983.5	2983.5	2622.857143	459	0	0	0	0
7	10237.5	0	0	2925	0	0	0	0	0	0	10237.5	0	2925	2925	2008.928571	0	0	0	0	0
8	10078.25	0	0	2879.5	1911.683437	0	0	0	0	0	10078.25	0	2879.5	2879.5	1911.683437	0	0	0	0	0
9	10374	10155.8724	0	2964	570	0	0	0	0	0	10374	10155.8724	2964	2964	570	0	570	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	2093.5355	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	2540.9415	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2341.62525	0	0	0
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	0	1968	0	0	0	0
14	11147.5	11147.5	3185	3185	0	0	0	0	1347.5	0	11147.5	11147.5	3185	3185	0	0	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	0	2925	0	0	0	0	0	0
16	10146.5	10146.5	0	0	0	0	0	1226.5	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	10123.75	0	0	0	1780	0	1223.75	0	0	10123.75	10123.75	0	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	1764	972.405	0	0	0	10032.75	10032.75	0	0	0	1764	972.405	0	0	0
19	10101	10101	0	0	0	1479.186	555	0	0	0	10101	10101	0	0	0	1479.186	555	0	0	0
20	10305.75	10305.75	0	0	0	0	566.25	0	0	0	10305.75	10305.75	0	0	3669.3	880.462125	566.25	0	0	0
21	10510.5	10510.5	0	0	3742.2	0	0	0	0	0	10510.5	10510.5	0	0	3742.2	0	0	0	0	0
22	10442.25	10442.25	2983.5	0	3717.9	0	0	0	0	0	10442.25	0	0	0	3717.9	0	0	0	0	0
23	10351.25	0	2957.5	0	3685.5	0	0	0	0	0	10351.25	0	2957.5	2957.5	3685.5	0	0	1251.25	0	0
24	10260.25	0	2931.5	2931.5	3653.1	0	0	0	0	0	10260.25	0	2931.5	2931.5	3653.1	0	0	0	0	0

Table-6.38e: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 81-100) with solar during summer

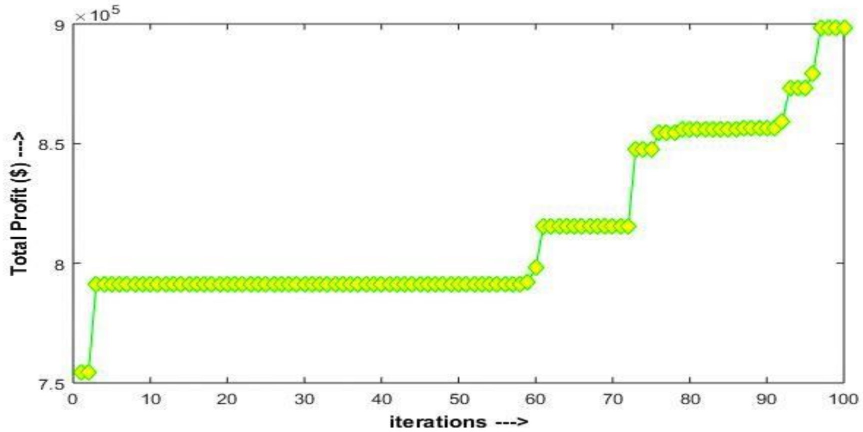
Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	10078.25	0	0	0	0	0	0	0	221.5	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	0	0	0	0	0	0	0	0	0	10010	0	0	2860	0	0	0	0	0	0
3	10510.5	0	0	0	0	0	577.5	0	0	0	10510.5	0	0	3003	0	462	0	0	0	0
4	10305.75	0	0	0	0	453	566.25	226.5	0	0	10305.75	0	0	2944.5	566.25	453	0	226.5	0	0
5	10578.75	0	0	3022.5	1943.035714	465	581.25	0	0	0	10578.75	0	0	3022.5	1943.035714	465	0	0	0	0
6	10442.25	0	0	2983.5	2622.857143	459	0	0	0	0	10442.25	0	0	2983.5	2622.857143	0	0	0	0	0
7	10237.5	0	2925	2925	2008.928571	450	0	0	0	0	10237.5	0	2925	2925	2008.928571	0	0	0	0	0
8	10078.25	0	2879.5	2879.5	1911.683437	0	0	0	0	0	10078.25	0	2879.5	2879.5	1911.683437	0	0	0	0	0
9	10374	10155.8724	2964	2964	570	0	0	0	0	0	10374	10155.8724	2964	2964	570	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	2093.5355	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	2540.9415	0	0	0
12	14400.75	14400.75	4114.5	4114.5	0	0	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2341.62525	0	0	0
13	11193	11193	3198	3198	0	0	1698.261	0	0	0	11193	11193	3198	3198	0	0	1698.261	0	0	0
14	11147.5	11147.5	3185	3185	0	0	1852.99625	0	0	0	11147.5	11147.5	3185	3185	0	0	0	0	0	0
15	10237.5	10237.5	0	2925	0	0	1689.345	0	0	0	10237.5	10237.5	0	2925	0	0	0	0	0	0
16	10146.5	10146.5	0	0	0	0	0	0	1226.5	0	10146.5	10146.5	0	0	0	0	0	0	0	0
17	10123.75	10123.75	0	0	0	1780	0	0	0	0	10123.75	10123.75	0	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	1764	0	0	0	0	10032.75	10032.75	0	0	0	1764	972.405	0	0	0
19	10101	10101	0	0	3596.4	1479.186	0	0	0	0	10101	10101	0	0	0	1479.186	555	0	0	0
20	10305.75	10305.75	0	0	3669.3	0	0	0	0	0	10305.75	10305.75	0	0	0	880.462125	566.25	0	0	0
21	10510.5	10510.5	0	0	3742.2	0	0	0	0	0	10510.5	10510.5	0	0	0	0	0	0	0	0
22	10442.25	10442.25	0	2983.5	3717.9	0	1847.475	0	0	0	10442.25	0	2983.5	0	0	0	0	0	0	0
23	10351.25	0	0	2957.5	3685.5	1820	1547	0	0	0	10351.25	0	2957.5	0	0	0	0	1251.25	0	0
24	10260.25	0	0	2931.5	3653.1	1804	1792.725	0	0	0	10260.25	0	2931.5	2931.5	0	0	0	0	0	0



(a) 10-Unit system



(b) 40-Unit system



(c) 100-Unit system

Fig.6.17: Convergence curve for 10-, 40- and 100-generating unit system using hCSMA-SCA optimization algorithm with solar during summer

The statistical analysis are also taken into consideration for 10-, 40 and 100-generating units. The 'Best', 'Average' and 'Worst' values for profit with standard deviation and median value of solutions have been stated for 30 trial result for PBUCP of power systems that are shown in Table-6.39. The best profit analysis using hCHHO-SCA considering RES in summer for 10-unit system is obtained as **105592.9791 $**, for 40 unit best profit is **449961.773 $** and for 100-unit system best profit is **978929.409 $**, which is higher than the profit obtain using the method hCSMA-SCA to solve PBUCP problem.

Table-6.39: Statistical analysis of results for hCHHO-SCA & hCSMA-SCA optimization algorithms with solar during summer for PBUCP

Test Systems	10 Unit System		40 Unit System		100 Unit System	
Methods	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**
Best Profit	**105592.9791**	92273.6016	**449961.773**	399358.83	**978929.409**	883387.929
Average Profit	105537.0498	92136.57976	414539.117	374868.559	885420.535	832132.856
Worst Profit	104376.4576	91792.55135	377108.946	361952.983	825493.98	805441.246
Std.	231.6005794	133.9500572	17283.7754	8792.59099	38335.0489	17693.7491
Median	105589.6509	92155.3411	409815.915	371648.544	875305.641	827943.407

The p-value is one of the most important test which approaches testing for hypothesis to calculate the probability whether for that problem there are evidences to discard the null hypothesis. Also, the null hypothesis is identified as conjecture that can initially claim population as well as data generating procedure. In case of alternative hypothesis whether population parameters differ from value of populations parameters stated in that conjecture. In case of practices, the significant levels are stated for advance to define the small number of p-values must be reject null hypothesis. The p-value helps to provide solutions over these types of problems.

h-value is one of the nonparametric one way ANOVA test (1952). The process is applied to make a comparison of more group of sets on dependent variables which can be measured on a level. This non parametric hypothesis value does not assume the data which come from specific distribution. The h-value is useful when the assumption of ANOVA are not met, i.e. this assumptions of the normality. This is sometime known as one way ANOVA on the ranks. The value of data in this rank are used for hypothesis test rather than the actual data. In this kind of test it define whether medians of more group of sets are dissimilar that can be compared to distributions cut-off points in statistics. This kind of statistical test are used to find out the optimum point is known as H statistics. Mainly two hypothesis are commonly applied which are given below.

• H0: The medians of the populations are equal.

• H1: The medians of the populations are not equal.

The p-value for wilcoxon-rank sum test and t-test and h-value for t-test is used to verify the efficiency of hCHHO-SCA optimizer that are shown in Table-6.40. The best, average and worst time are also taken into consideration, are shown in Table-6.41.

Table-6.40: Hypothetical testing of hCHHO-SCA & hCSMA-SCA optimization algorithms with solar during summer for PBUCP

Test System s		10 Unit System		40 Unit System		100 Unit System	
Methods		hCHHO-SCA	hCSMA-SCA	hCHHO-SCA	hCSMA-SCA	hCHHO-SCA	hCSMA-SCA
Wilcoxon-rank sum test [p-value]		9.41739E-07	1.63848E-06	1.7344E-06	1.7344E-06	1.7344E-06	1.7344E-06
t-test	p-value	7.11522E-79	4.6378E-84	8.4217E-42	4.866E-49	2.5086E-41	2.8316E-50
	h-value	1	1	1	1	1	1

Table-6.41: Comparison of computational time for hCHHO-SCA & hCSMA-SCA optimization algorithms with solar during summer for PBUCP

Test Systems	10 Unit System		40 Unit System		100 Unit System	
Methods	hCHHO-SCA	hCSMA-SCA	hCHHO-SCA	hCSMA-SCA	hCHHO-SCA	hCSMA-SCA
Best time(sec.)	0.09375	0.010473	0.4375	0.013527	0.375	0.015625
Average time (sec.)	0.370833333	0.015104167	3.73802083	0.0171875	1.64427083	0.0390625
Worst tim (sec.)	0.90625	0.015625	6.828125	0.03125	3.125	0.109375

6.6.5 Hybrid Chaotic Harris Hawks-Sine Cosine Optimization Algorithm with solar PV during Winter

The proposed optimizer hCHHO-SCA have certain major performances in the phases of explorations. Not only this, but also had major approach in adaptation from phases of explorations to the phases of exploitations. The number of populations are 40 for 10-, 40- and 100-generating unit systems.

6.6.5.1 Ten Generating Unit System

The test system is used to check the efficiency of the proposed hCHHO-SCA optimizer. The system contains of 10-generating unit system having a 24-hour electricity demand. The hCHHO-SCA technique is evaluated for 100 iterations. The hCHHO- SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.18**. The commitment status, the optimal scheduling and the profit table of the 10-generating unit system have been shown in Table-6.46a and Table-6.46b respectively.

The Table-6.42a have been shown for the commitment status and optimum scheduling of the generators during 24 hours considering solar PV in winter using hCHHO-SCA optimizer. In this case, the PGU1 and PGU2 are on for 24 hours. PGU1 generates 455 MW of power for 24 hours. Further, displays The PGU3 generates 130 MW of power for 9th to 14th hours. The PGU4 is remain off for 1 to 4th hours and 23rd and 24th hour. It is on only for 5th hour to 22nd hour. In those time, for which the PFU4 is on, it generates 130 MW power for each hour.

The Table-6.42b shows the hourly profit of 10-unit system considering solar PV in winter using hCHHO-SCA optimizer. For PGU1 and PGU2 maximum profit can be obtained because it is on for the whole day. For PGU3 the profit value differs from 2964 $ to 4114.5 $ only for 9th hour to 14th hour. For PGU7 to PGU10 no profit will be gained as it is not committed.

Table-6.42a: Commitment status and scheduling for 10-generating unit system using hCHHO-SCA optimization algorithm with solar during winter

Commitment status of thermal units								Scheduling of the committed generating units						
HOURS	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**
1	1	1	0	0	0	0	0	455	245	0	0	0	0	0
2	1	1	0	0	0	0	0	455	295	0	0	0	0	0
3	1	1	0	0	0	0	0	455	395	0	0	0	0	0
4	1	1	0	0	0	0	0	455	455	0	0	0	0	0
5	1	1	0	1	0	0	0	455	415	0	130	0	0	0
6	1	1	0	1	0	0	0	455	455	0	130	0	0	0
7	1	1	0	1	0	0	0	455	455	0	130	0	0	0
8	1	1	0	1	0	0	0	455	455	0	130	0	0	0
9	1	1	1	1	0	0	0	455	454.4271	130	130	0	0	0
10	1	1	1	1	1	1	0	455	455	130	130	162	64.4400001	0
11	1	1	1	1	1	1	0	455	455	130	130	162	73.4	0
12	1	1	1	1	1	1	0	455	455	130	130	162	61.96	0
13	1	1	1	1	1	0	0	455	455	130	130	140.01	0	0
14	1	1	1	1	1	0	0	455	455	130	130	113.48	0	0
15	1	1	0	1	1	0	0	455	455	0	130	127.88	0	0
16	1	1	0	1	0	0	0	455	426.4	0	130	0	0	0
17	1	1	0	1	0	0	0	455	391.91	0	130	0	0	0
18	1	1	0	1	0	0	0	455	436.68	0	130	0	0	0
19	1	1	0	1	0	0	0	455	447.02	0	130	0	0	0
20	1	1	0	1	0	0	0	455	454.82	0	130	0	0	0
21	1	1	0	1	0	0	0	455	455	0	130	0	0	0
22	1	1	0	1	0	0	0	455	455	0	130	0	0	0
23	1	1	0	0	0	0	0	455	445	0	0	0	0	0
24	1	1	0	0	0	0	0	455	345	0	0	0	0	0

Table-6.46b: Hourly profit for 10-generating unit system using hCHHO-SCA optimization algorithm with solar during winter

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7 to PG10	Start-up Cost	Hourly Profit
1	10078.25	5426.75	0	0	0	0	0	0	15505
2	10010	6490	0	0	0	0	0	0	16500
3	10510.5	9124.5	0	0	0	0	0	0	19635
4	10305.75	10305.75	0	0	0	0	0	0	20611.5
5	10578.75	9648.75	0	3022.5	0	0	0	550	23250
6	10442.25	10442.25	0	2983.5	0	0	0	0	23868
7	10237.5	10237.5	0	2925	0	0	0	0	23400
8	10078.25	10078.25	0	2879.5	0	0	0	0	23036
9	10374	10360.9379	2964	2964	0	0	0	1120	26662.9379
10	13354.25	13354.25	3815.5	3815.5	4754.7	1891.314	0	2320	40985.514
11	13718.25	13718.25	3919.5	3919.5	4884.3	2213.01	0	0	42372.81
12	14400.75	14400.75	4114.5	4114.5	5127.3	1961.034	0	0	44118.834
13	11193	11193	3198	3198	3444.246	0	0	0	32226.246
14	11147.5	11147.5	3185	3185	2780.26	0	0	0	31445.26
15	10237.5	10237.5	0	2925	2877.3	0	0	0	26277.3
16	10146.5	9508.72	0	2899	0	0	0	0	22554.22
17	10123.75	8719.9975	0	2892.5	0	0	0	340	21736.2475
18	10032.75	9628.794	0	2866.5	0	0	0	0	22528.044
19	10101	9923.844	0	2886	0	0	0	0	22910.844
20	10305.75	10301.673	0	2944.5	0	0	0	550	23551.923
21	10510.5	10510.5	0	3003	0	0	0	0	24024
22	10442.25	10442.25	0	2983.5	0	0	0	0	23868
23	10351.25	10123.75	0	0	0	0	0	0	20475
24	10260.25	7779.75	0	0	0	0	0	1070	18040

6.6.5.2 Forty Generating Unit System

This test system is used to check the efficiency of the proposed hCHHO-SCAoptimizer. The system contains of 40-generating units having a 24-hourelectricity demand. The hCHHO-SCA technique is evaluated for 100 iterations solar energy as solar PV in winter. The hCHHO- SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.18**. Table-6.43 represents the hourly profit with startup cost and fuel cost for 40-generating unit system using hCHHO-SCA optimization algorithm with solar PV during winter. The optimal scheduling of 40-generating unit systems are shown in Table-6.44a and Table-6.44b. The hourly profit table for this system is shown in Table-6.45a and Table-6.45b respectively.

Table-6.43: Hourly profit with startup cost and fuel cost for 40-generating unit system using hCHHO-SCA optimization algorithm with solar during winter

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	62020	170	53787.3293	**13**	130527.846	620	102845.113
2	66000	730	57283.9693	**14**	126995.26	560	100698.958
3	78540	2020	65457.854	**15**	107277.3	0	91918.5395
4	82446	11800	70578.81	**16**	92130.22	430	79854.0848
5	93000	2140	77802.3628	**17**	88486.2475	1270	76229.9948
6	95472	1040	80603.6428	**18**	95465.724	5000	79700.1584
7	93600	120	80603.6428	**19**	92174.844	2360	80908.2277
8	92144	0	80021.3612	**20**	94219.923	0	81069.7059
9	106690.938	10230	90038.7636	**21**	96096	1700	81073.438
10	164255.514	11160	108517.518	**22**	95472	5820	81073.438
11	170088.21	290	109305.858	**23**	81900	2530	71488.3962
12	178188.234	1070	109105.251	**24**	72160	0	62700.2652

Table-6.44a: Generation scheduling for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with solar during winter

HOURS	PGU 1	PGU2	PGU3	PGU 4	PGU5	PGU 6-10	PGU-11	PGU-12	PGU-13	PGU-14	PGU-15	PGU-16-20
1	455	326.66667	326.66667	0	0	0	455	0	326.66667	0	0	0
2	455	393.33333	393.33333	0	0	0	455	0	393.33333	0	0	0
3	455	440	440	0	0	0	455	0	440	0	0	0
4	455	390	390	0	0	0	455	0	390	0	0	0
5	455	384	384	0	0	0	455	0	384	0	0	0
6	455	416	416	0	0	0	455	0	416	0	0	0
7	455	416	416	0	0	0	455	0	416	0	0	0
8	455	442	442	130	0	0	455	0	442	0	0	0
9	455	454.90452	454.90452	130	0	0	455	454.90452	454.90452	0	0	0
10	455	439.555	439.555	130	0	0	455	439.555	439.555	130	0	0
11	455	445.175	445.175	130	0	0	455	445.175	445.175	130	0	0
12	455	443.745	443.745	130	0	0	455	443.745	443.745	130	0	0
13	455	419.50125	419.50125	0	0	0	455	419.50125	419.50125	130	0	0
14	455	404.185	404.185	0	0	0	455	404.185	404.185	130	0	0
15	455	421.12571	421.12571	0	0	0	455	421.12571	421.12571	0	0	0
16	455	385.23333	385.23333	0	0	0	455	385.23333	0	0	0	0
17	455	431.382	431.382	0	0	0	455	431.382	0	0	0	0
18	455	438.336	438.336	130	0	0	455	438.336	0	0	0	0
19	455	455	455	130	122.02	0	455	455	0	0	0	0
20	455	455	455	130	129.82	0	455	455	0	0	0	0
21	455	455	455	130	130	0	455	455	0	0	0	0
22	455	455	455	130	130	0	455	455	0	0	0	0
23	455	455	0	130	116.66667	0	455	0	0	130	116.66667	0
24	455	455	0	0	113.33333	0	455	0	0	130	113.33333	0

The optimal power generation scheduling for 40-generating unit system using hCHHO-SCA optimizer have been shown in Table-6.44a. Out of 40-generating units Table-6.30a represent PGU1 to PGU20 for 24 hours considering solar PV in winter. The optimal scheduling have been obtained from PGU1, PGU2 and PGU11 for 24 hours. The PGU6 to PGU10 and PGU16 to PGU20 remain off during 24 hours. So, the output power is became ‘0’. The other units have been on for few hours. Thus the optimum scheduling can be obtain for that particular hour.

Table-6.44b: Generation scheduling for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40) with solar during winter

HOURS	PGU21	PGU22	PGU23	PGU24	PGU25-30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36-40
1	455	0	0	0	0	455	0	0	0	0	0
2	455	0	0	0	0	455	0	0	0	0	0
3	455	0	0	130	0	455	0	0	130	0	0
4	455	0	390	130	0	455	0	0	130	0	0
5	455	0	384	130	0	455	0	384	130	0	0
6	455	0	416	130	0	455	0	416	130	0	0
7	455	0	416	130	0	455	0	416	130	0	0
8	455	0	442	0	0	455	0	442	0	0	0
9	455	0	454.90452	0	0	455	0	454.90452	0	0	0
10	455	439.555	439.555	0	0	455	439.555	439.555	0	0	0
11	455	445.175	445.175	0	0	455	445.175	445.175	0	0	0
12	455	443.745	443.745	0	0	455	443.745	443.745	0	0	0
13	455	419.50125	419.50125	0	0	455	419.50125	419.50125	0	0	0
14	455	404.185	404.185	0	0	455	404.185	404.185	0	0	0
15	455	421.12571	421.12571	0	0	455	421.12571	0	0	0	0
16	455	385.23333	385.23333	0	0	455	385.23333	0	0	0	0
17	455	431.382	0	0	0	455	431.382	0	0	0	0
18	455	438.336	0	0	0	455	438.336	0	0	0	0
19	455	0	0	130	0	455	455	0	130	0	0
20	455	0	0	130	0	455	455	0	130	0	0
21	455	0	0	130	0	455	455	0	130	0	0
22	455	0	0	130	0	455	455	0	130	0	0
23	455	0	0	130	0	455	0	455	130	116.66	0
24	455	0	0	0	0	455	0	455	0	113.333	0

The suggested hCHHO-SCA optimization algorithm is used to solve PBUCP for 40-unit test system with solar PV in winter. The Table-6.44b represents the optimum scheduling of PGU21 to PGU40. The power scheduling for PGU21 and PGU31 is 455 MW for 24 hours. Further, PGU25 to PGU30 and PGU36 to PGU40 has been off throughout the 24 hours. For 3rd to 7th and again 19th to 23rd hours, the PGU24 have been on. The optimal power generation is 130 MW for that hours. The PGU22, PGU23 and PGU32, PGU33 are kept on for some few hours. Further PGU35 has been remained on only for 23rd and 24th hour.

Table-6.45a and Table-6.45b represents the hourly profit for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with solar PV during summer.

Table-6.45a: Hourly profit for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with solar during winter

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	GPU16	PGU17	PGU 18	PGU19	PGU 20
1	10078.25	7235.66667	7235.66667	0	0	0	0	0	0	0	10078.25	0	7235.66667	0	0	0	0	0	0	0
2	10010	8653.33333	8653.33333	0	0	0	0	0	0	0	10010	0	8653.33333	0	0	0	0	0	0	0
3	10510.5	10164	10164	0	0	0	0	0	0	0	10510.5	0	10164	0	0	0	0	0	0	0
4	10305.75	8833.5	8833.5	0	0	0	0	0	0	0	10305.75	0	8833.5	0	0	0	0	0	0	0
5	10578.75	8928.00001	8928.00001	0	0	0	0	0	0	0	10578.75	0	8928.00001	0	0	0	0	0	0	0
6	10442.25	9547.2	9547.2	0	0	0	0	0	0	0	10442.25	0	9547.2	0	0	0	0	0	0	0
7	10237.5	9360	9360	0	0	0	0	0	0	0	10237.5	0	9360	0	0	0	0	0	0	0
8	10078.25	9790.3	9790.3	2879.5	0	0	0	0	0	0	10078.25	0	9790.3	0	0	0	0	0	0	0
9	10374	10371.823	10371.823	2964	0	0	0	0	0	0	10374	10371.823	10371.823	0	0	0	0	0	0	0
10	13354.25	12900.9393	12900.9393	3815.5	0	0	0	0	0	0	13354.25	12900.9393	12900.9393	3815.5	0	0	0	0	0	0
11	13718.25	13422.0263	13422.0263	3919.5	0	0	0	0	0	0	13718.25	13422.0263	13422.0263	3919.5	0	0	0	0	0	0
12	14400.75	14044.5293	14044.5293	4114.5	0	0	0	0	0	0	14400.75	14044.5293	14044.5293	4114.5	0	0	0	0	0	0
13	11193	10319.7308	10319.7308	0	0	0	0	0	0	0	11193	10319.7308	10319.7308	3197.99999	0	0	0	0	0	0
14	11147.5	9902.5325	9902.5325	0	0	0	0	0	0	0	11147.5	9902.5325	9902.5325	3184.99999	0	0	0	0	0	0
15	10237.5	9475.32857	9475.32857	0	0	0	0	0	0	0	10237.5	9475.32857	9475.32857	0	0	0	0	0	0	0
16	10146.5	8590.70333	8590.70333	0	0	0	0	0	0	0	10146.5	8590.70333	0	0	0	0	0	0	0	0
17	10123.75	9598.2495	9598.2495	0	0	0	0	0	0	0	10123.75	9598.2495	0	0	0	0	0	0	0	0
18	10487.75	10103.6448	10103.6448	2996.5	0	0	0	0	0	0	10487.75	10103.6448	0	0	0	0	0	0	0	0
19	10101	10101	10101	2886	2708.844	0	0	0	0	0	10101	10101	0	0	0	0	0	0	0	0
20	10305.75	10305.75	10305.75	2944.5	2940.423	0	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
21	10510.5	10510.5	10510.5	3003	3003	0	0	0	0	0	10510.5	10510.5	0	0	0	0	0	0	0	0
22	10442.25	10442.25	10442.25	2983.5	2983.5	0	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	10351.25	0	2957.5	2654.16667	0	0	0	0	0	10351.25	0	0	2957.5	2654.16667	0	0	0	0	0
24	10260.25	10260.25	0	0	2555.66667	0	0	0	0	0	10260.25	0	0	2931.5	2555.66667	0	0	0	0	0

Table-6.45b: Hourly profit for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40) with solar during winter

HOURS	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PG34	PGU35	GPU36	PGU37	PGU 38	PGU39	PGU 40
1	10078.25	0	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	0	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	0	0	3003	0	0	0	0	0	0	10510.5	0	0	3003	0	0	0	0	0	0
4	10305.75	0	8833.5	2944.49999	0	0	0	0	0	0	10305.75	0	0	2944.49999	0	0	0	0	0	0
5	10578.75	0	8928.00001	3022.49999	0	0	0	0	0	0	10578.75	0	8928.00001	3022.49999	0	0	0	0	0	0
6	10442.25	0	9547.2	2983.5	0	0	0	0	0	0	10442.25	0	9547.2	2983.5	0	0	0	0	0	0
7	10237.5	0	9360	2925	0	0	0	0	0	0	10237.5	0	9360	2925	0	0	0	0	0	0
8	10078.25	0	9790.3	0	0	0	0	0	0	0	10078.25	0	9790.3	0	0	0	0	0	0	0
9	10374	0	10371.823	0	0	0	0	0	0	0	10374	0	10371.823	0	0	0	0	0	0	0
10	13354.25	12900.9393	12900.9393	0	0	0	0	0	0	0	13354.25	12900.9393	12900.9393	0	0	0	0	0	0	0
11	13718.25	13422.0263	13422.0263	0	0	0	0	0	0	0	13718.25	13422.0263	13422.0263	0	0	0	0	0	0	0
12	14400.75	14044.5293	14044.5293	0	0	0	0	0	0	0	14400.75	14044.5293	14044.5293	0	0	0	0	0	0	0
13	11193	10319.7308	10319.7308	0	0	0	0	0	0	0	11193	10319.7308	10319.7308	0	0	0	0	0	0	0
14	11147.5	9902.5325	9902.5325	0	0	0	0	0	0	0	11147.5	9902.5325	9902.5325	0	0	0	0	0	0	0
15	10237.5	9475.32857	9475.32857	0	0	0	0	0	0	0	10237.5	9475.32857	0	0	0	0	0	0	0	0
16	10146.5	8590.70333	8590.70333	0	0	0	0	0	0	0	10146.5	8590.70333	0	0	0	0	0	0	0	0
17	10123.75	9598.2495	0	0	0	0	0	0	0	0	10123.75	9598.2495	0	0	0	0	0	0	0	0
18	10487.75	10103.6448	0	0	0	0	0	0	0	0	10487.75	10103.6448	0	0	0	0	0	0	0	0
19	10101	0	0	2886	0	0	0	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	0	0	2944.5	0	0	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	0	0	0	0
21	10510.5	0	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	0	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	0	0	0	0	0	0
23	10351.25	0	0	2957.5	0	0	0	0	0	0	10351.25	0	10351.25	2957.5	2654.16667	0	0	0	0	0
24	10260.25	0	0	0	0	0	0	0	0	0	10260.25	0	10260.25	0	2555.66667	0	0	0	0	0

6.6.5.3 Hundred Generating Unit System

This test system is used to check the efficiency of the proposed hCHHO-SCA optimizer. The system contains of 100-generating unit system having a 24-hour electricity demand. The hCHHO-SCA technique is evaluated for 100 iterations solar energy as RES in winter. The hCHHO- SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.18.** Table-6.46 shows the hourly profit with start-up cost and fuel cost for100-generating unit system using hCHHO-SCA optimization algorithm with solar PV during winter. The optimal scheduling of 100-generating unit systems are shown in Table-6.47a to Table-6.47e. The hourly profit table for this system is shown in Table-6.48a to Table-6.48e respectively.

Table-6.46: Hourly profit with start-up cost and fuel cost for100-generating unit system using hCHHO-SCA optimization algorithm with solar during winter

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	155050	4210	136155.93	**13**	327131.05	2230	270519.26
2	165000	5950	147195.84	**14**	318095.26	940	263096.55
3	196350	6630	166380.06	**15**	269277.3	460	240727.93
4	206115	4150	179705.68	**16**	231282.22	1050	203409.55
5	232500	2760	198775.56	**17**	221986.25	1590	194171.32
6	238680	2070	209577.41	**18**	228916.04	1690	203428.14
7	234000	520	208109.86	**19**	230702.84	4590	204326.99
8	230360	1530	213306.63	**20**	235555.92	4010	205302.73
9	266746.94	12180	238519.47	**21**	240240	5700	204864.29
10	410795.51	2170	292611.53	**22**	238680	2500	206664.86
11	425519.01	350	292135.93	**23**	204750	2610	179566.3
12	446327.03	610	292053.73	**24**	180400	1420	162318.99

Table-6.47a: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with solar during winter

HOUR	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	455	273.75	0	0	0	0	0	0	0	0	455	273.75	0	0	0	0	0	0	0	0
2	455	284.375	0	130	0	0	0	0	0	0	455	284.375	0	130	25	0	0	0	0	0
3	455	373.75	0	130	0	0	0	0	0	0	455	373.75	0	130	25	0	0	0	0	0
4	455	394.375	0	130	0	0	0	0	0	0	455	394.375	0	130	25	0	0	0	0	0
5	455	448.75	0	130	25	0	0	0	0	0	455	448.75	0	130	25	0	0	0	0	0
6	455	444.375	130	130	25	0	0	0	0	0	455	444.375	0	130	25	0	0	0	0	0
7	455	446.25	130	130	25	0	0	0	0	0	455	446.25	0	130	25	0	0	0	0	0
8	455	409.375	130	130	25	0	25	0	0	0	455	409.375	0	130	25	0	0	0	0	0
9	455	444.44271	130	130	25	0	25	0	0	0	455	444.44271	0	130	25	0	0	0	0	0
10	455	455	130	130	162	0	43.688	0	0	0	455	455	130	130	162	0	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	55	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	64.01	0	0	0
14	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	75.74	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	85	0	0	0
16	455	445.14	0	130	0	0	0	0	0	0	455	445.14	0	130	0	0	0	0	0	0
17	455	425.691	0	130	0	0	0	0	0	0	455	425.691	0	130	0	0	0	0	0	0
18	455	455	0	130	0	0	25	0	0	0	455	455	0	130	0	0	0	0	0	0
19	455	455	0	130	0	0	46.01	0	0	0	455	455	0	130	0	0	0	0	0	0
20	455	455	0	130	0	0	74.91	0	0	0	455	455	0	130	0	0	0	0	0	0
21	455	455	0	130	0	0	0	0	0	45	455	455	0	130	0	0	0	0	0	0
22	455	455	130	130	0	0	0	55	0	0	455	455	0	0	0	0	84	0	0	0
23	455	455	130	0	0	0	0	0	55	0	455	455	130	0	0	0	71	0	0	0
24	455	455	130	0	0	0	0	0	0	0	455	455	130	0	0	80	69.333333	0	0	0

Table-6.47b: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40) with solar during winter

HOUR	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	273.75	0	0	0	0	0	0	0	0	455	273.75	0	0	0	0	0	0	0	0
2	455	284.375	0	0	0	0	0	0	0	0	455	284.375	0	0	0	0	0	0	0	0
3	455	373.75	0	0	0	0	0	0	0	0	455	373.75	0	130	0	0	0	0	0	0
4	455	394.375	0	0	0	0	0	0	0	0	455	394.375	130	130	0	0	0	0	0	0
5	455	448.75	130	130	25	0	0	0	0	0	455	448.75	130	130	25	0	0	0	0	0
6	455	444.375	130	130	25	0	0	0	0	0	455	444.375	130	130	25	0	0	0	0	0
7	455	446.25	130	130	25	0	0	0	0	0	455	446.25	130	130	25	0	0	0	0	0
8	455	409.375	130	130	25	0	25	0	0	0	455	409.375	130	130	25	0	25	0	0	0
9	455	444.44271	130	130	25	0	25	0	0	0	455	444.44271	130	130	25	0	25	0	0	0
10	455	455	130	130	162	80	43.688	55	0	0	455	455	130	130	162	0	43.688	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	43.4	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	47.32
13	455	455	130	130	162	0	0	0	0	0	455	455	130	130	0	80	0	0	0	0
14	455	455	130	130	162	0	0	0	0	0	455	455	130	130	0	0	75.74	0	0	0
15	455	455	130	130	162	0	0	0	0	0	455	455	130	130	0	0	85	0	0	0
16	455	445.14	0	130	0	0	0	0	0	0	455	445.14	0	130	0	0	25	0	0	0
17	455	425.691	0	130	0	0	0	0	0	0	455	425.691	0	130	0	0	0	0	0	0
18	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	61.68	0	0	0	0
19	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	80	0	0	0	0
20	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	80	0	0	0	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	455	130	0	162	0	0	0	0	0	455	455	0	0	0	0	84	0	0	0
23	455	455	130	0	162	0	0	0	0	0	455	455	0	0	0	0	71	0	0	0
24	455	455	130	0	162	80	0	0	0	0	455	0	0	0	0	0	69.333333	0	0	0

The Table-6.47a represents the generation scheduling of 100-generating unit system with effect of solar PV using hCHHO-SCA optimization algorithm in winter for PGU1 to PGU20. Where PGU1, PGU2, PGU11 and PGU12 are remain on for 24 hours. The 455 MW power output can be measured from PGU1 and PGU11 for 24 hours. PGU19 and PGU20 is totally off for 24 hours. So, no power generation can be obtained from those units. Further others unit are on for some few hours and off some few hours. Thus the optimal generation can be taken only those are in on condition.

Table-6.47b gives the optimal power scheduling of 100-uniut system with effect of solar PV by suggested hCHHO-SCA method in winter for PGU21 to PGU40. The PGU21, PGU22 and PGU31 are in on condition for 24 hours. And other PGU are sometimes on and sometimes off. PGU29 to PGU30 and PGU38 are off during 24 hours.

Table-6.47c presents the generation scheduling of 100-unit system with effect of solar PV using proposed hCHHO-SCA optimization algorithm in winter for PGU41 to PGU60. Here, PGU41, PGU42 and PGU51 are on for 24 hours. The 455 MW power can be generated from PGU41 and PGU51. The output power is ‘0’ for PGU50 and PGU60. The PGU47 generate power for 8^{th} to 10^{th} hours, i.e. 25 MW for 8^{th} and 9^{th} hours and 43.688 MW for 10^{th} hour. The other PGU are on and off for few hours and output power generation can be measured through the table.

Thable-6.47d signifies the generation scheduling of 100-generating unit by hCHHO-SCA algorithm for PGU61 to PGU80 considering the effect of solar PV in winter. The PGU61 and PGU71 is on for 24 hours. The 455 MW power output can be shown from PGU61 and PGU71 for 24 hours. The power output from PGU69 and PGU79 is ‘0’ for 24 hours.

Table-6.47c: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 41-60) with solar during winter

Hour	PGU41	PGU42	PGU43	PGU44	PGU45	PGU46	PGU47	PGU48	PGU49	PGU50	PGU51	PGU52	PGU53	PGU54	PGU55	PGU56	PGU57	PGU58	PGU59	PGU60
1	455	273.75	0	0	0	0	0	0	0	0	455	273.75	0	0	0	0	0	0	0	0
2	455	284.375	0	0	0	0	0	0	0	0	455	284.375	0	0	0	0	0	0	0	0
3	455	373.75	0	0	0	0	0	0	0	0	455	373.75	130	0	0	0	0	0	0	0
4	455	394.375	0	0	0	0	0	0	0	0	455	394.375	130	0	0	20	0	0	0	0
5	455	448.75	0	130	0	0	0	0	0	0	455	448.75	130	0	0	20	0	0	0	0
6	455	444.375	0	130	0	0	0	0	0	0	455	444.375	130	130	25	20	0	0	0	0
7	455	446.25	0	130	0	0	0	0	0	0	455	446.25	130	130	25	0	0	0	0	0
8	455	409.375	0	130	0	20	25	0	0	0	455	409.375	130	130	25	0	0	0	0	0
9	455	444.44271	130	130	0	20	25	0	0	0	455	444.44271	130	130	25	0	0	0	0	0
10	455	455	130	130	162	80	43.688	0	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	162	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
15	455	455	130	130	162	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
16	455	445.14	130	130	0	0	0	0	0	0	455	445.14	0	130	0	0	0	0	0	0
17	455	425.691	130	130	0	0	0	0	0	0	455	425.691	0	130	0	0	0	0	0	0
18	455	455	130	130	0	0	0	0	0	0	455	455	0	130	0	0	25	0	0	0
19	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	46.01	0	0	0
20	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	74.91	0	0	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	455	0	0	0	0	0	0	55	0	455	455	0	0	0	0	0	0	0	0
23	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
24	455	455	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	55	0

Table-6.47d: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 61-80) with solar during winter

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	455	273.75	130	130	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	284.375	130	130	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	373.75	130	130	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
4	455	394.375	130	130	0	0	0	0	0	0	455	0	130	0	0	0	0	0	0	0
5	455	448.75	130	130	0	0	0	0	0	0	455	0	130	0	0	0	0	0	0	0
6	455	444.375	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	10	0	0
7	455	446.25	130	130	25	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
8	455	409.375	130	130	25	20	25	0	0	0	455	0	130	130	0	0	0	0	0	0
9	455	444.44271	130	130	25	20	25	0	0	0	455	444.44271	130	130	0	0	0	0	0	0
10	455	455	130	130	162	80	43.688	55	0	0	455	455	130	130	0	80	0	55	0	0
11	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	55	0	0
12	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	0	0	47.32
13	455	455	130	130	0	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	0	80	0	0	0	0	455	455	130	130	162	0	0	0	0	0
15	455	455	0	130	0	80	0	0	0	51.88	455	455	0	130	162	0	0	0	0	0
16	455	445.14	0	130	0	20	0	0	0	0	455	445.14	0	130	25	0	0	0	0	0
17	455	425.691	0	130	0	0	0	0	0	0	455	425.691	0	130	0	0	0	0	0	0
18	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
19	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	80	0	0	0	0
20	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	80	0	0	0	0
21	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	80	0	0	0	0
22	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
23	455	455	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
24	455	0	130	0	0	80	0	0	55	0	455	0	0	0	0	0	0	0	0	0

Table-6.47e: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 81-100) with solar during winter

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	455	0	0	0	0	0	0	0	0	0	455	273.75	0	0	0	0	0	0	0	0
2	455	0	0	0	0	0	0	0	0	0	455	284.375	130	0	0	0	0	0	0	0
3	455	0	0	0	25	0	0	0	0	0	455	373.75	130	0	0	0	0	0	0	0
4	455	0	130	0	25	0	0	0	0	0	455	394.375	130	0	25	0	0	0	0	0
5	455	0	130	0	25	0	0	0	0	0	455	448.75	130	0	25	0	0	0	0	0
6	455	0	130	0	25	0	0	0	10	0	455	444.375	130	0	25	0	0	0	0	0
7	455	0	130	0	25	0	0	0	0	0	455	446.25	130	0	25	0	0	0	0	0
8	455	0	130	0	25	0	0	0	0	0	455	409.375	130	130	25	0	0	0	0	0
9	455	444.44271	130	0	25	0	0	0	0	0	455	444.44271	130	130	25	0	0	0	0	0
10	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	55	0	0
11	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	47.32
13	455	455	130	130	0	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
14	455	455	130	130	0	80	0	0	0	0	455	455	130	130	162	0	0	0	0	0
15	455	455	0	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
16	455	445.14	0	0	0	0	0	0	0	0	455	445.14	130	0	0	0	0	0	0	0
17	455	425.691	0	0	0	0	0	0	0	0	455	425.691	0	0	0	0	0	0	0	0
18	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
19	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
20	455	455	130	0	0	80	0	0	0	0	455	455	0	0	0	0	0	0	0	0
21	455	455	130	130	0	80	0	55	0	0	455	455	0	0	0	0	0	0	0	0
22	455	455	130	130	0	80	0	0	0	0	455	455	130	0	0	0	0	0	0	0
23	455	0	130	130	0	0	71	0	0	0	455	0	130	0	0	0	0	55	0	0
24	455	0	130	130	0	0	69.333333	0	0	0	455	0	130	0	0	0	0	0	0	0

Table-6.47e gives the optimal power scheduling of 100-uniut system by suggested hCHHO-SCA method for PGU81 to PGU100 considering the effect of solar PV in winter. PGU90 and PGU99 is totally off throughout the day. So, no power generation can be obtained from those units. Further others unit are on for some few hours and off some few hours. Thus the optimal generation can be taken only those are in on condition.

Table-6.48a shows the best profit of PGU1 to PGU20 for each unit for particular hours considering the effect of solar PV in winter. The duration of total hour is 24 hours. The suggested hCHHO-SCA optimizer is tested on 100-unit system. The profit from PGU8 can be obtained for 22nd hours, i.e. 1262.25 $ for that hours and for the other hours it remains off.

Table-6.48b represents the hourly profit for 100-generating unit system by hCHHO-SCA optimizer for PGU21 to PGU40 considering the effect of solar PV in winter. The PGU21, PGU22 and PGU31 are on throughout 24 hours. So, for those units the profit values are obtained in each hour. The PGU29 to PGU30 and PGU38 are off during 24 hours.

The Table-6.48c is presented the hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm for units 41 to unit 60 with solar PV in winter. The PGU41 and PGU51 remain on for 24 hours. The PGU50 and PGU60 remain close throughout the whole day. That’s why no profit come from those units, the output is ‘0’.

The Table-6.48d and Table-6.48e is presented the hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm for PGU61 to PGU80 and PGU81 to PGU100 with solar PV in winter. The PGU61, PGU71, PGU81 and PGU91 remain on for 24 hours. The PGU77, PGU79 and PGU90 as well as PGU97 remain close throughout the whole day. That’s why no profit come from those units, the output is ‘0’.

Table-6.48a: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 1-20) with solar during winter

Hour	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	10078.25	6063.5625	0	0	0	0	0	0	0	0	10078.25	6063.5625	0	0	0	0	0	0	0	0
2	10010	6256.25	0	2860	0	0	0	0	0	0	10010	6256.25	0	2860	550	0	0	0	0	0
3	10510.5	8633.625	0	3003	0	0	0	0	0	0	10510.5	8633.625	0	3003	577.5	0	0	0	0	0
4	10305.75	8932.5938	0	2944.5	0	0	0	0	0	0	10305.75	8932.5938	0	2944.5	566.25	0	0	0	0	0
5	10578.75	10433.438	0	3022.5	581.25001	0	0	0	0	0	10578.75	10433.438	0	3022.5	581.25001	0	0	0	0	0
6	10442.25	10198.406	2983.5	2983.5	573.75	0	0	0	0	0	10442.25	10198.406	0	2983.5	573.75	0	0	0	0	0
7	10237.5	10040.625	2925	2925	562.5	0	0	0	0	0	10237.5	10040.625	0	2925	562.5	0	0	0	0	0
8	10078.25	9067.6562	2879.5	2879.5	553.75	0	553.75	0	0	0	10078.25	9067.6562	0	2879.5	553.75	0	0	0	0	0
9	10374	10133.294	2964	2964	570	0	570	0	0	0	10374	10133.294	0	2964	570	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	1282.2428	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	1658.25	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3985.2	1968	0	0	0	0	11193	11193	3198	3198	3985.2	1968	1574.646	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	0	0	0	11147.5	11147.5	3185	3185	3969	0	1855.63	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	1912.5	0	0	0
16	10146.5	9926.622	0	2899	0	0	0	0	0	0	10146.5	9926.622	0	2899	0	0	0	0	0	0
17	10123.75	9471.6248	0	2892.5	0	0	0	0	0	0	10123.75	9471.6248	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	551.25	0	0	0	10032.75	10032.75	0	2866.5	0	0	0	0	0	0
19	10101	10101	0	2886	0	0	1021.422	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	1696.7115	0	0	0	10305.75	10305.75	0	2944.5	0	0	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	1039.5	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	2983.5	0	0	0	1262.25	0	0	10442.25	10442.25	0	0	0	0	1927.8	0	0	0
23	10351.25	10351.25	2957.5	0	0	0	0	0	1251.25	0	10351.25	10351.25	2957.5	0	0	0	1615.25	0	0	0
24	10260.25	10260.25	2931.5	0	0	0	0	0	0	0	10260.25	10260.25	2931.5	0	0	1804	1563.4667	0	0	0

Table-6.48b: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 21-40) with solar during winter

Hour	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU 29	PGU 30	PGU31	PGU32	PGU33	PGU 34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	10078.25	6063.5625	0	0	0	0	0	0	0	0	10078.25	6063.5625	0	0	0	0	0	0	0	0
2	10010	6256.25	0	0	0	0	0	0	0	0	10010	6256.25	0	0	0	0	0	0	0	0
3	10510.5	8633.625	0	0	0	0	0	0	0	0	10510.5	8633.625	0	3003	0	0	0	0	0	0
4	10305.75	8932.5938	0	0	0	0	0	0	0	0	10305.75	8932.5938	2944.5	2944.5	0	0	0	0	0	0
5	10578.75	10433.438	3022.5	3022.5	581.25001	0	0	0	0	0	10578.75	10433.438	3022.5	3022.5	581.25001	0	0	0	0	0
6	10442.25	10198.406	2983.5	2983.5	573.75	0	0	0	0	0	10442.25	10198.406	2983.5	2983.5	573.75	0	0	0	0	0
7	10237.5	10040.625	2925	2925	562.5	0	0	0	0	0	10237.5	10040.625	2925	2925	562.5	0	0	0	0	0
8	10078.25	9067.6562	2879.5	2879.5	553.75	0	553.75	0	0	0	10078.25	9067.6562	2879.5	2879.5	553.75	0	553.75	0	0	0
9	10374	10133.294	2964	2964	570	0	570	0	0	0	10374	10133.294	2964	2964	570	0	570	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	1282.2428	1614.25	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	1282.2428	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	1308.51	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	1497.678
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	0	1968	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	0	0	0	11147.5	11147.5	3185	3185	0	0	1855.63	0	0	0
15	10237.5	10237.5	2925	2925	3645	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	1912.5	0	0	0
16	10146.5	9926.622	0	2899	0	0	0	0	0	0	10146.5	9926.622	0	2899	0	0	557.5	0	0	0
17	10123.75	9471.6248	0	2892.5	0	0	0	0	0	0	10123.75	9471.6248	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	1360.044	0	0	0	0
19	10101	10101	0	2886	0	0	0	0	0	0	10101	10101	0	2886	0	1776	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	0	0	0	0	10305.75	10305.75	0	2944.5	0	1812	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	0	3717.9	0	0	0	0	0	10442.25	10442.25	0	0	0	0	1927.8	0	0	0
23	10351.25	10351.25	2957.5	0	3685.5	0	0	0	0	0	10351.25	10351.25	0	0	0	0	1615.25	0	0	0
24	10260.25	10260.25	2931.5	0	3653.1	1804	0	0	0	0	10260.25	0	0	0	0	0	1563.4667	0	0	0

Table-6.48c: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 41-60) with solar during winter

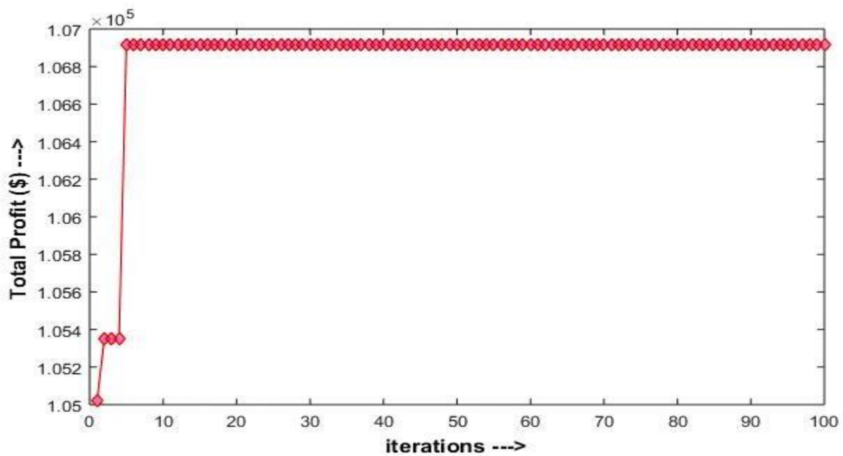
Hour	PGU41	PGU42	PGU43	PGU 44	PGU45	PGU46	PGU 47	PGU48	PGU49	PGU50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PGU56	PGU57	PGU 58	PGU 59	PGU 60
1	10078.25	6063.5625	0	0	0	0	0	0	0	0	10078.25	6063.5625	0	0	0	0	0	0	0	0
2	10010	6256.25	0	0	0	0	0	0	0	0	10010	6256.25	0	0	0	0	0	0	0	0
3	10510.5	8633.625	0	0	0	0	0	0	0	0	10510.5	8633.625	3003	0	0	0	0	0	0	0
4	10305.75	8932.5938	0	0	0	0	0	0	0	0	10305.75	8932.5938	2944.5	0	0	453	0	0	0	0
5	10578.75	10433.438	0	3022.5	0	0	0	0	0	0	10578.75	10433.438	3022.5	0	0	465	0	0	0	0
6	10442.25	10198.406	0	2983.5	0	0	0	0	0	0	10442.25	10198.406	2983.5	2983.5	573.75	459	0	0	0	0
7	10237.5	10040.625	0	2925	0	0	0	0	0	0	10237.5	10040.625	2925	2925	562.5	0	0	0	0	0
8	10078.25	9067.6562	0	2879.5	0	443	553.75	0	0	0	10078.25	9067.6562	2879.5	2879.5	553.75	0	0	0	0	0
9	10374	10133.294	2964	2964	0	456	570	0	0	0	10374	10133.294	2964	2964	570	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	1282.2428	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	0	0	0	11147.5	11147.5	3185	3185	0	0	0	0	0	0
15	10237.5	10237.5	2925	2925	3645	0	0	0	0	0	10237.5	10237.5	0	2925	0	0	0	0	0	0
16	10146.5	9926.622	2899	2899	0	0	0	0	0	0	10146.5	9926.622	0	2899	0	0	0	0	0	0
17	10123.75	9471.6248	2892.5	2892.5	0	0	0	0	0	0	10123.75	9471.6248	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	2866.5	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	551.25	0	0	0
19	10101	10101	0	2886	0	0	0	0	0	0	10101	10101	0	2886	0	0	1021.422	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	1696.7115	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	0	0	0	0	0	0	1262.25	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	10351.25	0	0	0	0	0	0	0	0	10351.25	10351.25	0	0	0	0	0	0	0	0
24	10260.25	10260.25	0	0	0	0	0	0	0	0	10260.25	0	0	0	0	0	0	0	1240.25	0

Table-6.48d: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 61-80) with solar during winter

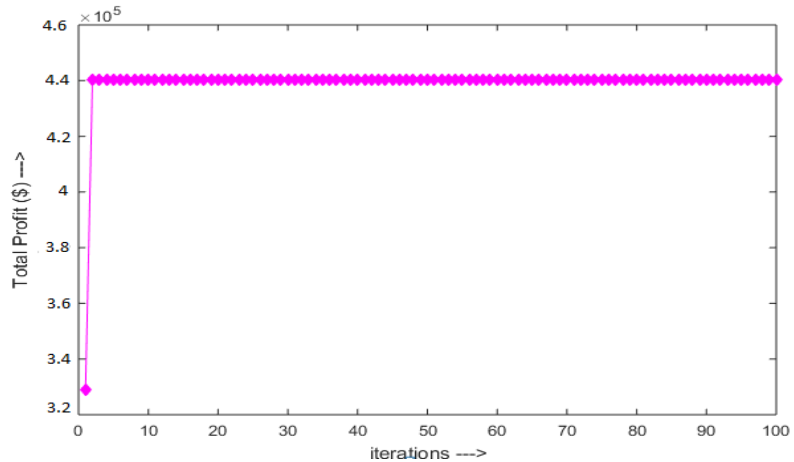
Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	10078.25	6063.5625	2879.5	2879.5	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	6256.25	2860	2860	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	8633.625	3003	3003	0	0	0	0	0	0	10510.5	0	0	0	0	0	0	0	0	0
4	10305.75	8932.5938	2944.5	2944.5	0	0	0	0	0	0	10305.75	0	2944.5	0	0	0	0	0	0	0
5	10578.75	10433.438	3022.5	3022.5	0	0	0	0	0	0	10578.75	0	3022.5	0	0	0	0	0	0	0
6	10442.25	10198.406	2983.5	2983.5	0	0	0	0	0	0	10442.25	0	2983.5	2983.5	0	0	0	229.5	0	0
7	10237.5	10040.625	2925	2925	562.5	0	0	0	0	0	10237.5	0	2925	2925	0	0	0	0	0	0
8	10078.25	9067.6562	2879.5	2879.5	553.75	443	553.75	0	0	0	10078.25	0	2879.5	2879.5	0	0	0	0	0	0
9	10374	10133.294	2964	2964	570	456	570	0	0	0	10374	10133.294	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	1282.2428	1614.25	0	0	13354.25	13354.25	3815.5	3815.5	0	2348	0	1614.25	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	1658.25	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	1497.678
13	11193	11193	3198	3198	0	0	0	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	0	1960	0	0	0	0	11147.5	11147.5	3185	3185	3969	0	0	0	0	0
15	10237.5	10237.5	0	2925	0	1800	0	0	0	1167.3	10237.5	10237.5	0	2925	3645	0	0	0	0	0
16	10146.5	9926.622	0	2899	0	446	0	0	0	0	10146.5	9926.622	0	2899	557.5	0	0	0	0	0
17	10123.75	9471.6248	0	2892.5	0	0	0	0	0	0	10123.75	9471.6248	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	0	0	0	0
19	10101	10101	0	2886	0	0	0	0	0	0	10101	10101	0	2886	0	1776	0	0	0	0
20	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	0	0	0	1812	0	0	0	0
21	10510.5	10510.5	0	0	0	0	0	0	0	0	10510.5	10510.5	0	0	0	1848	0	0	0	0
22	10442.25	10442.25	0	0	0	0	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	10351.25	0	0	0	0	0	0	0	0	10351.25	0	0	0	0	0	0	0	0	0
24	10260.25	0	2931.5	0	0	1804	0	0	1240.25	0	10260.25	0	0	0	0	0	0	0	0	0

Table-6.48e: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 81-100) with solar during winter

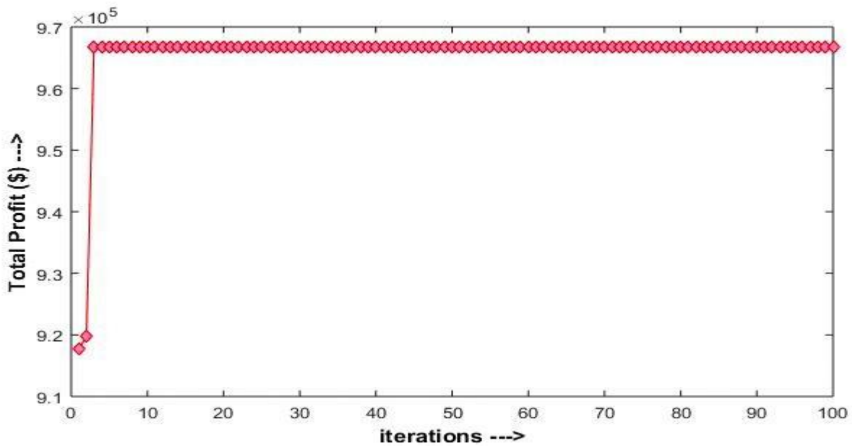
Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	10078.25	0	0	0	0	0	0	0	0	0	10078.25	6063.5625	0	0	0	0	0	0	0	0
2	10010	0	0	0	0	0	0	0	0	0	10010	6256.25	2860	0	0	0	0	0	0	0
3	10510.5	0	0	0	577.5	0	0	0	0	0	10510.5	8633.625	3003	0	0	0	0	0	0	0
4	10305.75	0	2944.5	0	566.25	0	0	0	0	0	10305.75	8932.5938	2944.5	0	566.25	0	0	0	0	0
5	10578.75	0	3022.5	0	581.25001	0	0	0	0	0	10578.75	10433.438	3022.5	0	581.25001	0	0	0	0	0
6	10442.25	0	2983.5	0	573.75	0	0	0	229.5	0	10442.25	10198.406	2983.5	0	573.75	0	0	0	0	0
7	10237.5	0	2925	0	562.5	0	0	0	0	0	10237.5	10040.625	2925	0	562.5	0	0	0	0	0
8	10078.25	0	2879.5	0	553.75	0	0	0	0	0	10078.25	9067.6562	2879.5	2879.5	553.75	0	0	0	0	0
9	10374	10133.294	2964	0	570	0	0	0	0	0	10374	10133.294	2964	2964	570	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	1614.25	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	1497.678
13	11193	11193	3198	3198	0	1968	0	0	0	0	11193	11193	3198	3198	3985.2	1968	0	0	0	0
14	11147.5	11147.5	3185	3185	0	1960	0	0	0	0	11147.5	11147.5	3185	3185	3969	0	0	0	0	0
15	10237.5	10237.5	0	2925	0	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
16	10146.5	9926.622	0	0	0	0	0	0	0	0	10146.5	9926.622	2899	0	0	0	0	0	0	0
17	10123.75	9471.6248	0	0	0	0	0	0	0	0	10123.75	9471.6248	0	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	0	0	0	0	0	10032.75	10032.75	0	0	0	0	0	0	0	0
19	10101	10101	0	0	0	0	0	0	0	0	10101	10101	0	0	0	0	0	0	0	0
20	10305.75	10305.75	2944.5	0	0	1812	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
21	10510.5	10510.5	3003	3003	0	1848	0	1270.5	0	0	10510.5	10510.5	0	0	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	2983.5	0	1836	0	0	0	0	10442.25	10442.25	2983.5	0	0	0	0	0	0	0
23	10351.25	0	2957.5	2957.5	0	0	1615.25	0	0	0	10351.25	0	2957.5	0	0	0	0	1251.25	0	0
24	10260.25	0	2931.5	2931.5	0	0	1563.4667	0	0	0	10260.25	0	2931.5	0	0	0	0	0	0	0



(a) 10-Unit system



(b) 40-Unit system



(c) 100-Unit system

Fig.6.18: Convergence curve for 10-, 40- and 100-generating unit system using hCHHO-SCA optimization algorithm with solar during winter

6.6.6 Hybrid Chaotic Slime Mould-Sine Cosine Optimization Algorithm with solar PV during Winter

The proposed hCSMA-SCA optimizer is established to increase the penetrating capability through the entire search region. This technique is unrivaled as the populace based enhancers are more reasonable to tackle ongoing issue since they can ready to stay away from the caught into nearby optima and investigate the pursuit district just as take advantage of worldwide ideal arrangement more steady than the individual based analyzer. The number of populations are taken as 40 for 10-, 40- and 100-generating unit systems.

6.6.6.1 Ten Generating Unit System

This system contains of 10-generating unit system having a 24-hour electricity demand.The hCSMA-SCA technique is evaluated for 100 iterations considering solar as solar PV in winter days. The hCSMA-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.19**. The commitment status and the optimal scheduling for this unit system are shown in Table-6.49a and the hourly profit of the 10-generating unit system have been shown in Table-6.49b.

The Table-6.49a represents the commitment status with optimum scheduling and profit of the generators for 24 hours considering effect of solar PV in winter. In this case, the PGU1 and PGU2 are on for 24 hours. From 9 to 22 hours, the PGU3 is on.

Table-6.49b represent the hourly profit table with start-up cost for 10-generating unit system using hCSMA-SCA optimization algorithm with solar PV during winter.

Table-6.49a: Commitment status and scheduling for 10-generating unit system using hCSMA-SCA optimization algorithm with solar during winter

Commitment status of thermal units										Scheduling of the committed generating units								
HOURS	**PGU 1**	**PGU 2**	**PGU 3**	**PGU 4**	**PGU 5**	**PGU 6**	**PGU7**	**PGU8**	**PGU9 to PG10**	**PGU1**	**PGU2**	**PGU 3**	**PGU4**	**PGU 5**	**PGU 6**	**PGU7**	**PGU8**	**PGU9 to PG10**
1	1	1	0	0	0	0	0	0	0	455	245	0	0	0	0	0	0	0
2	1	1	0	0	0	0	0	0	0	455	295	0	0	0	0	0	0	0
3	1	1	0	0	1	0	0	0	0	455	370	0	0	25	0	0	0	0
4	1	1	0	0	1	0	0	0	0	455	430	0	0	25	0	0	0	0
5	1	1	0	1	1	0	0	0	0	455	390	0	130	25	0	0	0	0
6	1	1	0	1	1	0	0	0	0	455	430	0	130	25	0	0	0	0
7	1	1	0	1	1	0	0	0	0	455	430	0	130	25	0	0	0	0
8	1	1	0	1	1	0	0	0	0	455	430	0	130	25	0	0	0	0
9	1	1	1	1	1	0	0	0	0	455	429.4271	130	130	25	0	0	0	0
10	1	1	1	1	1	1	1	1	0	455	455	130	130	162	29.44	25	10	0
11	1	1	1	1	1	1	1	1	0	455	455	130	130	162	38.4	25	10	0
12	1	1	1	1	1	1	1	1	0	455	455	130	130	162	26.96	25	10	0
13	1	1	1	1	1	1	1	0	0	455	455	130	130	95.01	20	25	0	0
14	1	1	1	1	1	1	0	0	0	455	455	130	130	93.48	20	0	0	0
15	1	1	1	1	1	0	0	0	0	455	427.88	130	130	25	0	0	0	0
16	1	1	1	1	0	0	0	0	0	455	296.4	130	130	0	0	0	0	0
17	1	1	1	1	0	0	0	0	0	455	261.91	130	130	0	0	0	0	0
18	1	1	1	1	0	0	0	0	0	455	306.68	130	130	0	0	0	0	0
19	1	1	1	1	0	0	0	0	0	455	317.02	130	130	0	0	0	0	0
20	1	1	1	1	0	0	0	0	0	455	324.82	130	130	0	0	0	0	0
21	1	1	1	1	0	0	0	0	0	455	325	130	130	0	0	0	0	0
22	1	1	1	1	0	0	0	0	0	455	325	130	130	0	0	0	0	0
23	1	1	0	1	0	0	0	0	0	455	315	0	130	0	0	0	0	0
24	1	1	0	0	0	0	0	0	0	455	345	0	0	0	0	0	0	0

Table-6.49b: Hourly profit for 10-generating unit system using hCSMA-SCA optimization algorithm with solar during winter

HOU RS	PGU1	PG U2	PGU3	PG U4	PGU5	PGU6	PGU7	PGU8	PGU9 to PG10	Start-up Cost	Hourly Profit
1	10078.25	5426.75	0	0	0	0	0	0	0	0	15505
2	10010	6490	0	0	0	0	0	0	0	0	16500
3	10510.5	8547	0	0	577.5	0	0	0	0	0	19635
4	10305.75	9739.5	0	0	566.25	0	0	0	0	0	20611.5
5	10578.75	9067.5	0	3022.5	581.25	0	0	0	0	0	23250
6	10442.25	9868.5	0	2983.5	573.75	0	0	0	0	0	23868
7	10237.5	9675	0	2925	562.5	0	0	0	0	0	23400
8	10078.25	9524.5	0	2879.5	553.75	0	0	0	0	0	23036
9	10374	9790.93788	2964	2964	570	0	0	0	0	0	26662.9379
10	13354.25	13354.25	3815.5	3815.5	4754.7	864.064	733.75	293.5	0	0	40985.514
11	13718.25	13718.25	3919.5	3919.5	4884.3	1157.76	753.75	301.5	0	0	42372.81
12	14400.75	14400.75	4114.5	4114.5	5127.3	853.284	791.25	316.5	0	0	44118.834
13	11193	11193	3198	3198	2337.246	492	615	0	0	0	32226.246
14	11147.5	11147.5	3185	3185	2290.26	490	0	0	0	0	31445.26
15	10237.5	9627.3	2925	2925	562.5	0	0	0	0	0	26277.3
16	10146.5	6609.72	2899	2899	0	0	0	0	0	0	22554.22
17	10123.75	5827.4975	2892.5	2892.5	0	0	0	0	0	0	21736.2475
18	10032.75	6762.294	2866.5	2866.5	0	0	0	0	0	0	22528.044
19	10101	7037.844	2886	2886	0	0	0	0	0	0	22910.844
20	10305.75	7357.173	2944.5	2944.5	0	0	0	0	0	0	23551.923
21	10510.5	7507.5	3003	3003	0	0	0	0	0	0	24024
22	10442.25	7458.75	2983.5	2983.5	0	0	0	0	0	0	23868
23	10351.25	7166.25	0	2957.5	0	0	0	0	0	0	20475
24	10260.25	7779.75	0	0	0	0	0	0	0	0	18040

6.6.6.2 Forty Generating Unit System

This system contains of 40-generating unit system having a 24-hour electricity demand. The hCSMA-SCA technique is evaluated for 100 iterations considering solar as solar PV in winter days. The hCSMA-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.19**. The profit with start-up cost and fuel cost of 24 hours are shown in Table-6.50. The optimal scheduling of 40-generating unit systems are shown in Table-6.51a and Table-6.51b. The hourly profit table for this system is shown in Table-6.52a and Table-6.52b respectively.

Table-6.50: Hourly profit with startup cost and fuel cost for 40-generating unit system using hCSMA-SCA optimization algorithm with solar during winter

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	62020	2530	53787.3293	**13**	130527.846	2020	104035.708
2	66000	1800	57283.9693	**14**	126995.26	2620	101802.082
3	78540	730	65457.854	**15**	107277.3	990	92893.3696
4	82446	12340	70578.81	**16**	92130.22	240	79854.0848
5	93000	0	77802.3628	**17**	88486.2475	960	76229.9948
6	95472	0	80603.6428	**18**	91324.044	610	79700.1584
7	93600	1700	80603.6428	**19**	92174.844	590	82140.3082
8	92144	1130	80354.594	**20**	94219.923	550	82190.1684
9	106690.938	4500	90038.7636	**21**	96096	5380	84288.2799
10	164255.514	10170	109822.056	**22**	95472	5400	82251.2093
11	170088.21	720	110749.988	**23**	81900	5410	70941.5305
12	178188.234	5460	110513.369	**24**	72160	820	62693.3483

Table-6.51a: Generation scheduling for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with solar during winter

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU-10	PGU-11	PGU-12	PGU-13	PGU-14	PGU-15	PGU-16	PGU-17	PGU-18	PGU-19	PGU-20
1	455	326.66667	326.66667	0	0	0	0	0	0	0	455	326.66667	0	0	0	0	0	0	0	0
2	455	393.33333	393.33333	0	0	0	0	0	0	0	455	393.33333	0	0	0	0	0	0	0	0
3	455	440	440	0	0	0	0	0	0	0	455	440	0	0	0	0	0	0	0	0
4	455	390	390	0	0	0	0	0	0	0	455	390	390	0	0	0	0	0	0	0
5	455	384	384	0	0	0	0	0	0	0	455	384	384	0	0	0	0	0	0	0
6	455	416	416	0	0	0	0	0	0	0	455	416	416	0	0	0	0	0	0	0
7	455	416	416	0	0	0	0	0	0	0	455	416	416	0	0	0	0	0	0	0
8	455	390	390	0	0	0	0	0	0	0	455	390	390	0	0	0	0	0	0	0
9	455	454.90452	454.90452	130	0	0	0	0	0	0	455	454.90452	454.90452	0	0	0	0	0	0	0
10	455	455	0	130	110.48	0	0	0	0	0	455	455	455	130	110.48	0	0	0	0	0
11	455	455	0	130	125.46667	0	0	0	0	0	455	455	455	130	125.46667	0	0	0	0	0
12	455	455	0	130	121.65333	0	0	0	0	0	455	455	455	130	121.65333	0	0	0	0	0
13	455	450.14429	0	130	25	0	0	0	0	0	455	450.14429	450.14429	130	25	0	0	0	0	0
14	455	455	0	130	124.49333	0	0	0	0	0	455	455	455	130	124.49333	0	0	0	0	0
15	455	455	0	0	72.626667	0	0	0	0	0	455	455	455	0	72.626667	0	0	0	0	0
16	455	385.23333	0	0	0	0	0	0	0	0	455	385.23333	385.23333	0	0	0	0	0	0	0
17	455	431.382	0	0	0	0	0	0	0	0	455	431.382	431.382	0	0	0	0	0	0	0
18	455	438.336	438.336	0	0	0	0	0	0	0	455	438.336	438.336	0	0	0	0	0	0	0
19	455	455	455	0	0	73.34	0	0	0	0	455	455	0	0	0	73.34	0	0	0	0
20	455	455	455	130	0	32.606667	0	0	0	0	455	455	0	0	0	32.606667	0	0	0	0
21	455	455	455	130	0	73.25	0	0	0	0	455	455	0	130	0	73.25	0	0	0	0
22	455	446	446	130	0	0	0	0	0	0	455	446	0	130	0	0	0	0	0	0
23	455	450	450	130	0	0	0	0	0	0	455	450	0	130	0	0	0	0	0	0
24	455	455	455	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0

Table-6.51b: Generation scheduling for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with solar during winter

Hour	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
4	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
5	455	0	384	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
6	455	0	416	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
7	455	0	416	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
8	455	0	390	0	0	0	0	0	0	0	455	0	390	0	0	0	0	0	0	0
9	455	0	454.90452	0	0	0	0	0	0	0	455	0	454.90452	0	0	0	0	0	0	0
10	455	455	455	0	110.48	0	0	0	0	0	455	455	455	0	0	0	0	0	0	0
11	455	455	455	0	125.46667	0	0	0	0	0	455	455	455	0	0	0	0	0	0	0
12	455	455	455	0	121.65333	0	0	0	0	0	455	455	455	0	0	0	0	0	0	0
13	455	450.14429	450.14429	0	25	0	0	0	0	0	455	450.14429	450.14429	0	0	0	0	0	0	0
14	455	455	0	0	124.49333	0	0	0	0	0	455	455	455	0	0	0	0	0	0	0
15	455	455	0	0	72.626667	0	0	0	0	0	455	455	455	0	0	0	0	0	0	0
16	455	385.23333	0	0	0	0	0	0	0	0	455	385.23333	385.23333	0	0	0	0	0	0	0
17	455	431.382	0	0	0	0	0	0	0	0	455	431.382	0	0	0	0	0	0	0	0
18	455	0	0	130	0	0	0	0	0	0	455	438.336	0	0	0	0	0	0	0	0
19	455	0	0	130	0	73.34	0	0	0	0	455	455	0	0	162	0	0	0	0	0
20	455	0	0	130	0	32.606667	0	0	0	0	455	455	0	0	162	0	0	0	0	0
21	455	0	0	130	0	73.25	0	0	0	0	0	455	0	130	162	73.25	0	0	0	0
22	455	0	446	130	0	0	0	0	0	0	0	446	0	130	25	20	0	0	0	0
23	455	0	450	0	0	0	0	0	0	0	0	0	0	130	25	20	0	0	0	0
24	455	0	455	0	0	0	0	0	0	0	0	0	0	130	80	0	0	0	0	0

Table-6.51a shows the optimal scheduling of PGU1 to PGU20 for 40-generating unit test system considering the effect of solar PV in winter using hCSMA-SCA optimizer. The PGU7 to PGU10 and PGU17 to PGU20 is off for 24 hours. The PGU1 and PGU11 is always remain on throughout the whole day and 455 MW power can be obtained. PGU6 and PGU16 gives 73.34 MW power for 19th hour, 32.606667 MW power for 20th hours and 73.25 MW power for 21st hour. Further, the PGU are sometimes remain on and off condition for optimum power generation scheduling.

In Table-6.51b represents the power scheduling of 21 to 40 unit for 40-unit system with solar PV in winter using hCSMA-SCA optimizer. The PGU21 is continuing on for 24 hours, PGU22 is on only for 10th to 17th hours. The PGU27 to PGU30 and PGU37 to PGU40 are remain off for 24th hours. The PGU26 is on for 19th to 22nd hours. The PGU36 is on for 21st to 23rd hour only. For this the output are 73.25 MW for 21st hour and 20 MW for 22nd and 23rd hour.

The hourly profit for 40-test system is presented in Table-6.52a and Table-6.52b using hCSMA-SCA optimizer with RES in winter. The Table-6.56a shows the hourly profit for PGU1 to PGU20 for whole day. The maximum number of profit can be obtained from the PGU1 and PGU11 as it was remain on for all hours. PGU6 and PGU16 gives 1628.148 $ for 19th hour, 738.541 $ for 20th hour and 1692.075 $ is for 21st hour. The other units are gives several amount of profit for that particular hour when it was on.

Table-6.52b shows that the hourly profit for PGU21 to PGU40 for this test system using hCSMA-SCA optimizer with solar PV in winter for 24 hours. The PGU21 is on for 24 hours, so that the profit from this units are maximum. Moreover for the others hours as it remain off, no profit come from that hour when the generating unit remain off.

Table-6.52a: Hourly profit for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with solar during winter

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	GPU16	PGU17	PGU 18	PGU19	PGU 20
1	10078.25	7235.66667	7235.66667	0	0	0	0	0	0	0	10078.25	7235.66667	0	0	0	0	0	0	0	0
2	10010	8653.33333	8653.33333	0	0	0	0	0	0	0	10010	8653.33333	0	0	0	0	0	0	0	0
3	10510.5	10164	10164	0	0	0	0	0	0	0	10510.5	10164	0	0	0	0	0	0	0	0
4	10305.75	8833.5	8833.5	0	0	0	0	0	0	0	10305.75	8833.5	8833.5	0	0	0	0	0	0	0
5	10578.75	8928	8928	0	0	0	0	0	0	0	10578.75	8928	8928	0	0	0	0	0	0	0
6	10442.25	9547.2	9547.2	0	0	0	0	0	0	0	10442.25	9547.2	9547.2	0	0	0	0	0	0	0
7	10237.5	9360	9360	0	0	0	0	0	0	0	10237.5	9360	9360	0	0	0	0	0	0	0
8	10078.25	8638.5	8638.5	0	0	0	0	0	0	0	10078.25	8638.5	8638.5	0	0	0	0	0	0	0
9	10374	10371.823	10371.823	2964	0	0	0	0	0	0	10374	10371.823	10371.823	0	0	0	0	0	0	0
10	13354.25	13354.25	0	3815.5	3242.588	0	0	0	0	0	13354.25	13354.25	13354.25	3815.5	3242.588	0	0	0	0	0
11	13718.25	13718.25	0	3919.5	3782.82	0	0	0	0	0	13718.25	13718.25	13718.25	3919.5	3782.82	0	0	0	0	0
12	14400.75	14400.75	0	4114.5	3850.328	0	0	0	0	0	14400.75	14400.75	14400.75	4114.5	3850.328	0	0	0	0	0
13	11193	11073.5494	0	3198	615	0	0	0	0	0	11193	11073.5494	11073.5494	3198	615	0	0	0	0	0
14	11147.5	11147.5	0	3185	3050.08667	0	0	0	0	0	11147.5	11147.5	11147.5	3185	3050.08667	0	0	0	0	0
15	10237.5	10237.5	0	0	1634.1	0	0	0	0	0	10237.5	10237.5	10237.5	0	1634.1	0	0	0	0	0
16	10146.5	8590.70333	0	0	0	0	0	0	0	0	10146.5	8590.70333	8590.70333	0	0	0	0	0	0	0
17	10123.75	9598.2495	0	0	0	0	0	0	0	0	10123.75	9598.2495	9598.2495	0	0	0	0	0	0	0
18	10032.75	9665.3088	9665.3088	0	0	0	0	0	0	0	10032.75	9665.3088	9665.3088	0	0	0	0	0	0	0
19	10101	10101	10101	0	0	1628.148	0	0	0	0	10101	10101	0	0	0	1628.148	0	0	0	0
20	10305.75	10305.75	10305.75	2944.5	0	738.541	0	0	0	0	10305.75	10305.75	0	0	0	738.541	0	0	0	0
21	10510.5	10510.5	10510.5	3003	0	1692.075	0	0	0	0	10510.5	10510.5	0	3003	0	1692.075	0	0	0	0
22	10442.25	10235.7	10235.7	2983.5	0	0	0	0	0	0	10442.25	10235.7	0	2983.5	0	0	0	0	0	0
23	10351.25	10237.5	10237.5	2957.5	0	0	0	0	0	0	10351.25	10237.5	0	2957.5	0	0	0	0	0	0
24	10260.25	10260.25	10260.25	2931.5	0	0	0	0	0	0	10260.25	0	0	2931.5	0	0	0	0	0	0

Table-6.52b: Hourly profit for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with solar during winter

HOURS	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PG34	PGU35	GPU36	PGU37	PGU 38	PGU39	PGU 40
1	10078.25	0	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	0	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	0	0	3003	0	0	0	0	0	0	10510.5	0	0	3003	0	0	0	0	0	0
4	10305.75	0	0	2944.5	0	0	0	0	0	0	10305.75	0	0	2944.5	0	0	0	0	0	0
5	10578.75	0	8928	3022.5	0	0	0	0	0	0	10578.75	0	0	3022.5	0	0	0	0	0	0
6	10442.25	0	9547.2	2983.5	0	0	0	0	0	0	10442.25	0	0	2983.5	0	0	0	0	0	0
7	10237.5	0	9360	2925	0	0	0	0	0	0	10237.5	0	0	2925	0	0	0	0	0	0
8	10078.25	0	8638.5	0	0	0	0	0	0	0	10078.25	0	8638.5	0	0	0	0	0	0	0
9	10374	0	10371.823	0	0	0	0	0	0	0	10374	0	10371.823	0	0	0	0	0	0	0
10	13354.25	13354.25	13354.25	0	3242.588	0	0	0	0	0	13354.25	13354.25	13354.25	0	0	0	0	0	0	0
11	13718.25	13718.25	13718.25	0	3782.82	0	0	0	0	0	13718.25	13718.25	13718.25	0	0	0	0	0	0	0
12	14400.75	14400.75	14400.75	0	3850.328	0	0	0	0	0	14400.75	14400.75	14400.75	0	0	0	0	0	0	0
13	11193	11073.5494	11073.5494	0	615	0	0	0	0	0	11193	11073.5494	11073.5494	0	0	0	0	0	0	0
14	11147.5	11147.5	0	0	3050.08667	0	0	0	0	0	11147.5	11147.5	11147.5	0	0	0	0	0	0	0
15	10237.5	10237.5	0	0	1634.1	0	0	0	0	0	10237.5	10237.5	10237.5	0	0	0	0	0	0	0
16	10146.5	8590.70333	0	0	0	0	0	0	0	0	10146.5	8590.70333	8590.70333	0	0	0	0	0	0	0
17	10123.75	9598.2495	0	0	0	0	0	0	0	0	10123.75	9598.2495	0	0	0	0	0	0	0	0
18	10032.75	0	0	2866.5	0	0	0	0	0	0	10032.75	9665.3088	0	0	0	0	0	0	0	0
19	10101	0	0	2886	0	1628.148	0	0	0	0	10101	10101	0	0	3596.4	0	0	0	0	0
20	10305.75	0	0	2944.5	0	738.541	0	0	0	0	10305.75	10305.75	0	0	3669.3	0	0	0	0	0
21	10510.5	0	0	3003	0	1692.075	0	0	0	0	0	10510.5	0	3003	3742.2	1692.075	0	0	0	0
22	10442.25	0	10235.7	2983.5	0	0	0	0	0	0	0	10235.7	0	2983.5	573.75	459	0	0	0	0
23	10351.25	0	10237.5	0	0	0	0	0	0	0	0	0	0	2957.5	568.75	455	0	0	0	0
24	10260.25	0	10260.25	0	0	0	0	0	0	0	0	0	0	2931.5	1804	0	0	0	0	0

6.6.6.3 Hundred Unit System

This system contains of 100-generating unit system having a 24-hour electricity demand. The hCSMA-SCA technique is evaluated for 100 iterations considering solar as solar PV in winter. The hCSMA-SCA algorithmis verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.19**.The profit with start-up cost and fuel cost of 24 hours are shown in Table-6.53. The optimal scheduling of 100-generating unit systems are shown in Table-6.54a to Table-6.54e. The hourly profit table for this system is shown in Table-6.55a to Table-6.55e respectively.

Table-6.53: Hourly profit with start-up cost and fuel cost for 100-generating unit system using hCSMA-SCA optimization algorithm with solar during winter

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	155050	6820	144861.67	**13**	327131.05	910	272702.94
2	165000	8540	151895.84	**14**	318095.26	580	268026.69
3	196350	2270	169202.5	**15**	269277.3	3950	246217.93
4	206115	2610	180280.99	**16**	231282.22	640	208386.16
5	232500	3490	196212.43	**17**	221986.25	240	197216.44
6	238680	360	209437.7	**18**	228916.04	1110	207299.19
7	234000	3480	210030.66	**19**	230702.84	2750	207051.87
8	230360	1210	208274.37	**20**	235555.92	6150	207073.97
9	266746.94	5940	235888.67	**21**	240240	4050	207213.85
10	410795.51	2310	289460.82	**22**	238680	5070	208001.94
11	425519.01	1110	292817.1	**23**	204750	960	182126.63
12	446327.03	1300	292607.02	**24**	180400	2160	156292.94

The comparison of statistical analysis, hypothetical testing outputs and the computational time have been shown in Table-6.56, Table-6.57 and Table-6.58 respectively.

Table-6.54a: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with solar during winter

HOUR	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	455	210.55556	0	0	0	0	25	10	0	0	455	210.55556	0	0	0	20	0	0	0	0
2	455	251.66667	0	0	0	0	25	0	0	0	455	251.66667	0	0	0	20	0	0	10	0
3	455	349.44444	0	0	0	0	25	0	0	0	455	349.44444	0	0	0	20	0	0	0	0
4	455	392.22222	0	0	0	0	25	10	0	0	455	392.22222	0	0	0	0	0	0	0	0
5	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
6	455	455	0	130	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	10
7	455	455	0	130	0	20	0	0	0	0	455	455	0	130	0	0	0	0	0	0
8	455	455	0	130	0	20	0	0	0	0	455	455	0	130	0	0	0	0	0	0
9	455	455	0	130	0	20	0	0	0	0	455	455	0	130	0	0	0	0	0	0
10	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	0	0	0	55	0
11	455	455	130	130	162	80	0	0	55	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	80	81.74	0	0	0	455	455	130	130	162	80	81.74	55	0	0
13	455	455	130	130	162	0	80.5025	0	0	0	455	455	130	130	162	80	80.5025	0	0	0
14	455	455	130	130	162	0	83.005339	0	0	0	455	455	130	130	162	0	83.005339	0	0	0
15	455	455	130	130	162	0	0	0	0	0	455	455	0	130	162	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
17	455	448.191	0	130	0	20	0	0	0	0	455	448.191	0	130	0	20	0	10	0	0
18	455	455	0	130	0	80	0	0	0	10	455	455	0	130	0	80	0	0	0	0
19	455	455	0	130	0	80	85	0	0	0	455	455	0	130	0	80	0	0	0	0
20	455	455	0	130	0	0	74.94	55	0	0	455	455	0	130	0	0	0	0	0	0
21	455	455	130	130	0	0	84.999998	0	0	25.000006	455	455	0	130	0	0	0	0	0	0
22	455	455	130	130	0	0	0	0	0	0	455	455	0	0	0	0	85	0	0	0
23	455	455	130	0	0	0	0	0	0	0	455	455	130	0	0	0	61.5	55	55	0
24	455	455	130	0	162	0	0	0	0	0	455	455	130	0	0	0	39	0	0	0

Table-6.54b: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with solar during in winter

HOUR	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	210.55556	0	0	0	0	0	10	0	0	455	210.55556	0	0	0	20	0	0	0	0
2	455	251.66667	0	0	0	0	0	0	0	0	455	251.66667	0	0	0	20	0	0	0	0
3	455	349.44444	0	0	0	0	0	0	0	0	455	349.44444	130	0	0	20	0	0	0	0
4	455	392.22222	0	130	0	0	0	0	0	0	455	392.22222	130	0	0	0	0	0	0	0
5	455	455	0	130	0	80	0	41	0	0	455	455	130	0	162	0	0	0	0	0
6	455	455	0	130	0	20	0	0	0	0	455	455	130	0	152.5	0	0	0	0	0
7	455	455	0	130	0	20	0	0	10	0	455	455	130	0	71.25	0	25	0	0	0
8	455	455	0	130	0	0	0	0	0	0	455	455	130	0	63	20	25	0	0	0
9	455	455	0	130	0	0	0	0	0	0	455	455	130	130	145.88542	20	25	0	0	0
10	455	455	130	130	162	0	85	0	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	80	85	0	55	0	455	455	130	130	162	0	0	0	0	0
12	455	455	130	130	162	80	81.74	0	0	0	455	455	130	130	162	0	0	0	0	0
13	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	162	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
15	455	455	0	130	162	0	0	55	0	0	455	455	0	130	0	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	51.6	25	0	0	0
17	455	448.191	0	130	0	0	0	0	0	0	455	448.191	0	130	0	20	25	0	0	0
18	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	80	30.84	0	0	0
19	455	455	0	130	0	80	0	0	0	0	455	455	0	130	0	0	0	0	0	0
20	455	455	0	130	0	80	0	0	0	0	455	455	0	130	0	0	0	0	0	0
21	455	455	0	130	0	80	0	0	0	0	455	455	0	0	0	0	0	0	0	0
22	455	455	0	0	0	0	0	0	0	48	455	455	130	0	162	0	0	0	0	0
23	455	455	0	0	0	0	0	0	0	0	455	455	130	0	162	0	0	55	0	0
24	455	455	0	0	0	0	0	0	0	0	455	455	130	0	162	0	0	0	0	0

The Table-6.54a is given as the power scheduling of 100-unit test system using hCSMA-SCA optimizer for PGU1 to PGU20 with solar PV in winter. The PGU10 is on for 21st hours. The PGU1, PGU2, PGU11 and PGU12 is always remain on throughout the whole day. The PGU9 gives 55 MW only for 11th hour. PGU20 gives 10 MW power only for 6th hour.

In Table-6.54b represents the power scheduling of 21 to 40 unit for 100-unit system using hCSMA-SCA optimizer with solar PV in winter. The PGU21, PGU22, PGU31 and PGU32 have been continuous on for 24 hours. The PGU30 and PGU40 remain off throughout the whole day. The PGU29 is on for 7th and 11thhour and PGU38 is on for 23rd hour, which gives 10 MW and 55 MW power for PGU29 and 55 MW for PGU40.

In Table-6.54c represents the power scheduling of 41 to 60 unit for 100-unit system using hCSMA-SCA optimizer with solar PV in winter. The PGU41, PGU42, PGU51 and PGU52 is continuous on for 24 hours. The PGU49 and PGU60 remain off throughout the whole day. The PGU50 is on only for 11th hour. For this the output is 38.4 MW for that hour. The PGU59 is on for 16th hour. The power output from that us is 10 MW for that particular hours.

Table-6.54d represents the power scheduling of 61 to 80 unit for 100-unit system using hCSMA-SCA optimizer with solar PV in winter. The PGU61 and PGU71 is always on and the output power is 455 MW for 24 hours. The PGU79 is on for 22nd hour and 55 MW is the output in this particular hour.

Table-6.54e represents the power scheduling of 81 to 100 unit for 100-unit system using hCSMA-SCA optimizer with solar PV in winter. The PGU81 and PGU91 is always on and the output power is 455 MW for 24 hours. The PGU89, PGU90 and PGU100 is off for the whole day.

Table-6.54c: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 41-60) with solar during winter

Hour	PG U41	PGU42	PGU 43	PGU 44	PGU45	PGU46	PGU 47	PGU 48	PGU49	PGU50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PGU56	PGU57	PGU58	PGU59	PGU60
1	455	210.55556	0	130	0	0	0	0	0	0	455	210.55556	0	0	0	20	0	0	0	0
2	455	251.66667	0	130	0	0	0	0	0	0	455	251.66667	130	0	0	20	25	0	0	0
3	455	349.44444	0	130	0	0	0	0	0	0	455	349.44444	130	0	0	20	25	0	0	0
4	455	392.22222	0	130	0	0	0	0	0	0	455	392.22222	130	0	0	0	25	0	0	0
5	455	455	0	130	0	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
6	455	455	0	130	152.5	0	0	0	0	10	455	455	130	0	0	0	0	10	0	0
7	455	455	130	130	71.25	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
8	455	455	130	130	63	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
9	455	455	130	130	145.88542	20	0	0	0	0	455	455	130	130	0	20	0	0	0	0
10	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	80	0	0	0	38.4	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	81.74	0	0	0
13	455	455	130	130	0	0	0	0	0	0	455	455	130	130	162	0	80.5025	0	0	0
14	455	455	130	130	0	0	83.005339	0	0	0	455	455	130	130	162	0	83.005339	0	0	0
15	455	455	130	130	0	0	74.47	0	0	0	455	455	0	130	162	0	74.47	55	0	0
16	455	455	0	130	0	51.6	25	0	0	0	455	455	0	130	0	0	25	0	10	0
17	455	448.191	0	130	0	20	0	0	0	0	455	448.191	0	130	0	0	0	0	0	0
18	455	455	0	130	0	80	0	0	0	0	455	455	0	130	0	0	0	55	0	0
19	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	55	0	0
20	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	80	0	0	0	0
21	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	80	0	0	0	0
22	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	80	0	0	0	0
23	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
24	455	455	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0

Table-6.54d: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 61-80) with solar during winter

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	455	210.55556	130	0	0	0	0	0	0	0	455	210.55556	0	0	0	0	0	0	10	0
2	455	251.66667	130	0	0	0	0	0	0	0	455	251.66667	0	0	0	0	0	0	0	0
3	455	349.44444	130	0	0	0	0	0	0	0	455	349.44444	0	0	0	0	0	0	0	0
4	455	392.22222	130	0	0	0	0	0	0	0	455	392.22222	0	0	0	0	0	0	0	0
5	455	455	130	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
6	455	455	130	0	0	0	25	10	0	10	455	455	0	0	152.5	0	0	0	0	0
7	455	455	130	0	0	0	25	0	0	0	455	455	0	0	71.25	0	25	0	0	0
8	455	455	130	0	0	0	25	0	0	0	455	455	0	0	63	0	25	0	0	0
9	455	455	130	0	0	0	25	0	0	0	455	455	0	130	145.88542	0	25	0	0	0
10	455	455	130	130	162	80	85	0	0	0	455	455	130	130	162	0	0	0	0	51.44
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	0	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	0	0	0	0	0
13	455	455	0	130	162	0	0	0	0	0	455	455	130	130	0	0	80.5025	0	0	0
14	455	455	0	130	162	0	0	0	0	23.453305	455	455	130	130	0	80	83.005339	0	0	0
15	455	455	0	0	162	0	0	55	55	0	455	455	0	0	0	80	74.47	0	0	0
16	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	51.6	0	10	0	0
17	455	448.191	0	0	0	0	0	0	0	0	455	448.191	0	0	0	0	0	0	0	0
18	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
19	455	455	0	0	0	0	0	0	0	47.02	455	455	0	0	0	0	85	0	0	0
20	455	455	0	130	0	0	74.94	0	0	0	455	455	0	130	0	80	74.94	0	0	0
21	455	455	0	130	0	0	84.999998	0	0	0	455	455	0	130	0	80	84.999998	0	0	0
22	455	455	0	130	0	0	85	0	0	0	455	455	0	130	0	80	0	0	55	0
23	455	455	0	130	0	0	61.5	0	55	0	455	0	0	130	0	0	0	55	0	0
24	455	0	0	130	162	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0

The Table-6.55a is presented the hourly profit for 100-generating unit system using proposed hCSMA-SCA optimization algorithm with solar PV in winter. From 100 numbers of power generating units, this table shows the hourly profit of PGU1 to PGU20 for 24 hours. The PGU1, PGU2, PGU11 and PGU12 are on for every hour, while PGU3 and PGU4 have been off for some hours. The PGU9 is on only for 11th hour only and 1658.25 $ profit can be achieved.

The Table-6.55b is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm for units 21 to unit 40 considering effect of solar PV in winter. In this table, the PGU21 and PGU31 are on for 24 hours and maximum profit are obtained. The PGU39 and PGU40 is off throughout the whole day. Others PGU are remained on for some hours and off for few hours. From those units, the profit can be measured for that particular hour when it was on.

The Table-6.55c is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm considering effect of solar PV in winter for PGU41 to PGU60. The PGU41 and PGU51 gives maximum profit as it is remained on for 24 hours. The PGU48, PGU49 and PGU60 remain close throughout the whole day. Other units are remained on sometime and off for few times.

The Table-6.55d is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm considering effect of solar PV in winter for units 61 to unit 80. The PGU61 and PGU71 are continuously on for 24 hours.

The Table-6.55e is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm considering effect of solar PV in winter for units 81 to unit 100. The PGU81 and PGU91 has been on for 24 hours. PGU89 and PGU100 have been off for through the whole day. The PGU90 gives 221.5 $ profit only for 1st hour, for others time it remains off.

Table-6.54e: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 81-100) with solar during winter

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	455	210.55556	0	130	0	20	0	10	0	10	455	0	0	0	0	0	0	0	10	0
2	455	251.66667	0	130	0	20	0	0	0	0	455	0	0	0	0	0	25	0	0	0
3	455	349.44444	0	130	0	20	0	0	0	0	455	0	0	0	0	0	25	0	0	0
4	455	392.22222	0	130	0	0	0	0	0	0	455	0	130	0	25	0	25	0	0	0
5	455	455	0	130	0	0	0	0	0	0	455	0	130	0	162	0	0	0	0	0
6	455	455	0	130	0	0	0	10	0	0	455	0	130	0	152.5	0	0	0	0	0
7	455	455	0	130	0	0	25	10	0	0	455	0	130	0	71.25	0	0	0	10	0
8	455	455	0	130	63	0	25	0	0	0	455	0	130	0	63	0	0	0	0	0
9	455	455	0	130	145.88542	0	25	0	0	0	455	455	130	0	145.88542	0	0	0	0	0
10	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	0	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	0	0	0	0	0
13	455	455	130	130	162	80	0	0	0	0	455	455	0	130	162	0	0	0	0	0
14	455	455	130	130	0	80	0	0	0	0	455	455	0	130	0	80	0	0	55	0
15	455	455	130	0	0	80	0	0	0	0	455	455	0	130	0	80	74.47	0	0	0
16	455	455	130	0	0	0	25	0	0	0	455	455	0	0	0	51.6	25	10	0	0
17	455	448.191	0	0	0	0	25	0	0	0	455	448.191	0	0	0	0	25	0	0	0
18	455	455	0	0	0	0	30.84	55	0	0	455	455	0	0	0	0	0	0	0	0
19	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
20	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
21	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
22	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	55	0	0
23	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	55	0	0
24	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0

Table-6.55a: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with solar during winter

Hour	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	10078.25	4663.8056	0	0	0	0	553.75	221.5	0	0	10078.25	4663.8056	0	0	0	443	0	0	0	0
2	10010	5536.6667	0	0	0	0	550	0	0	0	10010	5536.6667	0	0	0	440	0	0	220	0
3	10510.5	8072.1667	0	0	0	0	577.5	0	0	0	10510.5	8072.1667	0	0	0	462	0	0	0	0
4	10305.75	8883.8333	0	0	0	0	566.25	226.5	0	0	10305.75	8883.8333	0	0	0	0	0	0	0	0
5	10578.75	10578.75	0	0	0	0	0	0	0	0	10578.75	10578.75	0	0	0	0	0	0	0	0
6	10442.25	10442.25	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	229.5
7	10237.5	10237.5	0	2925	0	450	0	0	0	0	10237.5	10237.5	0	2925	0	0	0	0	0	0
8	10078.25	10078.25	0	2879.5	0	443	0	0	0	0	10078.25	10078.25	0	2879.5	0	0	0	0	0	0
9	10374	10374	0	2964	0	456	0	0	0	0	10374	10374	0	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	1614.25	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	1658.25	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2587.071	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2587.071	1740.75	0	0
13	11193	11193	3198	3198	3985.2	0	1980.3615	0	0	0	11193	11193	3198	3198	3985.2	1968	1980.3615	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	2033.6308	0	0	0	11147.5	11147.5	3185	3185	3969	0	2033.6308	0	0	0
15	10237.5	10237.5	2925	2925	3645	0	0	0	0	0	10237.5	10237.5	0	2925	3645	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	9972.2498	0	2892.5	0	445	0	0	0	0	10123.75	9972.2498	0	2892.5	0	445	0	222.5	0	0
18	10032.75	10032.75	0	2866.5	0	1764	0	0	0	220.5	10032.75	10032.75	0	2866.5	0	1764	0	0	0	0
19	10101	10101	0	2886	0	1776	1887	0	0	0	10101	10101	0	2886	0	1776	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	1697.391	1245.75	0	0	10305.75	10305.75	0	2944.5	0	0	0	0	0	0
21	10510.5	10510.5	3003	3003	0	0	1963.5	0	0	577.50014	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	0	0	0	1950.75	0	0	0
23	10351.25	10351.25	2957.5	0	0	0	0	0	0	0	10351.25	10351.25	2957.5	0	0	0	1399.125	1251.25	1251.25	0
24	10260.25	10260.25	2931.5	0	3653.1	0	0	0	0	0	10260.25	10260.25	2931.5	0	0	0	879.45	0	0	0

Table-6.55b: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with solar during winter

Hour	**PGU21**	**PGU22**	**PGU23**	**PGU24**	**PGU25**	**PGU26**	**PGU27**	**PGU28**	**PGU29**	**PGU30**	**PGU31**	**PGU32**	**PGU33**	**PGU34**	**PGU35**	**PGU36**	**PGU37**	**PGU38**	**PGU39**	**PGU40**
1	10078.25	4663.8056	0	0	0	0	0	221.5	0	0	10078.25	4663.8056	0	0	0	443	0	0	0	0
2	10010	5536.6667	0	0	0	0	0	0	0	0	10010	5536.6667	0	0	0	440	0	0	0	0
3	10510.5	8072.1667	0	0	0	0	0	0	0	0	10510.5	8072.1667	3003	0	0	462	0	0	0	0
4	10305.75	8883.8333	0	2944.5	0	0	0	0	0	0	10305.75	8883.8333	2944.5	0	0	0	0	0	0	0
5	10578.75	10578.75	0	3022.5	0	1860	0	953.25	0	0	10578.75	10578.75	3022.5	0	3766.5	0	0	0	0	0
6	10442.25	10442.25	0	2983.5	0	459	0	0	0	0	10442.25	10442.25	2983.5	0	3499.875	0	0	0	0	0
7	10237.5	10237.5	0	2925	0	450	0	0	225	0	10237.5	10237.5	2925	0	1603.125	0	562.5	0	0	0
8	10078.25	10078.25	0	2879.5	0	0	0	0	0	0	10078.25	10078.25	2879.5	0	1395.45	443	553.75	0	0	0
9	10374	10374	0	2964	0	0	0	0	0	0	10374	10374	2964	2964	3326.1876	456	570	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	2494.75	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	2562.75	0	1658.25	0	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2587.071	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0
13	11193	11193	3198	3198	3985.2	1968	0	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	0	0	0	11147.5	11147.5	3185	3185	0	0	0	0	0	0
15	10237.5	10237.5	0	2925	3645	0	0	1237.5	0	0	10237.5	10237.5	0	2925	0	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	1150.68	557.5	0	0	0
17	10123.75	9972.2498	0	2892.5	0	0	0	0	0	0	10123.75	9972.2498	0	2892.5	0	445	556.25	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	1764	680.022	0	0	0
19	10101	10101	0	2886	0	1776	0	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	1812	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	0	0	0	0
21	10510.5	10510.5	0	3003	0	1848	0	0	0	0	10510.5	10510.5	0	0	0	0	0	0	0	0
22	10442.25	10442.25	0	0	0	0	0	0	0	1101.6	10442.25	10442.25	2983.5	0	3717.9	0	0	0	0	0
23	10351.25	10351.25	0	0	0	0	0	0	0	0	10351.25	10351.25	2957.5	0	3685.5	0	0	1251.25	0	0
24	10260.25	10260.25	0	0	0	0	0	0	0	0	10260.25	10260.25	2931.5	0	3653.1	0	0	0	0	0

Table-6.55c: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 41-60) with solar during winter

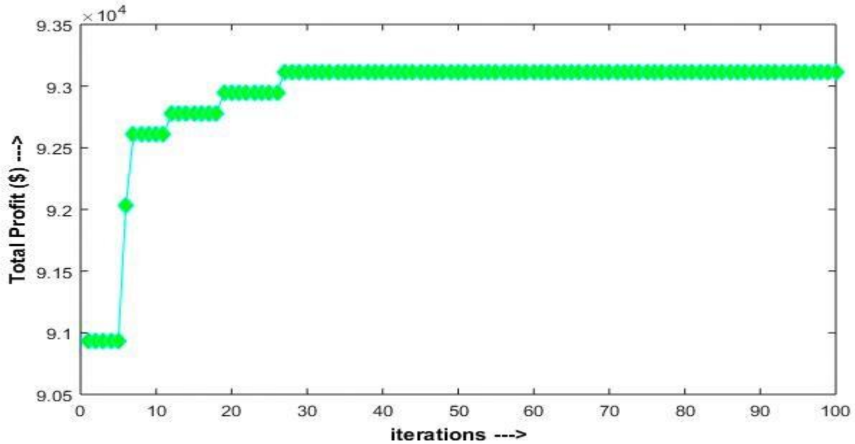
Hour	PGU41	PGU42	PGU43	PGU 44	PGU45	PGU46	PGU 47	PGU4 8	PGU 49	PGU 50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PG U56	PGU57	PGU 58	PGU 59	PGU 60
1	10078.25	4663.8056	0	2879.5	0	0	0	0	0	0	10078.25	4663.8056	0	0	0	443	0	0	0	0
2	10010	5536.6667	0	2860	0	0	0	0	0	0	10010	5536.6667	2860	0	0	440	550	0	0	0
3	10510.5	8072.1667	0	3003	0	0	0	0	0	0	10510.5	8072.1667	3003	0	0	462	577.5	0	0	0
4	10305.75	8883.8333	0	2944.5	0	0	0	0	0	0	10305.75	8883.8333	2944.5	0	0	0	566.25	0	0	0
5	10578.75	10578.75	0	3022.5	0	0	0	0	0	0	10578.75	10578.75	3022.5	0	0	0	0	0	0	0
6	10442.25	10442.25	0	2983.5	3499.875	0	0	0	0	229.5	10442.25	10442.25	2983.5	0	0	0	0	229.5	0	0
7	10237.5	10237.5	2925	2925	1603.125	0	0	0	0	0	10237.5	10237.5	2925	0	0	0	0	0	0	0
8	10078.25	10078.25	2879.5	2879.5	1395.45	0	0	0	0	0	10078.25	10078.25	2879.5	0	0	0	0	0	0	0
9	10374	10374	2964	2964	3326.1876	456	0	0	0	0	10374	10374	2964	2964	0	456	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	1157.76	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	0	2587.071	0	0	0
13	11193	11193	3198	3198	0	0	0	0	0	0	11193	11193	3198	3198	3985.2	0	1980.3615	0	0	0
14	11147.5	11147.5	3185	3185	0	0	2033.6308	0	0	0	11147.5	11147.5	3185	3185	3969	0	2033.6308	0	0	0
15	10237.5	10237.5	2925	2925	0	0	1675.575	0	0	0	10237.5	10237.5	0	2925	3645	0	1675.575	1237.5	0	0
16	10146.5	10146.5	0	2899	0	1150.68	557.5	0	0	0	10146.5	10146.5	0	2899	0	0	557.5	0	223	0
17	10123.75	9972.2498	0	2892.5	0	445	0	0	0	0	10123.75	9972.2498	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	1764	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	0	1212.75	0	0
19	10101	10101	0	2886	0	0	0	0	0	0	10101	10101	0	2886	0	0	0	1221	0	0
20	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	0	0	0	1812	0	0	0	0
21	10510.5	10510.5	0	0	0	0	0	0	0	0	10510.5	10510.5	0	0	0	1848	0	0	0	0
22	10442.25	10442.25	0	0	0	0	0	0	0	0	10442.25	10442.25	0	0	0	1836	0	0	0	0
23	10351.25	10351.25	0	0	0	0	0	0	0	0	10351.25	10351.25	0	0	0	0	0	0	0	0
24	10260.25	10260.25	0	0	0	0	0	0	0	0	10260.25	0	0	0	0	0	0	0	0	0

Table-6.55d: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 61-80) with solar during winter

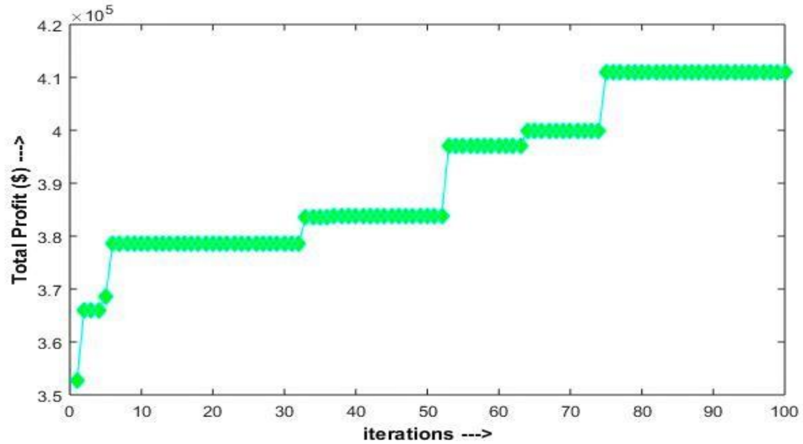
Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	10078.25	4663.8056	2879.5	0	0	0	0	0	0	0	10078.25	4663.8056	0	0	0	0	0	0	221.5	0
2	10010	5536.6667	2860	0	0	0	0	0	0	0	10010	5536.6667	0	0	0	0	0	0	0	0
3	10510.5	8072.1667	3003	0	0	0	0	0	0	0	10510.5	8072.1667	0	0	0	0	0	0	0	0
4	10305.75	8883.8333	2944.5	0	0	0	0	0	0	0	10305.75	8883.8333	0	0	0	0	0	0	0	0
5	10578.75	10578.75	3022.5	0	0	0	0	0	0	0	10578.75	10578.75	0	0	0	0	0	0	0	0
6	10442.25	10442.25	2983.5	0	0	0	573.75	229.5	0	229.5	10442.25	10442.25	0	0	3499.875	0	0	0	0	0
7	10237.5	10237.5	2925	0	0	0	562.5	0	0	0	10237.5	10237.5	0	0	1603.125	0	562.5	0	0	0
8	10078.25	10078.25	2879.5	0	0	0	553.75	0	0	0	10078.25	10078.25	0	0	1395.45	0	553.75	0	0	0
9	10374	10374	2964	0	0	0	570	0	0	0	10374	10374	0	2964	3326.1876	0	570	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	2494.75	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	1509.764
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0
13	11193	11193	0	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	0	0	1980.3615	0	0	0
14	11147.5	11147.5	0	3185	3969	0	0	0	0	574.60597	11147.5	11147.5	3185	3185	0	1960	2033.6308	0	0	0
15	10237.5	10237.5	0	0	3645	0	0	1237.5	1237.5	0	10237.5	10237.5	0	0	0	1800	1675.575	0	0	0
16	10146.5	10146.5	0	0	0	0	0	0	0	0	10146.5	10146.5	0	0	0	1150.68	0	223	0	0
17	10123.75	9972.2498	0	0	0	0	0	0	0	0	10123.75	9972.2498	0	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	0	0	0	0	0	10032.75	10032.75	0	0	0	0	0	0	0	0
19	10101	10101	0	0	0	0	0	0	0	1043.844	10101	10101	0	0	0	0	1887	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	1697.391	0	0	0	10305.75	10305.75	0	2944.5	0	1812	1697.391	0	0	0
21	10510.5	10510.5	0	3003	0	0	1963.5	0	0	0	10510.5	10510.5	0	3003	0	1848	1963.5	0	0	0
22	10442.25	10442.25	0	2983.5	0	0	1950.75	0	0	0	10442.25	10442.25	0	2983.5	0	1836	0	0	1262.25	0
23	10351.25	10351.25	0	2957.5	0	0	1399.125	0	1251.25	0	10351.25	0	0	2957.5	0	0	0	1251.25	0	0
24	10260.25	0	0	2931.5	3653.1	0	0	0	0	0	10260.25	0	0	2931.5	0	0	0	0	0	0

Table-6.55e: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 81-100) with solar during winter

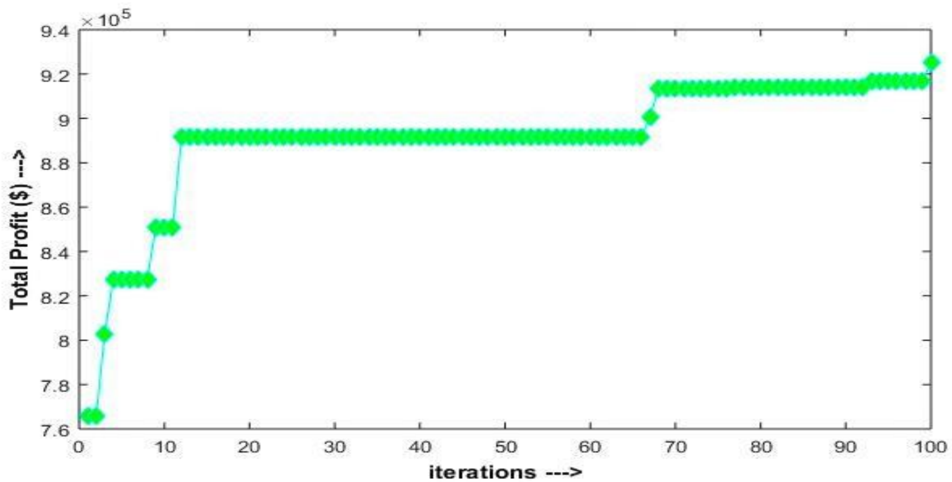
Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	10078.25	4663.8056	0	2879.5	0	443	0	221.5	0	221.5	10078.25	0	0	0	0	0	0	0	221.5	0
2	10010	5536.6667	0	2860	0	440	0	0	0	0	10010	0	0	0	0	0	550	0	0	0
3	10510.5	8072.1667	0	3003	0	462	0	0	0	0	10510.5	0	0	0	0	0	577.5	0	0	0
4	10305.75	8883.8333	0	2944.5	0	0	0	0	0	0	10305.75	0	2944.5	0	566.25	0	566.25	0	0	0
5	10578.75	10578.75	0	3022.5	0	0	0	0	0	0	10578.75	0	3022.5	0	3766.5	0	0	0	0	0
6	10442.25	10442.25	0	2983.5	0	0	0	229.5	0	0	10442.25	0	2983.5	0	3499.875	0	0	0	0	0
7	10237.5	10237.5	0	2925	0	0	562.5	225	0	0	10237.5	0	2925	0	1603.125	0	0	0	225	0
8	10078.25	10078.25	0	2879.5	1395.45	0	553.75	0	0	0	10078.25	0	2879.5	0	1395.45	0	0	0	0	0
9	10374	10374	0	2964	3326.1876	0	570	0	0	0	10374	10374	2964	0	3326.1876	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0
13	11193	11193	3198	3198	3985.2	1968	0	0	0	0	11193	11193	0	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	0	1960	0	0	0	0	11147.5	11147.5	0	3185	0	1960	0	0	1347.5	0
15	10237.5	10237.5	2925	0	0	1800	0	0	0	0	10237.5	10237.5	0	2925	0	1800	1675.575	0	0	0
16	10146.5	10146.5	2899	0	0	0	557.5	0	0	0	10146.5	10146.5	0	0	0	1150.68	557.5	223	0	0
17	10123.75	9972.2498	0	0	0	0	556.25	0	0	0	10123.75	9972.2498	0	0	0	0	556.25	0	0	0
18	10032.75	10032.75	0	0	0	0	680.022	1212.75	0	0	10032.75	10032.75	0	0	0	0	0	0	0	0
19	10101	10101	0	0	0	0	0	0	0	0	10101	10101	0	0	0	0	0	0	0	0
20	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
21	10510.5	10510.5	0	0	0	0	0	0	0	0	10510.5	10510.5	0	0	0	0	0	0	0	0
22	10442.25	10442.25	0	0	0	0	0	0	0	0	10442.25	10442.25	0	0	0	0	0	1262.25	0	0
23	10351.25	0	0	0	0	0	0	0	0	0	10351.25	0	0	0	0	0	0	1251.25	0	0
24	10260.25	0	0	0	0	0	0	0	0	0	10260.25	0	0	0	0	0	0	0	0	0



(a) 10-Unit system



(b) 40-Unit system



(c) 100-Unit system

Fig.6.19: Convergence curve for 10-, 40- and 100-generating unit system using hCSMA-SCA optimization algorithm with solar during winter

Table-6.56: Statistical analysis of results for hCHHO-SCA & hCSMA-SCA optimization algorithms with solar during winter for PBUCP

Test Systems	10 Unit System		40 Unit System		100 Unit System	
Methods	hCHHO-SCA	hCSMA-SCA	hCHHO-SCA	hCSMA-SCA	hCHHO-SCA	hCSMA-SCA
Best Profit	**106917.3426**	93109.58378	**440563.577**	414311.957	**966825.849**	924140.066
Average Profit	106917.3426	93088.40098	414629.635	378748.854	884044.958	841659.891
Worst Profit	106917.3426	92948.08528	395505.32	366849.122	829806.129	803184.113
Std.	4.44021E-11	48.01551444	11516.7771	12322.1552	36595.9704	28996.8621
Median	106917.3426	93109.58378	414595.288	375010.293	871951.01	836654.764

Table-6.57: Hypothetical testing of hCHHO-SCA & hCSMA-SCA optimization algorithms with solar during winter for PBUCP

Test Systems		10 Unit System		40 Unit System		100 Unit System	
Methods		hCHHO-SCA	hCSMA-SCA	hCHHO-SCA	hCSMA-SCA	hCHHO-SCA	hCSMA-SCA
Wilcoxon-rank sum test [p-value]		4.32046E-08	4.16235E-07	1.7344E-06	1.7344E-06	1.7344E-06	1.7344E-06
t-test	p-value	0	4.12671E-97	6.5376E-47	6.3827E-45	6.8428E-42	3.3554E-44
	h-value	1	1	1	1	1	1

Table-6.58: Comparison of computational time for hCHHO-SCA & hCSMA-SCA optimization algorithms with solar during winter for PBUCP

Test Systems	10 Unit System		40 Unit System		100 Unit System	
Methods	hCHHO-SCA	hCSMA-SCA	hCHHO-SCA	hCSMA-SCA	hCHHO-SCA	hCSMA-SCA
Best time (sec.)	0.109375	0.014374	0.203125	0.015625	0.40625	0.017851
Average time (sec.)	0.340625	0.015104167	1.30520833	0.01614583	1.71927083	0.04010417
Worst time (sec.)	0.765625	0.015625	3.953125	0.03125	3.21875	0.109375

6.6.7 Hybrid Chaotic Harris Hawks-Sine Cosine Optimization Algorithm with PEVs and solar PV during Summer

Highly penetrations of solar PV to the power grid might cause various issues, for example, market prices, mismatching of electricity demand and supply, fluctuation of voltage and even instability of power networks. PEVs are fit for supporting the network with enormous combination of solar PV by charging the excess amount of energy and by discharging i.e. returning this to the power grid when it's required. A new suggested hybrid algorithm hCHHO-SCA is established by relating chaotic maps with the HHO as well as the SCA method, include exploratory as well as exploitative phase that is stimulated by surprise attacks, the natures of explorations of prey and various strategies are based upon aggressive attacked phenomenon of the Harris hawks birds. This is one of the gradient-free with consideration of inhabitants based calculations for the new optimization strategy, which will be helpful to detail on any kinds of optimization issues. The optimizer hCHHO-SCA have certain major performances in the phases of explorations. Not only this, but also had major approach in adaptation from phases of explorations to the phases of exploitations. The number of the populations are 40 for 10-, 40- and 100-generating unit systems.

6.6.7.1 Ten Generating Unit System

This test system is used to check the efficiency of the proposed hCHHO-SCA optimizer. The system contains of 10-generating unit system having a 24-hour electricity demand. The hCHHO-SCA technique is evaluated for 100 iterations. The hCHHO- SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.20**. The commitment status, the optimal scheduling and the profit table of the 10-generating unit system have been shown in Table-6.59a and Table-6.59b respectively. The hypothesis tests are also taken into consideration. The 'Best', 'Average' and 'Worst' values for profit with standard deviation and median value of solutions have been stated for 30 trial result for PBUCP of power systems that are shown in Table-6.73. The p-value for wilcoxon-rank sum test and t-test and h-value for t-test is used to verify the efficiency of hCHHO-SCA optimizer that are shown in Table-6.74. The best, average and worst time are also taken into consideration, are shown in Table-6.75.

Table-6.59a: Commitment status and scheduling for 10-generating unit system using hCHHO-SCA optimization algorithm with PEVs and solar during summer

Commitment status of thermal units								Scheduling of the committed generating units						
HOURS	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**
1	1	1	0	0	0	0	0	455	277.4	0	0	0	0	0
2	1	1	0	0	0	0	0	455	316.5	0	0	0	0	0
3	1	1	0	0	0	0	0	455	416.24	0	0	0	0	0
4	1	1	0	1	0	0	0	455	367.35	0	130	0	0	0
5	1	1	0	1	0	0	0	455	437.99	0	130	0	0	0
6	1	1	0	1	1	0	0	455	455	0	130	39.24	0	0
7	1	1	0	1	1	0	0	455	443.54	0	130	25	0	0
8	1	1	0	1	1	0	0	455	429.12	0	130	25	0	0
9	1	1	0	1	1	0	0	455	455	0	130	67.5700001	0	0
10	1	1	1	1	1	0	0	455	455	130	130	157.18	0	0
11	1	1	1	1	1	1	0	455	455	130	130	161.6	10	0
12	1	1	1	1	1	0	0	455	455	130	130	147.21	0	0
13	1	1	1	1	1	0	0	455	455	130	130	63.41	0	0
14	1	1	1	1	1	0	0	455	455	130	130	73.0600002	0	0
15	1	1	1	1	1	0	0	455	444.43	130	130	25	0	0
16	1	1	0	1	0	0	0	455	412.95	0	130	0	0	0
17	1	1	0	1	0	0	0	455	411.96	0	130	0	0	0
18	1	1	0	1	0	1	0	455	451.96	0	130	0	10	0
19	1	1	0	1	0	1	0	455	455	0	130	0	21.62	0
20	1	1	0	1	0	0	0	455	401.53	0	130	0	0	0
21	1	1	0	1	0	0	0	455	438.26	0	130	0	0	0
22	1	1	0	1	0	0	0	455	407.56	0	130	0	0	0
23	1	1	0	0	0	0	0	455	409.08	0	0	0	0	0
24	1	1	0	0	0	0	0	455	300.59	0	0	0	0	0

Table-6.59b: Hourly profit for 10-generating unit system using hCHHO-SCA optimization algorithm with PEVs and solar during summer

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7 to PG10	Start-up Cost	Hourly Profit
1	10078.25	6144.41	0	0	0	0	0	1370	16222.66
2	10010	6963	0	0	0	0	0	0	16973
3	10510.5	9615.144	0	0	0	0	0	900	20125.644
4	10305.75	8320.4775	0	2944.5	0	0	0	0	21570.7275
5	10578.75	10183.2675	0	3022.5	0	0	0	460	23784.5175
6	10442.25	10442.25	0	2983.5	900.558	0	0	0	24768.558
7	10237.5	9979.65	0	2925	562.5	0	0	0	23704.65
8	10078.25	9505.008	0	2879.5	553.75	0	0	0	23016.508
9	10374	10374	0	2964	1540.596	0	0	260	25252.596
10	13354.25	13354.25	3815.5	3815.5	4613.233	0	0	120	38952.733
11	13718.25	13718.25	3919.5	3919.5	4872.24	301.5	0	60	40449.24
12	14400.75	14400.75	4114.5	4114.5	4659.1965	0	0	0	41689.6965
13	11193	11193	3198	3198	1559.886	0	0	0	30341.886
14	11147.5	11147.5	3185	3185	1789.97	0	0	0	30454.97
15	10237.5	9999.675	2925	2925	562.5	0	0	260	26649.675
16	10146.5	9208.785	0	2899	0	0	0	0	22254.285
17	10123.75	9166.11	0	2892.5	0	0	0	0	22182.36
18	10032.75	9965.718	0	2866.5	0	220.5	0	460	23085.468
19	10101	10101	0	2886	0	479.964	0	0	23567.964
20	10305.75	9094.6545	0	2944.5	0	0	0	0	22344.9045
21	10510.5	10123.806	0	3003	0	0	0	550	23637.306
22	10442.25	9353.502	0	2983.5	0	0	0	0	22779.252
23	10351.25	9306.57	0	0	0	0	0	0	19657.82
24	10260.25	6778.3045	0	0	0	0	0	0	17038.5545

6.6.7.2 Forty Generating Unit System

This test system is used to check the efficiency of the proposed hCHHO-SCAoptimizer. The system contains of 40-generating unit system having a 24-hourelectricity demand. The hCHHO-SCA technique is evaluated for 100 iterations and 30 trail runs. The convergence graph of total profit is shown in **Fig.6.20**. Table-6.60 shows the hourly profit with startup cost and fuel cost for 40-generating unit system using hCHHO-SCA optimization algorithm with PEVs and RES during summer. The optimal scheduling of 40-generating unit systems are shown in Table-6.61a and Table-6.61b. The hourly profit table for this system is shown in Table-6.62a and Table-6.62b respectively.

Table-6.60: Hourly profit with startup cost and fuel cost for 40-generating unit system using hCHHO-SCA optimization algorithm with PEVs and solar during summer

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	62737.66	560	54353.2239	**13**	128643.486	270	105590.851
2	66473	2260	57660.3502	**14**	126004.97	290	103364.479
3	79030.644	3320	65830.2973	**15**	107649.675	960	95531.1447
4	83405.2275	1720	71602.2227	**16**	91830.285	320	80149.4677
5	93534.5175	1450	79381.0865	**17**	88932.36	260	77415.6696
6	96372.558	180	83083.7413	**18**	91881.468	550	81476.2882
7	93904.65	2780	82633.1144	**19**	92831.964	260	81741.5653
8	92124.508	60	82380.3322	**20**	93012.9045	2190	80172.7165
9	105280.596	5290	91328.1838	**21**	95709.306	2020	81364.2927
10	162222.733	780	113367.241	**22**	94383.252	1540	80659.5091
11	168164.64	580	114809.752	**23**	81082.82	1670	71073.1955
12	175759.096	0	114242.241	**24**	71158.5545	640	62026.7979

Table-6.61a: Generation scheduling for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with PEVs and solar during summer

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU-12	PGU-13	PGU-14	PGU-15	PGU-16	PGU-17	PGU-18	PGU-19	PGU-20
1	455	337.4666667	0	0	0	0	0	0	0	0	455	337.4666667	0	0	0	0	0	0	0	0
2	455	400.5	0	0	0	0	0	0	0	0	455	400.5	0	0	0	0	0	0	0	0
3	455	447.08	0	130	0	0	0	0	0	0	455	447.08	0	130	0	0	0	0	0	0
4	455	447.45	130	130	0	0	0	0	0	0	455	447.45	0	130	0	0	0	0	0	0
5	455	430.9966667	130	130	0	0	0	0	0	0	455	430.9966667	130	130	0	0	0	0	0	0
6	455	446.4133333	130	130	0	0	0	0	0	0	455	446.4133333	130	130	0	0	0	0	0	0
7	455	437.8466667	130	130	0	0	0	0	0	0	455	437.8466667	130	130	0	0	0	0	0	0
8	455	433.04	130	130	0	0	0	0	0	0	455	433.04	130	130	0	0	0	0	0	0
9	455	439.3925	130	130	0	0	0	0	0	0	455	439.3925	130	130	0	0	0	0	0	0
10	455	455	130	130	162	0	39.1800001	0	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	74.8666667	25	0	0	0	455	455	130	130	162	74.8666667	0	0	0	0
12	455	455	130	130	162	66.7366667	25	0	0	0	455	455	130	130	162	66.7366667	0	0	0	0
13	455	455	130	130	162	31.41	0	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	148.265	0	0	0	0	0	455	455	130	130	148.265	0	0	0	0	0
15	455	455	130	130	123.6075	0	0	0	0	0	455	455	0	130	123.6075	0	0	0	0	0
16	455	444.4875	130	130	0	0	0	0	0	0	455	444.4875	0	130	0	0	0	0	0	0
17	455	446.74	0	130	0	0	0	0	0	0	455	446.74	0	130	0	0	0	0	0	0
18	455	451.74	0	130	0	20	0	0	0	0	455	451.74	0	130	0	0	0	0	0	0
19	455	455	0	130	0	21.62	0	0	0	0	455	455	0	130	0	0	0	0	0	0
20	455	455	0	130	0	76.53	0	0	0	0	455	455	130	0	0	0	0	0	0	0
21	455	455	0	0	0	0	0	0	0	0	455	455	130	0	0	56.63	0	0	0	0
22	455	455	0	0	0	0	0	0	0	0	455	455	130	0	0	41.28	0	0	0	0
23	455	455	130	0	144.08	0	0	0	0	0	455	455	130	0	0	20	0	0	0	0
24	455	395.295	130	0	25	0	0	0	0	0	455	395.295	130	0	0	0	0	0	0	0

Table-6.61b: Generation scheduling for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40) with PEVS and solar during summer

HOURS	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	337.4666667	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	400.5	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	447.08	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
4	455	447.45	0	130	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
5	455	430.9966667	0	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
6	455	446.4133333	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
7	455	437.8466667	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
8	455	433.04	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
9	455	439.3925	130	130	0	0	0	0	0	0	455	439.3925	130	130	0	0	0	0	0	0
10	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	0	0	0	0	0
11	455	455	130	130	162	74.8666667	0	0	0	0	455	455	130	130	162	0	0	0	0	0
12	455	455	130	130	162	66.7366667	0	0	0	0	455	455	130	130	162	0	0	0	0	0
13	455	455	0	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	0	130	148.265	0	0	0	0	0	455	455	130	130	148.265	0	0	0	0	0
15	455	455	0	130	123.6075	0	0	0	0	0	455	455	0	130	123.6075	0	0	0	0	0
16	455	444.4875	0	0	0	0	0	0	0	0	455	444.4875	0	130	0	0	0	0	0	0
17	455	446.74	0	0	0	0	0	0	0	0	455	446.74	0	130	0	0	0	0	0	0
18	455	451.74	130	0	0	0	0	0	0	0	455	451.74	0	130	0	0	0	0	0	0
19	455	455	130	0	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
20	455	455	130	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
21	455	455	130	130	0	56.63	0	0	0	0	455	455	0	0	0	0	0	0	0	0
22	455	455	130	130	0	41.28	0	0	0	0	455	455	0	0	0	0	0	0	0	0
23	455	0	130	130	0	20	0	0	0	0	455	0	130	0	0	0	0	0	0	0
24	455	0	0	130	0	0	0	0	0	0	455	0	130	0	0	0	0	0	0	0

Table-6.62a: Hourly profit for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with PEVs and solar during summer

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	GPU16	PGU17	PGU 18	PGU19	PGU 20
1	10078.25	7474.88667	0	0	0	0	0	0	0	0	10078.25	7474.88667	0	0	0	0	0	0	0	0
2	10010	8811	0	0	0	0	0	0	0	0	10010	8811	0	0	0	0	0	0	0	0
3	10510.5	10327.548	0	3003	0	0	0	0	0	0	10510.5	10327.548	0	3003	0	0	0	0	0	0
4	10305.75	10134.7425	2944.5	2944.5	0	0	0	0	0	0	10305.75	10134.7425	0	2944.5	0	0	0	0	0	0
5	10578.75	10020.6725	3022.5	3022.5	0	0	0	0	0	0	10578.75	10020.6725	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	10245.186	2983.5	2983.5	0	0	0	0	0	0	10442.25	10245.186	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	9851.55	2925	2925	0	0	0	0	0	0	10237.5	9851.55	2925	2925	0	0	0	0	0	0
8	10078.25	9591.836	2879.5	2879.5	0	0	0	0	0	0	10078.25	9591.836	2879.5	2879.5	0	0	0	0	0	0
9	10374	10018.149	2964	2964	0	0	0	0	0	0	10374	10018.149	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	1149.933	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2257.23	753.75	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2257.23	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2112.2155	791.25	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2112.2155	0	0	0	0
13	11193	11193	3198	3198	3985.2	772.686	0	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3632.4925	0	0	0	0	0	11147.5	11147.5	3185	3185	3632.4925	0	0	0	0	0
15	10237.5	10237.5	2925	2925	2781.16875	0	0	0	0	0	10237.5	10237.5	0	2925	2781.16875	0	0	0	0	0
16	10146.5	9912.07125	2899	2899	0	0	0	0	0	0	10146.5	9912.07125	0	2899	0	0	0	0	0	0
17	10123.75	9939.965	0	2892.5	0	0	0	0	0	0	10123.75	9939.965	0	2892.5	0	0	0	0	0	0
18	10032.75	9960.867	0	2866.5	0	441	0	0	0	0	10032.75	9960.867	0	2866.5	0	0	0	0	0	0
19	10101	10101	0	2886	0	479.964	0	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	1733.4045	0	0	0	0	10305.75	10305.75	2944.5	0	0	0	0	0	0	0
21	10510.5	10510.5	0	0	0	0	0	0	0	0	10510.5	10510.5	3003	0	0	1308.153	0	0	0	0
22	10442.25	10442.25	0	0	0	0	0	0	0	0	10442.25	10442.25	2983.5	0	0	947.376	0	0	0	0
23	10351.25	10351.25	2957.5	0	3277.82	0	0	0	0	0	10351.25	10351.25	2957.5	0	0	455	0	0	0	0
24	10260.25	8913.90225	2931.5	0	563.75	0	0	0	0	0	10260.25	8913.90225	2931.5	0	0	0	0	0	0	0

Table-6.61a represents the optimal scheduling of power PGU1 to PGU20 for 40-unit test system with effect of PEVs and solar PV in summer. The PGU8 to PGU10, PGU17 and PGU20 is off for 24 hours, while PGU1, PGU2, PGU11 and PGU12 is always on for 24 hours. PGU gives 39.1800001 MW for 10th hour, 25 MW for 11th and 12th hour as it is on in that particular hour. The rest of the PGU are sometimes remain on and sometimes remain off to give the optimal output.

In the Table-6.61b shows the scheduling for PGU21 to PGU40 unit for 40-unit system with PEVs and solar PV in summer. The PGU21 and PGU31 is remaining always on for 24 hours. The PGU27 to PGU30 and PGU36 and PGU40 are off for whole day. The PGU35 is on only for 10th hours to 15th hour and 162 MW power is generated from 10th to 13th hour and 148.265 MW power generated from 14th hour and 123.6075 MW power generated from15th hours.

The hourly profit for 40-test system is shown in Table-6.62a and Table-6.62b. The Table-6.62a shows the hourly profit for PGU20 unit for 24 hours. The maximum amount of profit can be measured from the PGU1, PGU2, PGU11 and PGU12 as it was on for the whole day. The PGU8, PGU9, PGU10, PGU17 to PGU20 remain off for 24 hours. The other units are gives several amount of profit for that particular hour when it was on.

Table-6.62b shows that the hourly profit of PGU21 to PGU40 for this test system for 24 hours. PGU21 and PGU31 are remain on for 24 hours, that why the profit from these units are maximum. For PGU27 to PGU30 and PGU36 to PGU40 no profit can be measured as those are in off mode.

Table-6.62b: Hourly profit for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40) with PEVs and solar during summer

HOURS	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PG34	PGU35	GPU36	PGU37	PGU 38	PGU39	PGU 40
1	10078.25	7474.88667	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	8811	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	10327.548	0	0	0	0	0	0	0	0	10510.5	0	0	0	0	0	0	0	0	0
4	10305.75	10134.7425	0	2944.5	0	0	0	0	0	0	10305.75	0	0	0	0	0	0	0	0	0
5	10578.75	10020.6725	0	3022.5	0	0	0	0	0	0	10578.75	0	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	10245.186	2983.5	2983.5	0	0	0	0	0	0	10442.25	0	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	9851.55	2925	2925	0	0	0	0	0	0	10237.5	0	2925	2925	0	0	0	0	0	0
8	10078.25	9591.836	2879.5	2879.5	0	0	0	0	0	0	10078.25	0	2879.5	2879.5	0	0	0	0	0	0
9	10374	10018.149	2964	2964	0	0	0	0	0	0	10374	10018.149	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2257.23	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2112.2155	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0
13	11193	11193	0	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	0	3185	3632.4925	0	0	0	0	0	11147.5	11147.5	3185	3185	3632.4925	0	0	0	0	0
15	10237.5	10237.5	0	2925	2781.16875	0	0	0	0	0	10237.5	10237.5	0	2925	2781.16875	0	0	0	0	0
16	10146.5	9912.07125	0	0	0	0	0	0	0	0	10146.5	9912.07125	0	2899	0	0	0	0	0	0
17	10123.75	9939.965	0	0	0	0	0	0	0	0	10123.75	9939.965	0	2892.5	0	0	0	0	0	0
18	10032.75	9960.867	2866.5	0	0	0	0	0	0	0	10032.75	9960.867	0	2866.5	0	0	0	0	0	0
19	10101	10101	2886	0	0	0	0	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	2944.5	0	0	0	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
21	10510.5	10510.5	3003	3003	0	1308.153	0	0	0	0	10510.5	10510.5	0	0	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	2983.5	0	947.376	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	0	2957.5	2957.5	0	455	0	0	0	0	10351.25	0	2957.5	0	0	0	0	0	0	0
24	10260.25	0	0	2931.5	0	0	0	0	0	0	10260.25	0	2931.5	0	0	0	0	0	0	0

6.6.7.3 Hundred Generating Unit System

The test system is used to check the efficiency of the proposed hCHHO-SCA optimizer. The system contains of 100-generating unit system having a 24-hour electricity demand. The hCHHO-SCA technique is evaluated for 100 iterations. The hCHHO-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.20**. Table-6.63 represents the hourly profit with start-up cost and fuel cost for100-generating unit system using hCHHO-SCA optimization algorithm with PEVs and RES during summer. The optimal scheduling of 100-generating unit systems are shown in Table-6.64a to Table-6.64e. The hourly profit table for this system is shown in Table-6.65a to Table-6.65e respectively.

Table-6.63: Hourly profit with start-up cost and fuel cost for100-generating unit system using hCHHO-SCA optimization algorithm with PEVs and solar during summer

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	155767.66	2150	138731.72	**13**	325246.69	60	267272.61
2	165473	3910	147760.72	**14**	317104.97	460	261656.62
3	196840.64	6900	165220.24	**15**	269649.68	0	240743.78
4	207074.23	6100	176443.2	16	230982.29	0	205153.43
5	233034.52	6290	195503.59	**17**	222432.36	2900	196116.85
6	239580.56	120	205723.55	**18**	229473.47	2920	208037.07
7	234304.65	780	204158.47	**19**	231359.96	3650	206294.41
8	230340.51	2550	207810.32	**20**	234348.9	2430	207256.21
9	265336.6	15340	233452.01	**21**	239853.31	1120	203600.23
10	408762.73	780	287365.98	**22**	237591.25	4190	205236.13
11	423595.44	1840	290730.7	**23**	203932.82	2740	177950.97
12	443897.9	1830	290288.62	**24**	179398.55	2870	156957.62

Table-6.64a: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with PEVs and solar during summer

HOUR	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	455	232.74	0	0	0	0	0	0	0	0	455	232.74	0	0	0	0	0	0	0	0
2	455	279.15	0	0	0	0	0	0	0	0	455	279.15	0	0	0	0	0	0	0	0
3	455	379.124	0	0	0	0	0	0	0	0	455	379.124	0	0	0	0	0	0	0	0
4	455	428.735	0	0	0	0	0	0	0	0	455	428.735	0	0	0	0	0	0	0	0
5	455	455	0	130	0	0	0	0	0	0	455	455	0	0	0	69.663333	0	0	0	0
6	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	56.31	0	0	0	0
7	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	20	0	0	0	0
8	455	455	0	130	0	20.000001	0	0	0	0	455	455	0	130	0	20.000001	0	0	0	10
9	455	455	0	130	0	35.856667	0	0	0	0	455	455	0	130	0	35.856667	0	0	0	0
10	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
15	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
16	455	455	0	130	0	0	50.983333	0	0	0	455	455	0	130	0	0	50.983333	0	0	0
17	455	433.196	0	130	0	0	25	0	0	0	455	433.196	0	130	0	0	25	0	0	0
18	455	455	0	130	0	0	56.993333	0	0	0	455	455	0	130	0	0	56.993333	0	0	0
19	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
20	455	455	0	130	0	0	0	10	0	0	455	455	0	130	0	0	0	0	0	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	455	130	130	162	0	72.186667	0	0	0	455	455	0	130	162	0	0	0	0	0
23	455	455	130	0	162	0	64.36	0	0	0	455	455	0	0	162	0	0	0	0	0
24	455	455	130	0	162	0	47.295	0	0	0	455	455	0	0	162	0	0	0	0	0

Table-6.64b: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40) with PEVs and solar during summer

HOUR	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	232.74	0	0	0	0	0	0	0	0	455	232.74	0	0	0	0	0	0	0	0
2	455	279.15	0	0	0	0	0	0	0	0	455	279.15	0	0	0	0	0	0	0	0
3	455	379.124	0	0	0	0	0	0	0	0	455	379.124	0	0	0	0	0	0	0	0
4	455	428.735	0	0	0	0	0	0	0	0	455	428.735	0	0	0	0	0	0	0	0
5	455	455	0	0	162	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
6	455	455	0	130	162	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
7	455	455	0	130	157.84667	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
8	455	455	0	130	98.53	0	0	10	0	0	455	455	0	0	0	0	0	0	0	0
9	455	455	0	130	162	0	0	10	0	0	455	455	0	130	0	0	0	0	0	0
10	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	55	0	0
12	455	455	130	130	162	80	0	0	55	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	0	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	0	130	162	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	10	455	455	0	130	0	0	0	0	0	0
17	455	433.196	0	130	0	0	0	0	0	0	455	433.196	0	130	0	0	0	0	0	0
18	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	56.993333	0	0	0
19	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	38.206667	0	0	0
20	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	25	0	0	0
21	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	455	0	0	0	80	0	0	0	0	455	455	0	0	0	0	0	0	0	0
23	455	455	0	0	0	80	0	0	0	0	455	455	0	0	0	80	0	0	0	0
24	455	455	0	0	0	80	0	0	0	0	455	455	0	0	0	80	0	0	0	0

The Table-6.64a represents the generation scheduling of 100-generating unit system with effect of PEVs and solar PV in summer using hCHHO-SCA optimization algorithm for PGU1 to PGU20. Where PGU1, PGU2, PGU11 and PGU12 are remain on for 24 hours. The 455 MW power output can be measured from PGU1 and PGU11 for 24 hours. PGU8 to PGU10 and PGU18 to PGU20 is totally off for 24 hours. So, no power generation can be obtained from those units. Further others unit are on for some few hours and off some few hours. Thus the optimal generation can be taken only those are in on condition.

Table-6.64b gives the optimal power scheduling of 100-uniut system with effect of PEVs and solar PV in summer by suggested hCHHO-SCA method for PGU21 to PGU40. The PGU21, PGU22, PGU31 and PGU32 are in on condition for 24 hours. And other PGU are sometimes on and sometimes off. PGU39 to PGU40 a are off during 24 hours.

Table-6.64c presents the generation scheduling of 100-unit system with effect of PEVs and solar PV in summer using proposed hCHHO-SCA optimization algorithm for PGU41 to PGU60. Here, PGU41, PGU42 and PGU51 are on for 24 hours. The 455 MW power can be generated from PGU41 and PGU51. The output power is '0' for PGU49 to PGU50 and PGU60. The PGU47 and PGU57 generate same power for 18th to 19th hours, i.e. 56.993333 MW for 18th, 38.206667 MW for 91th and PGU57 generates 64.11729 MW for 10th hour. The other PGU are on and off for few hours and output power generation can be measured through the table.

Thable-6.64d signifies the generation scheduling of 100-generating unit by hCHHO-SCA algorithm for PGU61 to PGU80 considering the effect of PEVs and RES in summer. The PGU61 and PGU71 is on for 24 hours. The 455 MW power output can be shown from PGU61 and PGU71 for 24 hours. The power output from PGU69 and PGU80 is '0' for 24 hours.

Table-6.64c: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 41-60) with PEVs and solar during summer

Hour	PGU41	PGU42	PGU43	PGU44	PGU45	PGU46	PGU47	PGU48	PGU49	PGU50	PGU51	PGU52	PGU53	PGU54	PGU55	PGU56	PGU57	PGU58	PGU59	PGU60
1	455	232.74	0	0	0	0	0	0	0	0	455	232.74	0	0	0	0	0	0	0	0
2	455	279.15	0	0	0	0	0	0	0	0	455	279.15	0	0	0	0	0	0	0	0
3	455	379.124	0	0	0	0	0	0	0	0	455	379.124	0	0	0	0	0	0	0	0
4	455	428.735	0	0	0	0	0	0	0	0	455	428.735	0	0	0	0	0	0	0	0
5	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	69.663333	0	0	0	0
6	455	455	0	0	0	56.31	0	0	0	0	455	455	0	0	0	56.31	0	0	0	0
7	455	455	0	0	0	20	0	0	0	0	455	455	0	0	0	20	0	0	0	0
8	455	455	0	0	0	20.000001	0	0	0	0	455	455	0	0	0	0	25	0	0	0
9	455	455	0	130	0	35.856667	0	0	0	0	455	455	130	130	162	0	25	0	0	0
10	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	0	64.11729	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	0	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	0	0	0	0	0
13	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	75.136667	0	0	0	0
14	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	0	0	0
15	455	455	0	130	162	0	0	0	0	0	455	455	130	130	0	80	0	0	47.215	0
16	455	455	0	130	0	0	0	55	0	0	455	455	0	130	0	0	0	0	0	0
17	455	433.196	0	130	0	0	0	0	0	0	455	433.196	0	130	0	0	0	0	0	0
18	455	455	0	130	0	0	56.993333	0	0	0	455	455	0	130	0	0	56.993333	55	0	0
19	455	455	0	130	0	0	38.206667	0	0	0	455	455	0	130	0	0	38.206667	0	0	0
20	455	455	0	130	0	0	25	0	0	0	455	455	0	130	0	0	25	10	0	10
21	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
22	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
23	455	455	0	0	0	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
24	455	455	0	0	0	0	0	0	0	0	455	0	130	0	0	0	0	0	0	0

Table-6.64d: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 61-80) with PEVs and solar during summer

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	455	232.74	0	0	0	0	25	0	0	0	455	232.74	0	0	0	0	0	0	0	0
2	455	279.15	0	0	0	0	25	0	0	0	455	279.15	0	0	0	0	0	0	0	0
3	455	379.124	0	0	0	0	25	0	0	0	455	379.124	0	0	0	0	0	0	0	0
4	455	428.735	0	0	0	0	0	0	0	0	455	428.735	0	0	0	20	0	0	0	0
5	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	69.663333	0	0	0	0
6	455	455	0	130	0	0	0	10	0	0	455	455	0	0	0	56.31	0	0	0	0
7	455	455	0	130	157.84667	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
8	455	455	0	130	98.53	0	0	0	0	0	455	455	0	0	0	0	0	10	0	10
9	455	455	0	130	162	0	0	0	0	0	455	455	0	130	0	0	25	0	0	0
10	455	455	130	130	162	0	64.11729	0	0	14.828129	455	455	130	130	162	0	64.11729	0	0	0
11	455	455	130	130	162	0	69.8	0	0	0	455	455	130	130	162	0	69.8	55	0	0
12	455	455	130	130	162	80	60.210001	55	0	0	455	455	130	130	162	0	0	0	0	0
13	455	455	130	130	0	75.136667	0	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	0	80	0	0	0	31.060004	455	455	130	130	162	0	0	0	0	0
15	455	455	0	130	0	0	0	0	0	0	455	455	0	130	162	0	0	0	47.215	0
16	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	50.983333	0	0	0
17	455	433.196	0	130	0	0	0	0	0	0	455	433.196	0	130	0	0	25	0	0	0
18	455	455	0	130	0	0	0	0	0	0	455	455	0	0	0	0	56.993333	0	0	0
19	455	455	0	130	0	0	0	0	0	0	455	455	0	0	0	0	0	0	55	0
20	455	455	0	130	0	20	0	0	0	0	455	455	0	0	0	0	0	0	0	10
21	455	455	0	130	0	80	0	0	0	0	455	455	0	0	0	0	0	0	0	0
22	455	455	0	0	0	80	0	0	0	0	455	455	0	0	0	0	72.186667	0	0	0
23	455	455	0	0	0	0	0	0	0	0	455	0	0	0	0	0	64.36	0	0	0
24	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	47.295	0	0	0

Table-6.64e: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 81-100) with PEVs and solar during summer

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	455	232.74	0	0	0	0	0	0	0	0	455	232.74	0	130	0	0	0	0	0	0
2	455	279.15	0	0	25	0	0	0	0	0	455	279.15	0	130	0	0	0	0	0	0
3	455	379.124	0	0	25	0	0	0	0	0	455	379.124	0	130	0	0	0	0	0	0
4	455	428.735	130	0	25	0	0	0	0	0	455	428.735	0	130	0	0	0	0	0	0
5	455	455	130	0	162	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
6	455	455	130	0	162	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
7	455	455	130	0	157.84667	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
8	455	455	130	0	98.53	0	0	0	0	0	455	455	0	130	98.53	0	0	0	0	0
9	455	455	130	130	162	0	0	0	0	0	455	455	0	130	162	0	0	0	0	0
10	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	0	0	0	0	0
12	455	455	130	130	162	80	0	0	55	0	455	455	130	130	162	0	0	0	0	0
13	455	455	130	130	0	75.136667	0	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	0	80	0	0	0	0	455	455	130	130	0	0	0	0	0	0
15	455	455	0	130	0	80	0	0	0	0	455	455	0	130	0	0	0	0	0	0
16	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
17	455	433.196	0	0	0	0	0	0	0	0	455	433.196	0	0	0	0	0	0	0	0
18	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
19	455	455	0	0	162	80	0	0	0	0	455	455	0	0	0	0	0	0	0	0
20	455	455	0	0	156.53	20	25	0	0	0	455	455	0	0	0	0	0	0	0	0
21	455	455	0	0	162	80	51.26	0	0	0	455	455	0	0	0	0	0	0	0	0
22	455	455	0	0	162	0	72.186667	0	0	0	455	455	0	0	0	0	0	0	0	0
23	455	0	0	130	162	0	64.36	0	0	0	455	0	0	0	0	0	0	0	0	0
24	455	0	0	130	162	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0

Table-6.64e gives the optimal power scheduling of 100-unit system by suggested hCHHO-SCA method for PGU81 to PGU100 considering the effect of PEVs and solar PV in summer. PGU88, PGU90 and PGU96 to PGU100 is totally off throughout the day. So, no power generation can be obtained from those units. Further others unit are on for some few hours and off some few hours. Thus the optimal generation can be taken only those are in on condition.

Table-6.65a shows the best profit of PGU1 to PGU20 for each unit for particular hours considering the effect of PEVs and solar PV in summer. The duration of total hour is 24 hours. The suggested hCHHO-SCA optimizer is tested on 100-unit system.

Table-6.65b represents the hourly profit for 100-generating unit system by hCHHO-SCA optimizer for PGU21 to PGU40 with PEVs and solar PV in summer. The PGU21, PGU22, PGU31 and PGU32 are on throughout 24 hours. So, for those units the profit values are obtained in each hour. The PGU38 is on only for 11^{th} hours and the profit can be obtained as 1658.25 $ for 11^{th} hour, and for other time period it will be off throughout the day.

The Table-6.65c is presented the hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm for units 41 to unit 60 with PEVs and solar PV in summer. The PGU41, PGU42 and PGU51 remain on for 24 hours. The PGU49 to PGU50 remain close throughout the whole day. That’s why no profit come from those units, the output is ‘0’.

The Table-6.65d and Table-6.65e is presented the hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm for PGU61 to PGU80 and PGU81 to PGU100 with PEVs and solar PV in summer. The PGU61, PGU71, PGU81 and PGU91 remain on for 24 hours. The PGU69, PGU88, PGU90, PGU96 to PGU100 as remain close throughout the whole day. That’s why no profit come from those units, the output is ‘0’.

Table-6.65a: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 1-20) with PEVs and solar during summer

Hour	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	10078.25	5155.191	0	0	0	0	0	0	0	0	10078.25	5155.191	0	0	0	0	0	0	0	0
2	10010	6141.3	0	0	0	0	0	0	0	0	10010	6141.3	0	0	0	0	0	0	0	0
3	10510.5	8757.7644	0	0	0	0	0	0	0	0	10510.5	8757.7644	0	0	0	0	0	0	0	0
4	10305.75	9710.8478	0	0	0	0	0	0	0	0	10305.75	9710.8478	0	0	0	0	0	0	0	0
5	10578.75	10578.75	0	3022.5	0	0	0	0	0	0	10578.75	10578.75	0	0	0	1619.6725	0	0	0	0
6	10442.25	10442.25	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	0	1292.3145	0	0	0	0
7	10237.5	10237.5	0	2925	0	0	0	0	0	0	10237.5	10237.5	0	2925	0	450	0	0	0	0
8	10078.25	10078.25	0	2879.5	0	443.00001	0	0	0	0	10078.25	10078.25	0	2879.5	0	443.00001	0	0	0	221.5
9	10374	10374	0	2964	0	817.532	0	0	0	0	10374	10374	0	2964	0	817.532	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	0	0	0	11147.5	11147.5	3185	3185	3969	0	0	0	0	0
15	10237.5	10237.5	2925	2925	3645	0	0	0	0	0	10237.5	10237.5	2925	2925	3645	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	1136.9283	0	0	0	10146.5	10146.5	0	2899	0	0	1136.9283	0	0	0
17	10123.75	9638.611	0	2892.5	0	0	556.25	0	0	0	10123.75	9638.611	0	2892.5	0	0	556.25	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	1256.703	0	0	0	10032.75	10032.75	0	2866.5	0	0	1256.703	0	0	0
19	10101	10101	0	2886	0	0	0	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	0	226.5	0	0	10305.75	10305.75	0	2944.5	0	0	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	2983.5	3717.9	0	1656.684	0	0	0	10442.25	10442.25	0	2983.5	3717.9	0	0	0	0	0
23	10351.25	10351.25	2957.5	0	3685.5	0	1464.19	0	0	0	10351.25	10351.25	0	0	3685.5	0	0	0	0	0
24	10260.25	10260.25	2931.5	0	3653.1	0	1066.5023	0	0	0	10260.25	10260.25	0	0	3653.1	0	0	0	0	0

Table-6.65b: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 21-40) with PEVs and solar during summer

Hour	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU 29	PGU 30	PGU31	PGU32	PGU33	PGU 34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	10078.25	5155.191	0	0	0	0	0	0	0	0	10078.25	5155.191	0	0	0	0	0	0	0	0
2	10010	6141.3	0	0	0	0	0	0	0	0	10010	6141.3	0	0	0	0	0	0	0	0
3	10510.5	8757.7644	0	0	0	0	0	0	0	0	10510.5	8757.7644	0	0	0	0	0	0	0	0
4	10305.75	9710.8478	0	0	0	0	0	0	0	0	10305.75	9710.8478	0	0	0	0	0	0	0	0
5	10578.75	10578.75	0	0	3766.5	0	0	0	0	0	10578.75	10578.75	0	0	0	0	0	0	0	0
6	10442.25	10442.25	0	2983.5	3717.9	0	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
7	10237.5	10237.5	0	2925	3551.55	0	0	0	0	0	10237.5	10237.5	0	0	0	0	0	0	0	0
8	10078.25	10078.25	0	2879.5	2182.4395	0	0	221.5	0	0	10078.25	10078.25	0	0	0	0	0	0	0	0
9	10374	10374	0	2964	3693.6	0	0	228	0	0	10374	10374	0	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	1658.25	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	1740.75	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	0	0	0	0	0	0	11147.5	11147.5	3185	3185	3969	0	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	0	2925	3645	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	223	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	9638.611	0	2892.5	0	0	0	0	0	0	10123.75	9638.611	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	1256.703	0	0	0
19	10101	10101	0	2886	0	0	0	0	0	0	10101	10101	0	2886	0	0	848.188	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	566.25	0	0	0
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	0	0	0	1836	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	10351.25	0	0	0	1820	0	0	0	0	10351.25	10351.25	0	0	0	1820	0	0	0	0
24	10260.25	10260.25	0	0	0	1804	0	0	0	0	10260.25	10260.25	0	0	0	1804	0	0	0	0

Table-6.65c: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 41-60) with PEVs and solar during summer

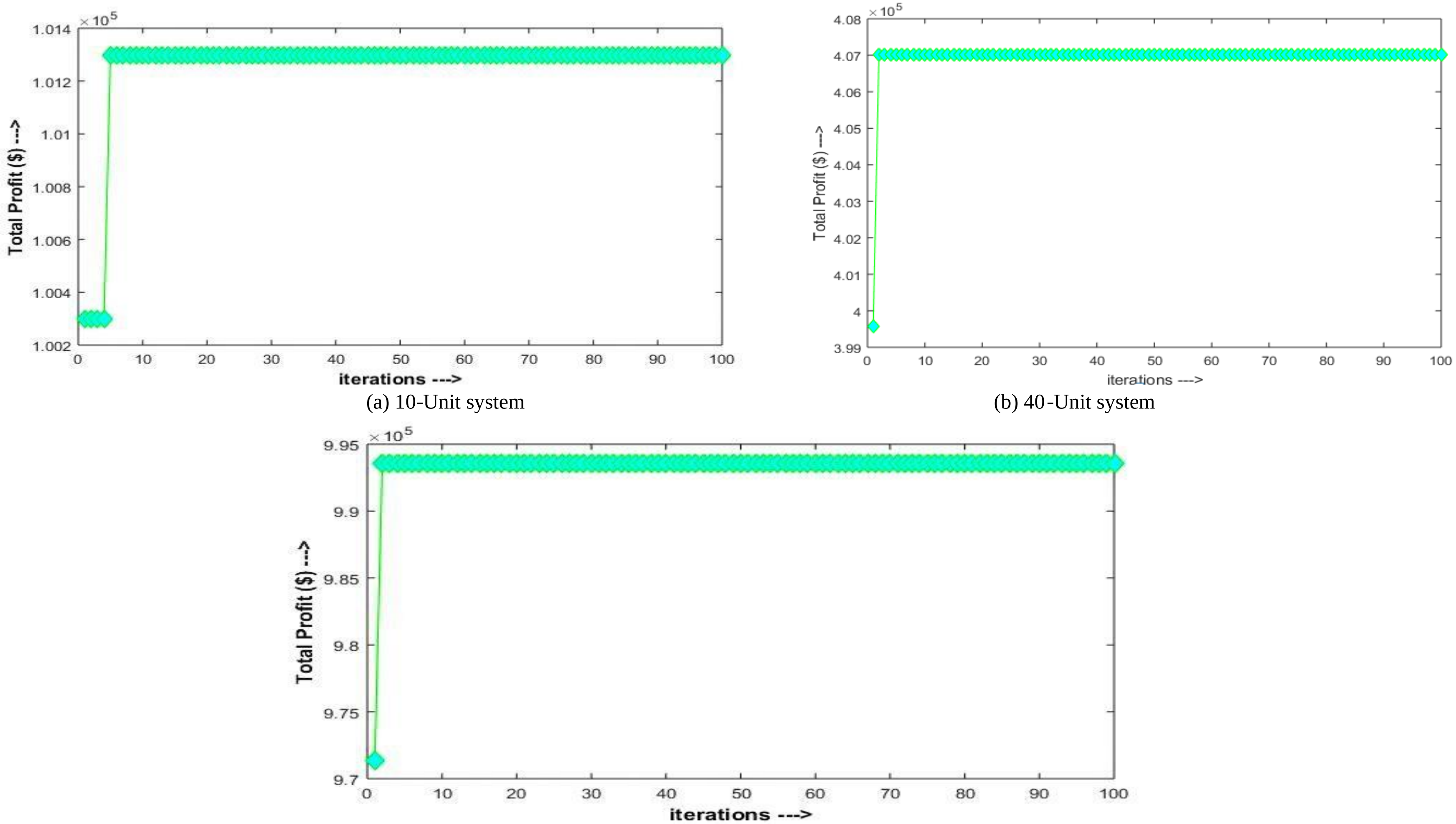
Hour	PGU41	PGU42	PGU43	PGU 44	PGU45	PGU46	PGU 47	PGU48	PGU49	PGU50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PGU56	PGU57	PGU 58	PGU 59	PGU 60
1	10078.25	5155.191	0	0	0	0	0	0	0	0	10078.25	5155.191	0	0	0	0	0	0	0	0
2	10010	6141.3	0	0	0	0	0	0	0	0	10010	6141.3	0	0	0	0	0	0	0	0
3	10510.5	8757.7644	0	0	0	0	0	0	0	0	10510.5	8757.7644	0	0	0	0	0	0	0	0
4	10305.75	9710.8478	0	0	0	0	0	0	0	0	10305.75	9710.8478	0	0	0	0	0	0	0	0
5	10578.75	10578.75	0	0	0	0	0	0	0	0	10578.75	10578.75	0	0	0	1619.6725	0	0	0	0
6	10442.25	10442.25	0	0	0	1292.3145	0	0	0	0	10442.25	10442.25	0	0	0	1292.3145	0	0	0	0
7	10237.5	10237.5	0	0	0	450	0	0	0	0	10237.5	10237.5	0	0	0	450	0	0	0	0
8	10078.25	10078.25	0	0	0	443.00001	0	0	0	0	10078.25	10078.25	0	0	0	0	553.75	0	0	0
9	10374	10374	0	2964	0	817.532	0	0	0	0	10374	10374	2964	2964	3693.6	0	570	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	1881.8425	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	3985.2	1848.362	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	0	0	0	11147.5	11147.5	3185	3185	3969	1960	0	0	0	0
15	10237.5	10237.5	0	2925	3645	0	0	0	0	0	10237.5	10237.5	2925	2925	0	1800	0	0	1062.3375	0
16	10146.5	10146.5	0	2899	0	0	0	1226.5	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	9638.611	0	2892.5	0	0	0	0	0	0	10123.75	9638.611	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	1256.703	0	0	0	10032.75	10032.75	0	2866.5	0	0	1256.703	1212.75	0	0
19	10101	10101	0	2886	0	0	848.188	0	0	0	10101	10101	0	2886	0	0	848.188	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	566.25	0	0	0	10305.75	10305.75	0	2944.5	0	0	566.25	226.5	0	226.5
21	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	0	0	0	0	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	10351.25	0	0	0	0	0	0	0	0	10351.25	10351.25	2957.5	0	0	0	0	0	0	0
24	10260.25	10260.25	0	0	0	0	0	0	0	0	10260.25	0	2931.5	0	0	0	0	0	0	0

Table-6.65d: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 61-80) with PEVs and solar during summer

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	10078.25	5155.191	0	0	0	0	553.75	0	0	0	10078.25	5155.191	0	0	0	0	0	0	0	0
2	10010	6141.3	0	0	0	0	550	0	0	0	10010	6141.3	0	0	0	0	0	0	0	0
3	10510.5	8757.7644	0	0	0	0	577.5	0	0	0	10510.5	8757.7644	0	0	0	0	0	0	0	0
4	10305.75	9710.8478	0	0	0	0	0	0	0	0	10305.75	9710.8478	0	0	0	453	0	0	0	0
5	10578.75	10578.75	0	0	0	0	0	0	0	0	10578.75	10578.75	0	0	0	1619.6725	0	0	0	0
6	10442.25	10442.25	0	2983.5	0	0	0	229.5	0	0	10442.25	10442.25	0	0	0	1292.3145	0	0	0	0
7	10237.5	10237.5	0	2925	3551.55	0	0	0	0	0	10237.5	10237.5	0	0	0	0	0	0	0	0
8	10078.25	10078.25	0	2879.5	2182.4395	0	0	0	0	0	10078.25	10078.25	0	0	0	0	0	221.5	0	221.5
9	10374	10374	0	2964	3693.6	0	0	0	0	0	10374	10374	0	2964	0	0	570	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	1881.8425	0	0	435.20558	13354.25	13354.25	3815.5	3815.5	4754.7	0	1881.8425	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	0	2104.47	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	0	2104.47	1658.25	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	1905.6465	1740.75	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0
13	11193	11193	3198	3198	0	1848.362	0	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	0	1960	0	0	0	760.97011	11147.5	11147.5	3185	3185	3969	0	0	0	0	0
15	10237.5	10237.5	0	2925	0	0	0	0	0	0	10237.5	10237.5	0	2925	3645	0	0	0	1062.3375	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	1136.9283	0	0	0
17	10123.75	9638.611	0	2892.5	0	0	0	0	0	0	10123.75	9638.611	0	2892.5	0	0	556.25	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	0	0	0	1256.703	0	0	0
19	10101	10101	0	2886	0	0	0	0	0	0	10101	10101	0	0	0	0	0	0	1221	0
20	10305.75	10305.75	0	2944.5	0	453	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	226.5
21	10510.5	10510.5	0	3003	0	1848	0	0	0	0	10510.5	10510.5	0	0	0	0	0	0	0	0
22	10442.25	10442.25	0	0	0	1836	0	0	0	0	10442.25	10442.25	0	0	0	0	1656.684	0	0	0
23	10351.25	10351.25	0	0	0	0	0	0	0	0	10351.25	0	0	0	0	0	1464.19	0	0	0
24	10260.25	0	0	0	0	0	0	0	0	0	10260.25	0	0	0	0	0	1066.5023	0	0	0

Table-6.65e: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 81-100) with PEVs and solar during summer

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	10078.25	5155.191	0	0	0	0	0	0	0	0	10078.25	5155.191	0	2879.5	0	0	0	0	0	0
2	10010	6141.3	0	0	550	0	0	0	0	0	10010	6141.3	0	2860	0	0	0	0	0	0
3	10510.5	8757.7644	0	0	577.5	0	0	0	0	0	10510.5	8757.7644	0	3003	0	0	0	0	0	0
4	10305.75	9710.8478	2944.5	0	566.25	0	0	0	0	0	10305.75	9710.8478	0	2944.5	0	0	0	0	0	0
5	10578.75	10578.75	3022.5	0	3766.5	0	0	0	0	0	10578.75	10578.75	0	3022.5	0	0	0	0	0	0
6	10442.25	10442.25	2983.5	0	3717.9	0	0	0	0	0	10442.25	10442.25	0	2983.5	0	0	0	0	0	0
7	10237.5	10237.5	2925	0	3551.55	0	0	0	0	0	10237.5	10237.5	0	2925	0	0	0	0	0	0
8	10078.25	10078.25	2879.5	0	2182.4395	0	0	0	0	0	10078.25	10078.25	0	2879.5	2182.4395	0	0	0	0	0
9	10374	10374	2964	2964	3693.6	0	0	0	0	0	10374	10374	0	2964	3693.6	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	1740.75	0	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0
13	11193	11193	3198	3198	0	1848.362	0	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	0	1960	0	0	0	0	11147.5	11147.5	3185	3185	0	0	0	0	0	0
15	10237.5	10237.5	0	2925	0	1800	0	0	0	0	10237.5	10237.5	0	2925	0	0	0	0	0	0
16	10146.5	10146.5	0	0	0	0	0	0	0	0	10146.5	10146.5	0	0	0	0	0	0	0	0
17	10123.75	9638.611	0	0	0	0	0	0	0	0	10123.75	9638.611	0	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	0	0	0	0	0	10032.75	10032.75	0	0	0	0	0	0	0	0
19	10101	10101	0	0	3596.4	1776	0	0	0	0	10101	10101	0	0	0	0	0	0	0	0
20	10305.75	10305.75	0	0	3545.4045	453	566.25	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
21	10510.5	10510.5	0	0	3742.2	1848	1184.106	0	0	0	10510.5	10510.5	0	0	0	0	0	0	0	0
22	10442.25	10442.25	0	0	3717.9	0	1656.684	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	0	0	2957.5	3685.5	0	1464.19	0	0	0	10351.25	0	0	0	0	0	0	0	0	0
24	10260.25	0	0	2931.5	3653.1	0	0	0	0	0	10260.25	0	0	0	0	0	0	0	0	0



(a) 10-Unit system

(b) 40-Unit system

(c) 100-Unit system

Fig.6.20: Convergence curve for 10-, 40- and 100-generating unit system using hCHHO-SCA optimization algorithm with PEVs and solar during summer

6.6.8 Hybrid Chaotic Slime Mould-Sine Cosine Optimization Algorithm with PEVs and solar during summer

The proposed hybrid algorithm, hCSMA-SCA is established to increase the penetrating capability through the entire search region. The alteration with input boundaries with chaotic map is thought about to make the hybridization SMA enhancer with SCA technique which is especially proficient to track down the ideal arrangement over the hunt locale. This technique is unrivaled as the populace based enhancers are more reasonable to tackle ongoing issue since they can ready to stay away from the caught into nearby optima and investigate the pursuit district just as take advantage of worldwide ideal arrangement more steady than the individual based analyzer. The number of populations are 40 for 10-, 40- and 100-generating unit systems.

6.6.8.1 Ten Unit System

The system contains of 10-generating unit system having a 24-hour electricity demand.The hCSMA-SCA technique is evaluated for 100 iterations. The hCSMA-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.21**. Thecommitment status and the optimal scheduling for this unit system are shown in Table-6.66a and the hourly profit of the 10-generating unit system have been shown in Table-6.66b.

The Table-6.66a and Table-6.66b represents the commitment status with optimum scheduling and profit of the generators for 24 hours considering effect of PEVs and RES for summer. In this case, the PGU1 and PGU2 are on for 24 hours. From 10 to 14 hours, the PGU3 is on. For 6^{th} to 22^{nd} hours PGU4 is on, PGU5 is on for 4^{th} to 15^{th} hours and PGU6 is on for 11^{th} to 13^{th} and 18^{th} to 20^{th} hours. The PGU7 to PGU10 are stayed off for 24 hours.

Table-6.66a: Commitment status and scheduling for 10-generating unit system using hCSMA-SCA optimization algorithm with PEVs and solar during summer

Commitment status of thermal units								Scheduling of the committed generating units						
HOURS	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**
1	1	1	0	0	0	0	0	455	277.4	0	0	0	0	0
2	1	1	0	0	0	0	0	455	316.5	0	0	0	0	0
3	1	1	0	0	0	0	0	455	416.24	0	0	0	0	0
4	1	1	0	0	1	0	0	455	455	0	0	42.35	0	0
5	1	1	0	0	1	0	0	455	455	0	0	112.99	0	0
6	1	1	0	1	1	0	0	455	455	0	130	39.24	0	0
7	1	1	0	1	1	0	0	455	443.54	0	130	25	0	0
8	1	1	0	1	1	0	0	455	429.12	0	130	25	0	0
9	1	1	0	1	1	0	0	455	455	0	130	67.57	0	0
10	1	1	1	1	1	0	0	455	455	130	130	157.18	0	0
11	1	1	1	1	1	1	0	455	455	130	130	151.6	20	0
12	1	1	1	1	1	1	0	455	455	130	130	127.21	20	0
13	1	1	1	1	1	1	0	455	455	130	130	43.41	20	0
14	1	1	1	1	1	0	0	455	455	130	130	73.06	0	0
15	1	1	0	1	1	0	0	455	455	0	130	144.43	0	0
16	1	1	0	1	0	0	0	455	412.95	0	130	0	0	0
17	1	1	0	1	0	0	0	455	411.96	0	130	0	0	0
18	1	1	0	1	0	1	0	455	441.96	0	130	0	20	0
19	1	1	0	1	0	1	0	455	455	0	130	0	21.62	0
20	1	1	0	1	0	1	0	455	381.53	0	130	0	20	0
21	1	1	0	1	0	0	0	455	438.26	0	130	0	0	0
22	1	1	0	1	0	0	0	455	407.56	0	130	0	0	0
23	1	1	0	0	0	0	0	455	409.08	0	0	0	0	0
24	1	1	0	0	0	0	0	455	300.59	0	0	0	0	0

Table-6.66b: Hourly profit for 10-generating unit system using hCSMA-SCA optimization algorithm with PEVs and solar during summer

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7 to PG10	Start-up Cost	Hourly Profit
1	10078.25	6144.41	0	0	0	0	0	1450	16222.66
2	10010	6963	0	0	0	0	0	560	16973
3	10510.5	9615.144	0	0	0	0	0	0	20125.644
4	10305.75	10305.75	0	0	959.2275	0	0	520	21570.7275
5	10578.75	10578.75	0	0	2627.0175	0	0	340	23784.5175
6	10442.25	10442.25	0	2983.5	900.558	0	0	0	24768.558
7	10237.5	9979.65	0	2925	562.5	0	0	0	23704.65
8	10078.25	9505.008	0	2879.5	553.75	0	0	0	23016.508
9	10374	10374	0	2964	1540.596	0	0	0	25252.596
10	13354.25	13354.25	3815.5	3815.5	4613.233	0	0	0	38952.733
11	13718.25	13718.25	3919.5	3919.5	4570.74	603	0	170	40449.24
12	14400.75	14400.75	4114.5	4114.5	4026.1965	633	0	260	41689.6965
13	11193	11193	3198	3198	1067.886	492	0	0	30341.886
14	11147.5	11147.5	3185	3185	1789.97	0	0	60	30454.97
15	10237.5	10237.5	0	2925	3249.675	0	0	0	26649.675
16	10146.5	9208.785	0	2899	0	0	0	0	22254.285
17	10123.75	9166.11	0	2892.5	0	0	0	0	22182.36
18	10032.75	9745.218	0	2866.5	0	441	0	260	23085.468
19	10101	10101	0	2886	0	479.964	0	120	23567.964
20	10305.75	8641.6545	0	2944.5	0	453	0	0	22344.9045
21	10510.5	10123.806	0	3003	0	0	0	550	23637.306
22	10442.25	9353.502	0	2983.5	0	0	0	0	22779.252
23	10351.25	9306.57	0	0	0	0	0	0	19657.82
24	10260.25	6778.3045	0	0	0	0	0	0	17038.5545

6.6.8.2 Forty Generating Unit System

The system contains of 40-generating unit system having a 24-hour electricity demand. The hCSMA-SCA technique is evaluated for 100 iterations with considering PEVs and solar PV in summer days. The hCSMA-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.21**. Table-6.67 gives the hourly profit with startup cost and fuel cost for 40-generating unit system using hCSMA-SCA optimization algorithm with PEVs and RES during summer. The optimal scheduling of 40-generating unit systems are shown in Table-6.68a and Table-6.68b. The hourly profit table for this system is shown in Table-6.69a and Table-6.69b respectively.

Table-6.67: Hourly profit with startup cost and fuel cost for 40-generating unit system using hCSMA-SCA optimization algorithm with PEVs and solar during summer

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	62737.66	1570	54353.22389	**13**	128643.486	340	105590.851
2	66473	0	57660.35023	**14**	126004.97	120	103765.321
3	79030.644	1150	65830.29729	**15**	107649.675	0	95775.8039
4	83405.2275	4360	71571.0817	**16**	91830.285	1020	80481.8727
5	93534.5175	3490	79381.08646	**17**	88932.36	230	77778.6176
6	96372.558	0	83083.74132	**18**	91881.468	380	81828.6918
7	93904.65	60	82633.11442	**19**	92831.964	230	82514.4535
8	92124.508	0	82380.33219	**20**	93012.9045	1800	80649.8061
9	105280.596	10000	91328.18375	**21**	95709.306	1700	81060.6319
10	162222.733	840	114577.026	**22**	94383.252	3630	81564.4299
11	168164.64	1010	115402.077	**23**	81082.82	1330	70425.3767
12	175759.097	0	115264.9119	**24**	71158.5545	60	62774.6784

Table-6.68a: Generation scheduling for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with PEVs and solar during summer

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU-10	PGU-11	PGU-12	PGU-13	PGU-14	PGU-15	PGU-16	PGU-17	PGU-18	PGU-19	PGU-20
1	455	337.4666667	0	0	0	0	0	0	0	0	455	337.4666667	0	0	0	0	0	0	0	0
2	455	400.5	0	0	0	0	0	0	0	0	455	400.5	0	0	0	0	0	0	0	0
3	455	447.08	0	130	0	0	0	0	0	0	455	447.08	0	130	0	0	0	0	0	0
4	455	447.45	0	130	0	0	0	0	0	0	455	447.45	0	130	0	0	0	0	0	0
5	455	430.9966667	130	130	0	0	0	0	0	0	455	430.9966667	130	130	0	0	0	0	0	0
6	455	446.4133333	130	130	0	0	0	0	0	0	455	446.4133333	130	130	0	0	0	0	0	0
7	455	437.8466667	130	130	0	0	0	0	0	0	455	437.8466667	130	130	0	0	0	0	0	0
8	455	433.04	130	130	0	0	0	0	0	0	455	433.04	130	130	0	0	0	0	0	0
9	455	439.3925	130	130	0	0	0	0	0	0	455	439.3925	130	130	0	0	0	0	0	0
10	455	455	130	130	162	80	60.59	0	0	0	455	455	130	130	0	0	60.59	0	0	0
11	455	455	130	130	162	66.5333333	25	0	0	0	455	455	130	130	162	0	25	0	0	0
12	455	455	130	130	162	80	57.605	0	0	0	455	455	130	130	162	0	57.605	0	0	0
13	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	31.41	0	0	0	0
14	455	455	130	130	143.265	0	0	0	0	0	455	455	130	130	143.265	20	0	0	0	0
15	455	455	130	130	151.1075	0	0	0	0	0	455	455	0	0	151.1075	20	0	0	0	0
16	455	455	0	0	0	0	0	0	0	0	455	455	0	0	159.316667	0	0	0	0	0
17	455	455	0	0	0	0	0	0	0	0	455	455	0	0	113.48	0	0	0	0	0
18	455	455	0	0	0	72.96	0	0	0	0	455	455	0	0	162	0	0	0	0	0
19	455	455	0	0	0	43.81	0	0	0	0	455	455	0	0	162	43.81	0	0	0	0
20	455	455	0	0	0	22.265	0	0	0	0	455	455	0	130	162	22.265	0	0	0	0
21	455	445.815	0	0	0	0	0	0	0	0	455	445.815	0	130	0	20	0	0	0	0
22	455	417.52	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
23	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
24	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0

Table-6.68b: Generation scheduling for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with PEVs and solar during summer

Hour	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	337.4666667	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	400.5	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	447.08	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
4	455	447.45	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
5	455	430.9966667	130	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
6	455	446.4133333	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
7	455	437.8466667	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
8	455	433.04	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
9	455	439.3925	130	130	0	0	0	0	0	0	455	439.3925	130	130	0	0	0	0	0	0
10	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	66.5333333	0	0	0	0	455	455	130	130	162	66.5333333	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	0	130	162	80	0	0	0	0
13	455	455	130	130	162	0	0	0	0	0	455	455	0	130	162	0	0	0	0	0
14	455	455	130	130	143.265	0	0	0	0	0	455	455	0	130	143.265	0	0	0	0	0
15	455	455	0	130	151.1075	0	0	0	0	0	455	455	0	130	151.1075	0	0	0	0	0
16	455	455	0	0	159.316667	0	0	0	0	0	455	455	0	0	159.316667	0	0	0	0	0
17	455	455	0	0	113.48	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
18	455	455	0	0	162	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
19	455	455	0	0	162	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
20	455	455	0	0	0	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
21	455	445.815	0	130	0	0	0	0	0	0	455	445.815	130	130	0	0	0	0	0	0
22	455	417.52	130	130	0	0	0	0	0	0	455	417.52	130	130	0	0	0	0	0	0
23	455	417.04	130	130	0	0	0	0	0	0	455	417.04	0	130	0	0	0	0	0	0
24	455	440.295	130	130	0	0	0	0	0	0	0	440.295	0	130	0	0	0	0	0	0

Table-6.68a shows the optimal scheduling of PGU1 to PGU20 for 40-generating unit test system considering the effect of PEVs and solar PV in summer using hCSMA-SCA optimizer. The PGU8 to PGU10 and PGU18 to PGU20 is off for 24 hours. The PGU1 and PGU11 is always remain on throughout the whole day. PGU7 and PGU17 gives 60.59 MW power for 10th hour, 25 MW for 11th hour and 57.605 MW for 12th hour. Further, the PGU are sometimes remain on and off condition for optimum power generation scheduling.

In Table-6.68b represents the power scheduling of 21 to 40 unit for 40-unit system with PEVs and solar PV in summer using hCSMA-SCA optimizer. The PGU21, PGU22 and PGU32 is continuing on for 24 hours. The PGU27 to PGU30 and PGU37 to PGU40 remain off throughout the whole day. The PGU26 and PGU36 are on for 10th to 12th hour only. For this the output is 80 MW for 10th hour, 66.5333333 MW for 11th hour and 80 MW for again 13th hour.

The hourly profit for 40-test system is presented in Table-6.69a and Table-6.69b using hCSMA-SCA optimizer with PEVs and solar PV in summer. The Table-6.73a shows the hourly profit for PGU1 to PGU20 for whole day. The maximum number of profit can be obtained from the PGU1 and PGU11 as it was remain on for all hours. PGU7and PGU7 gives 1778.3165 $ for 10th hour, 753.75 $ for 11th hour and 1823.19825 $ for 12th hour.

Table-6.69b shows that the hourly profit for PGU21 to PGU40 for this test system for 24 hours. The PGU21 and PGU22 are on for 24 hours, so that the profit from these units are maximum. Moreover for the others hours as it remain off, no profit come from that hour when the generating unit remain off.

Table-6.69a: Hourly profit for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with PEVs and solar during summer

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	GPU16	PGU17	PGU 18	PGU19	PGU 20
1	10078.25	7474.886667	0	0	0	0	0	0	0	0	10078.25	7474.886667	0	0	0	0	0	0	0	0
2	10010	8811	0	0	0	0	0	0	0	0	10010	8811	0	0	0	0	0	0	0	0
3	10510.5	10327.548	0	3003	0	0	0	0	0	0	10510.5	10327.548	0	3003	0	0	0	0	0	0
4	10305.75	10134.7425	0	2944.5	0	0	0	0	0	0	10305.75	10134.7425	0	2944.5	0	0	0	0	0	0
5	10578.75	10020.6725	3022.5	3022.5	0	0	0	0	0	0	10578.75	10020.6725	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	10245.186	2983.5	2983.5	0	0	0	0	0	0	10442.25	10245.186	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	9851.55	2925	2925	0	0	0	0	0	0	10237.5	9851.55	2925	2925	0	0	0	0	0	0
8	10078.25	9591.836	2879.5	2879.5	0	0	0	0	0	0	10078.25	9591.836	2879.5	2879.5	0	0	0	0	0	0
9	10374	10018.149	2964	2964	0	0	0	0	0	0	10374	10018.149	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	1778.3165	0	0	0	13354.25	13354.25	3815.5	3815.5	0	0	1778.3165	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2005.98	753.75	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	0	753.75	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	1823.19825	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	0	1823.19825	0	0	0
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	3985.2	772.686	0	0	0	0
14	11147.5	11147.5	3185	3185	3509.9925	0	0	0	0	0	11147.5	11147.5	3185	3185	3509.9925	490	0	0	0	0
15	10237.5	10237.5	2925	2925	3399.91875	0	0	0	0	0	10237.5	10237.5	0	0	3399.91875	450	0	0	0	0
16	10146.5	10146.5	0	0	0	0	0	0	0	0	10146.5	10146.5	0	0	3552.76167	0	0	0	0	0
17	10123.75	10123.75	0	0	0	0	0	0	0	0	10123.75	10123.75	0	0	2524.93	0	0	0	0	0
18	10032.75	10032.75	0	0	0	1608.768	0	0	0	0	10032.75	10032.75	0	0	3572.1	0	0	0	0	0
19	10101	10101	0	0	0	972.582	0	0	0	0	10101	10101	0	0	3596.4	972.582	0	0	0	0
20	10305.75	10305.75	0	0	0	504.30225	0	0	0	0	10305.75	10305.75	0	2944.5	3669.3	504.30225	0	0	0	0
21	10510.5	10298.3265	0	0	0	0	0	0	0	0	10510.5	10298.3265	0	3003	0	462	0	0	0	0
22	10442.25	9582.084	2983.5	2983.5	0	0	0	0	0	0	10442.25	0	2983.5	2983.5	0	0	0	0	0	0
23	10351.25	0	2957.5	2957.5	0	0	0	0	0	0	10351.25	0	2957.5	2957.5	0	0	0	0	0	0
24	10260.25	0	2931.5	2931.5	0	0	0	0	0	0	10260.25	0	2931.5	2931.5	0	0	0	0	0	0

Table-6.69b: Hourly profit for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with PEVs and solar during summer

HOURS	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PG34	PGU35	GPU36	PGU37	PGU 38	PGU39	PGU 40
1	10078.25	7474.886667	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	8811	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	10327.548	0	0	0	0	0	0	0	0	10510.5	0	0	0	0	0	0	0	0	0
4	10305.75	10134.7425	0	2944.5	0	0	0	0	0	0	10305.75	0	0	2944.5	0	0	0	0	0	0
5	10578.75	10020.6725	3022.5	3022.5	0	0	0	0	0	0	10578.75	0	0	3022.5	0	0	0	0	0	0
6	10442.25	10245.186	2983.5	2983.5	0	0	0	0	0	0	10442.25	0	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	9851.55	2925	2925	0	0	0	0	0	0	10237.5	0	2925	2925	0	0	0	0	0	0
8	10078.25	9591.836	2879.5	2879.5	0	0	0	0	0	0	10078.25	0	2879.5	2879.5	0	0	0	0	0	0
9	10374	10018.149	2964	2964	0	0	0	0	0	0	10374	10018.149	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2005.98	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2005.98	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	0	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	0	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3509.9925	0	0	0	0	0	11147.5	11147.5	0	3185	3509.9925	0	0	0	0	0
15	10237.5	10237.5	0	2925	3399.91875	0	0	0	0	0	10237.5	10237.5	0	2925	3399.91875	0	0	0	0	0
16	10146.5	10146.5	0	0	3552.76167	0	0	0	0	0	10146.5	10146.5	0	0	3552.76167	0	0	0	0	0
17	10123.75	10123.75	0	0	2524.93	0	0	0	0	0	10123.75	10123.75	2892.5	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	3572.1	0	0	0	0	0	10032.75	10032.75	2866.5	0	0	0	0	0	0	0
19	10101	10101	0	0	3596.4	0	0	0	0	0	10101	10101	2886	0	0	0	0	0	0	0
20	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	2944.5	0	0	0	0	0	0	0
21	10510.5	10298.3265	0	3003	0	0	0	0	0	0	10510.5	10298.3265	3003	3003	0	0	0	0	0	0
22	10442.25	9582.084	2983.5	2983.5	0	0	0	0	0	0	10442.25	9582.084	2983.5	2983.5	0	0	0	0	0	0
23	10351.25	9487.66	2957.5	2957.5	0	0	0	0	0	0	10351.25	9487.66	0	2957.5	0	0	0	0	0	0
24	10260.25	9928.65225	2931.5	2931.5	0	0	0	0	0	0	0	9928.65225	0	2931.5	0	0	0	0	0	0

6.6.8.3 Hundred Generating Unit System

The system contains of 100-generating unit system having a 24-hour electricity demand. The hCSMA-SCA technique is evaluated for 100 iterations with impact of PEVs in summer days. The hCSMA-SCA algorithmis verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.21**.The optimal scheduling of 100-generating unit systems are shown in Table-6.71a to Table-6.71e. The hourly profit table for this system is shown in Table-6.72a to Table-6.72e respectively. The Table-6.70 have been shown about hourly profit with startup and fuel cost.

Table-6.70: Hourly profit with start-up cost and fuel cost for 100-generating unit system using hCSMA-SCA optimization algorithm with PEVs and solar during summer

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	155767.66	10160	134875.629	**13**	325246.686	910	267714.9858
2	165473	6840	149488.493	**14**	317104.97	670	263435.1404
3	196840.644	1710	170493.331	**15**	269649.675	1640	245170.0559
4	207074.228	3330	185247.872	**16**	230982.285	320	205225.0012
5	233034.518	1570	203999.039	**17**	222432.36	1980	198296.1404
6	239580.558	2500	213657.844	**18**	229473.468	2520	207506.1814
7	234304.65	3800	213384.722	**19**	231359.964	3800	208313.3914
8	230340.508	1020	211782.347	**20**	234348.9045	3980	207484.3119
9	265336.596	980	234302.64	**21**	239853.306	3900	207284.2025
10	408762.733	2010	289622.013	**22**	237591.252	5300	204056.8754
11	423595.44	1820	293713.444	**23**	203932.82	3320	185553.4101
12	443897.897	470	294239.571	**24**	179398.5545	970	159350.9924

Table-6.71a: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with PEVs and solar during summer

HOUR	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	455	370.4	0	0	0	0	0	0	0	0	455	370.4	130	0	0	0	0	0	0	0
2	455	334.416667	0	0	0	0	0	10	0	10	455	334.416667	130	0	0	0	0	0	0	0
3	455	455	0	130	0	0	25	0	0	0	455	455	130	0	0	27.08	0	10	0	0
4	455	455	0	130	0	0	25	0	0	0	455	455	130	0	0	20	0	0	0	0
5	455	455	0	130	0	0	25	0	0	0	455	455	130	0	0	23.9985714	0	0	0	0
6	455	455	0	130	142.034286	0	25	0	0	0	455	455	130	0	142.034286	0	0	0	0	0
7	455	455	0	130	99.2822222	20	0	0	0	0	455	455	130	0	99.2822222	0	0	0	10	0
8	455	455	130	130	81.912	20	0	0	0	0	455	455	130	0	81.912	0	0	0	0	0
9	455	447.757	130	130	25	20	0	0	0	0	455	447.757	130	130	25	0	0	0	0	0
10	455	455	130	130	162	80	51.836	0	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	0	49.32	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	0	50.3683324	0	0	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	162	0	0	55	0	0	455	455	130	130	0	0	0	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	55	0	51.4766667
16	455	455	0	130	0	22.19	0	0	0	0	455	455	0	130	0	0	0	0	0	0
17	455	444.696	0	130	0	20	0	0	0	0	455	444.696	0	130	0	20	0	0	0	0
18	455	455	0	130	0	65.8266667	0	0	0	0	455	455	0	130	0	65.8266667	25	0	0	0
19	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	80	79.905	0	0	0
20	455	455	0	130	0	0	84.506	0	0	0	455	455	0	130	0	0	84.506	0	0	0
21	455	455	0	0	0	0	78.315	0	0	0	455	455	0	0	0	0	78.315	0	0	0
22	455	455	0	0	0	0	67.28	0	0	0	455	455	130	0	0	0	0	0	0	0
23	455	455	0	0	0	0	85	0	0	0	455	455	130	0	0	0	0	0	55	0
24	455	455	0	0	0	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0

Table-6.71b: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with PEVs and solar during summer

HOUR	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	370.4	0	0	0	0	0	0	0	0	455	370.4	0	0	0	0	0	0	0	0
2	455	334.416667	0	130	0	0	0	0	0	0	455	334.416667	0	0	0	0	0	0	0	0
3	455	455	0	130	0	0	0	0	0	0	455	455	0	0	0	27.08	0	0	0	0
4	455	455	130	130	0	20	0	0	0	0	455	455	0	130	0	20	0	0	0	0
5	455	455	130	130	162	23.9985714	0	0	0	0	455	455	0	130	0	23.9985714	0	0	0	0
6	455	455	130	130	142.034286	20	25	0	0	0	455	455	0	130	0	20	25	0	0	0
7	455	455	130	130	99.2822222	0	25	0	0	0	455	455	0	130	99.2822222	0	25	0	0	0
8	455	455	130	130	81.912	0	25	0	0	0	455	455	0	130	81.912	0	25	0	0	0
9	455	447.757	130	130	25	0	0	0	0	0	455	447.757	0	130	25	0	0	0	0	0
10	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	130	162	80	50.3683324	0	55	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	162	0	65.41	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	162	0	83.06	0	55	0	455	455	130	130	0	0	0	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	22.19	25	0	0	0
17	455	444.696	0	130	0	0	0	0	0	0	455	444.696	0	130	0	20	25	0	0	0
18	455	455	0	130	0	65.8266667	0	0	0	0	455	455	0	130	0	65.8266667	25	0	0	0
19	455	455	0	130	0	80	0	0	0	0	455	455	0	130	0	0	0	0	0	0
20	455	455	0	0	0	80	0	0	0	0	455	455	0	0	0	0	0	0	0	0
21	455	455	0	0	162	80	0	0	0	0	455	455	0	0	0	0	0	0	0	0
22	455	455	130	0	162	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
23	455	455	130	0	162	0	0	0	0	34.54	455	455	0	0	0	0	85	55	0	0
24	455	455	130	0	162	0	0	0	0	0	455	0	0	0	0	0	55.295	0	0	0

The Table-6.71a is given as the power scheduling of 100-unit test system using hCSMA-SCA optimizer considering effect of PEVs and solar PV in summer for PGU1 to PGU20 with PEVs. The PGU9 and PGU10 is off for 24 hours. The PGU1, PGU2, PGU11 and PGU12 is always remain on throughout the whole day. PGU8 and PGU18 gives 55 MW power only for 14th and 15th hour respectively and 10 MW power for PGU18 in 3rd hour. PGU19 gives 10 MW power for 7th hour as it have been on for that particular hour only.

In Table-6.71b represents the power scheduling of 21 to 40 unit for 100-unit system using hCSMA-SCA optimizer considering the effect of PEVs and solar PV in summer. The PGU21, PGU22 and PGU31 is continuous on for 24 hours. The PGU28, PGU39 and PGU40 remain off throughout the whole day. The PGU29 is on for 12th and 14thhour, gives 55 MW power.

In Table-6.71c represents the power scheduling of 41 to 60 unit for 100-unit system using hCSMA-SCA optimizer with PEVs and solar PV in summer. The PGU41 and PGU51 is continuous on for 24 hours and 455 MW power can be obtained. PGU42 is on from 1th hour to 23rd hour. The PGU48 and PGU49 remain off throughout the whole day.

Table-6.71d represents the power scheduling of 61 to 80 unit for 100-unit system using hCSMA-SCA optimizer considering the effect of PEVs and solar PV in summer. The PGU61 and PGU71 is always on and the output power is 455 MW for 24 hours. The PGU69 is on only for 11th hour and 55 MW output power can be measured, PGU70 and PGU78 is off for the whole day.

Table-6.71e represents the power scheduling of 81 to 100 unit for 100-unit system using hCSMA-SCA optimizer considering the effect of PEVs and solar PV in summer. The PGU81 and PGU91 is always on and the output power is 455 MW for 24 hours. The PGU88, PGU89 and PGU100 is off for the whole day.

Table-6.71c: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 41-60) with PEVs and solar during summer

Hour	PGU41	PGU42	PGU43	PGU44	PGU45	PGU46	PGU47	PGU48	PGU49	PGU50	PGU51	PGU52	PGU53	PGU54	PGU55	PGU56	PGU57	PGU58	PGU59	PGU60
1	455	370.4	0	0	0	0	0	0	0	0	455	370.4	0	0	0	0	0	0	0	0
2	455	334.416667	0	0	0	0	0	0	0	0	455	334.416667	130	130	0	0	0	0	0	0
3	455	455	0	0	0	0	0	0	0	0	455	455	130	130	0	27.08	0	0	0	0
4	455	455	0	0	0	20	0	0	0	0	455	455	130	130	64.1166667	20	0	0	0	0
5	455	455	0	0	162	23.9985714	0	0	0	0	455	455	130	130	162	23.9985714	0	0	0	0
6	455	455	0	130	142.034286	20	0	0	0	0	455	455	130	130	142.034286	20	0	0	0	0
7	455	455	130	130	99.2822222	0	0	0	0	0	455	455	130	130	99.2822222	20	0	0	0	0
8	455	455	130	130	81.912	0	0	0	0	0	455	455	130	130	81.912	0	0	0	0	0
9	455	447.757	130	130	25	0	0	0	0	0	455	447.757	130	130	25	0	0	0	0	0
10	455	455	130	130	162	80	51.836	0	0	0	455	455	130	130	162	0	0	55	0	0
11	455	455	130	130	162	80	49.32	0	0	0	455	455	130	130	162	80	0	0	55	0
12	455	455	130	130	162	80	50.3683324	0	0	10.0000018	455	455	130	130	162	80	0	0	0	10.0000018
13	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	0	0	0
14	455	455	130	130	162	0	0	0	0	0	455	455	130	130	0	80	0	0	0	0
15	455	455	130	130	0	0	0	0	0	51.4766667	455	455	130	130	0	0	85	0	0	51.4766667
16	455	455	130	0	0	0	0	0	0	0	455	455	130	0	0	0	25	0	0	0
17	455	444.696	0	0	0	20	0	0	0	0	455	444.696	130	0	0	0	25	0	0	0
18	455	455	0	0	0	65.8266667	25	0	0	0	455	455	130	0	0	0	0	0	0	0
19	455	455	0	0	0	80	79.905	0	0	0	455	455	0	0	0	0	0	0	0	0
20	455	455	0	0	0	80	84.506	0	0	0	455	455	0	0	0	0	0	0	0	0
21	455	455	0	0	162	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
22	455	455	0	0	162	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
23	455	455	130	0	162	0	0	0	0	0	455	0	0	0	162	0	85	0	0	34.54
24	455	0	130	0	162	0	0	0	0	0	455	0	130	130	162	0	55.295	0	0	0

Table-6.71d: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 61-80) with PEVs and solar during summer

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	0	0	0	0	0	0	0	0	0	455	0	130	0	0	0	0	0	0	0
3	455	0	0	0	0	0	0	0	0	0	455	0	130	0	0	0	25	0	0	0
4	455	0	0	0	0	20	0	0	0	0	455	0	130	0	64.1166667	20	25	0	0	0
5	455	0	130	0	0	23.9985714	0	0	0	0	455	0	130	130	162	23.9985714	25	0	0	0
6	455	0	130	130	0	20	0	0	0	0	455	0	130	130	142.034286	20	0	0	0	0
7	455	0	130	130	0	20	0	0	0	0	455	0	130	130	99.2822222	20	0	0	0	0
8	455	0	130	130	81.912	0	0	0	0	0	455	0	130	130	81.912	0	0	0	0	0
9	455	447.757	130	130	25	0	0	0	0	0	455	447.757	130	130	25	0	0	0	0	0
10	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	51.836	0	55	0
11	455	455	130	130	162	0	0	0	55	0	455	455	130	130	162	0	49.32	0	0	0
12	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	50.3683324	0	0	10.0000018
13	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	0	0	0
15	455	455	130	130	0	80	85	0	0	0	455	455	0	130	0	80	0	0	0	0
16	455	455	0	130	0	22.19	25	0	0	0	455	455	0	0	0	22.19	0	0	0	0
17	455	444.696	0	130	0	20	25	0	0	0	455	444.696	0	0	0	0	0	0	0	0
18	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
19	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	79.905	0	0	0
20	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	80	84.506	0	0	0
21	455	455	0	0	0	0	78.315	0	0	0	455	455	0	0	162	80	78.315	0	0	0
22	455	455	0	0	0	0	67.28	0	0	0	455	455	0	130	162	80	0	0	0	0
23	455	0	0	0	0	0	85	0	0	0	455	0	0	130	162	80	0	0	0	0
24	455	0	0	0	0	0	0	0	0	0	455	0	130	130	162	0	0	0	0	0

Table-6.71e: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 81-100) with PEVs and solar during summer

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	455	0	130	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	0	130	0	0	0	25	0	0	10	455	0	130	0	0	0	0	0	0	0
3	455	0	130	0	0	0	25	10	0	0	455	0	130	0	0	0	25	0	0	0
4	455	0	130	130	0	0	25	0	0	0	455	0	130	0	64.1166667	0	25	0	0	0
5	455	0	130	130	0	0	0	0	0	0	455	0	130	0	162	0	25	0	0	0
6	455	0	130	130	0	0	0	0	0	0	455	0	130	0	142.034286	20	0	0	0	0
7	455	0	130	130	99.2822222	0	0	0	0	0	455	0	130	0	99.2822222	20	0	0	0	0
8	455	0	130	130	81.912	0	0	0	0	0	455	0	130	0	81.912	20	0	0	0	0
9	455	447.757	130	130	25	0	0	0	0	0	455	447.757	130	0	25	0	0	0	0	0
10	455	455	130	130	162	0	51.836	0	0	0	455	455	130	130	0	0	51.836	0	0	0
11	455	455	130	130	162	80	49.32	0	0	0	455	455	130	130	0	0	49.32	0	55	0
12	455	455	130	130	162	80	50.3683324	0	0	0	455	455	130	130	0	0	50.3683324	0	0	0
13	455	455	130	130	0	80	0	0	0	0	455	455	130	130	0	0	0	0	0	0
14	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	80	0	0	0	0
15	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	80	0	55	0	0
16	455	455	0	0	0	0	0	0	0	0	455	455	0	0	162	22.19	0	0	0	0
17	455	444.696	0	0	0	20	0	0	0	0	455	444.696	0	0	25	0	0	0	0	0
18	455	455	0	0	0	65.8266667	25	0	0	0	455	455	0	0	162	0	0	0	0	0
19	455	455	0	0	0	80	79.905	0	0	0	455	455	0	0	162	0	0	0	0	0
20	455	455	0	0	162	0	84.506	0	0	0	455	455	0	0	162	0	0	0	0	0
21	455	455	0	0	162	0	0	0	0	0	455	455	0	0	162	0	0	0	0	0
22	455	455	0	0	162	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
23	455	0	0	0	162	0	0	0	0	0	455	0	130	0	0	80	0	0	0	0
24	455	0	0	0	162	0	0	0	0	0	455	0	130	0	0	80	0	0	0	0

The Table-6.72a is presented the hourly profit for 100-generating unit system using proposed hCSMA-SCA optimization algorithm with PEVs and solar PV in summer. From 100 numbers of power generating units, this table shows the hourly profit of PGU1 to PGU20 for 24 hours. The PGU1, PGU2, PGU11 and PGU12 are on for every hours, while PGU3 and PGU4 have been off for some hours. The PGU8 is on only for 14th hour and 1347.5 $ profit can be obtained.

The Table-6.72b is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm for units 21 to unit 40 considering effect of solar PV in summer. In this table, the PGU21, PGU22 and PGU31 are on for 24 hours and maximum profit are obtained. The PGU28, PGU39 and PGU40 are off throughout the whole day. Others PGU are remained on for some hours and off for few hours. From those units, the profit can be measured for that particular hour when it was on.

The Table-6.72c is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm considering effect of solar PV in summer for PGU41 to PGU60. The PGU41 and PGU51 remain on for 24 hours. The PGU48 and PGU49 remain close throughout the whole day. Other units are remained on sometime and off for few times.

The Table-6.72d is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm considering effect of solar PV in summer for units 61 to unit 80. The PGU61 and PGU71 are continuously on for 24 hours. Further PGU68, PGU70 and PGU78 is off for 24 hours.

The Table-6.72e is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm considering effect of solar PV in summer for units 81 to unit 100. The PGU81 and PGU91 has been on for 24 hours. PGU89 and PGU100 have been off for through the whole day.

Table-6.72a: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with PEVs and solar during summer

Hour	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	10078.25	8204.36	0	0	0	0	0	0	0	0	10078.25	8204.36	2879.5	0	0	0	0	0	0	0
2	10010	7357.166667	0	0	0	0	0	220	0	220	10010	7357.166667	2860	0	0	0	0	0	0	0
3	10510.5	10510.5	0	3003	0	0	577.5	0	0	0	10510.5	10510.5	3003	0	0	625.548	0	231	0	0
4	10305.75	10305.75	0	2944.5	0	0	566.25	0	0	0	10305.75	10305.75	2944.5	0	0	453	0	0	0	0
5	10578.75	10578.75	0	3022.5	0	0	581.25	0	0	0	10578.75	10578.75	3022.5	0	0	557.966786	0	0	0	0
6	10442.25	10442.25	0	2983.5	3259.686857	0	573.75	0	0	0	10442.25	10442.25	2983.5	0	3259.686857	0	0	0	0	0
7	10237.5	10237.5	0	2925	2233.85	450	0	0	0	0	10237.5	10237.5	2925	0	2233.85	0	0	0	225	0
8	10078.25	10078.25	2879.5	2879.5	1814.3508	443	0	0	0	0	10078.25	10078.25	2879.5	0	1814.3508	0	0	0	0	0
9	10374	10208.8596	2964	2964	570	456	0	0	0	0	10374	10208.8596	2964	2964	570	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	1521.3866	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	0	1486.998	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	0	1594.157722	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	1347.5	0	0	11147.5	11147.5	3185	3185	0	0	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	1237.5	0	1158.225
16	10146.5	10146.5	0	2899	0	494.837	0	0	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	9894.486	0	2892.5	0	445	0	0	0	0	10123.75	9894.486	0	2892.5	0	445	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	1451.478	0	0	0	0	10032.75	10032.75	0	2866.5	0	1451.478	551.25	0	0	0
19	10101	10101	0	2886	0	0	0	0	0	0	10101	10101	0	2886	0	1776	1773.891	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	1914.0609	0	0	0	10305.75	10305.75	0	2944.5	0	0	1914.0609	0	0	0
21	10510.5	10510.5	0	0	0	0	1809.0765	0	0	0	10510.5	10510.5	0	0	0	0	1809.0765	0	0	0
22	10442.25	10442.25	0	0	0	0	1544.076	0	0	0	10442.25	10442.25	2983.5	0	0	0	0	0	0	0
23	10351.25	10351.25	0	0	0	0	1933.75	0	0	0	10351.25	10351.25	2957.5	0	0	0	0	0	1251.25	0
24	10260.25	10260.25	0	0	0	0	0	0	0	0	10260.25	10260.25	2931.5	0	0	0	0	0	0	0

Table-6.72b: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with PEVs and solar during summer

Hour	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	10078.25	8204.36	0	0	0	0	0	0	0	0	10078.25	8204.36	0	0	0	0	0	0	0	0
2	10010	7357.166667	0	2860	0	0	0	0	0	0	10010	7357.166667	0	0	0	0	0	0	0	0
3	10510.5	10510.5	0	3003	0	0	0	0	0	0	10510.5	10510.5	0	0	0	625.548	0	0	0	0
4	10305.75	10305.75	2944.5	2944.5	0	453	0	0	0	0	10305.75	10305.75	0	2944.5	0	453	0	0	0	0
5	10578.75	10578.75	3022.5	3022.5	3766.5	557.966786	0	0	0	0	10578.75	10578.75	0	3022.5	0	557.966786	0	0	0	0
6	10442.25	10442.25	2983.5	2983.5	3259.686857	459	573.75	0	0	0	10442.25	10442.25	0	2983.5	0	459	573.75	0	0	0
7	10237.5	10237.5	2925	2925	2233.85	0	562.5	0	0	0	10237.5	10237.5	0	2925	2233.85	0	562.5	0	0	0
8	10078.25	10078.25	2879.5	2879.5	1814.3508	0	553.75	0	0	0	10078.25	10078.25	0	2879.5	1814.3508	0	553.75	0	0	0
9	10374	10208.8596	2964	2964	570	0	0	0	0	0	10374	10208.8596	0	2964	570	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	1594.157722	0	1740.75	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3985.2	0	1609.086	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	2034.97	0	1347.5	0	11147.5	11147.5	3185	3185	0	0	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	494.837	557.5	0	0	0
17	10123.75	9894.486	0	2892.5	0	0	0	0	0	0	10123.75	9894.486	0	2892.5	0	445	556.25	0	0	0
18	10032.75	10032.75	0	2866.5	0	1451.478	0	0	0	0	10032.75	10032.75	0	2866.5	0	1451.478	551.25	0	0	0
19	10101	10101	0	2886	0	1776	0	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	0	0	0	1812	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
21	10510.5	10510.5	0	0	3742.2	1848	0	0	0	0	10510.5	10510.5	0	0	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	0	3717.9	0	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	10351.25	2957.5	0	3685.5	0	0	0	0	785.785	10351.25	10351.25	0	0	0	0	1933.75	1251.25	0	0
24	10260.25	10260.25	2931.5	0	3653.1	0	0	0	0	0	10260.25	0	0	0	0	0	1246.90225	0	0	0

Table-6.72c: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 41-60) with PEVs and solar during summer

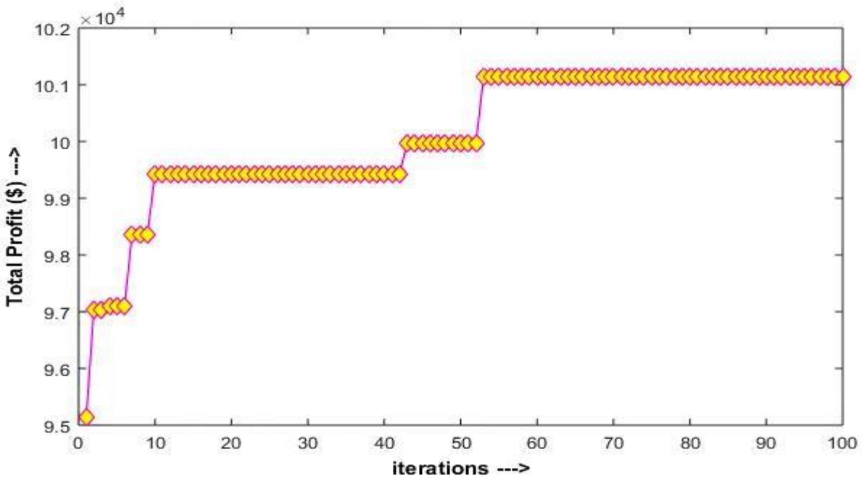
Hour	PGU41	PGU42	PGU43	PGU 44	PGU45	PGU46	PGU 47	PGU48	PGU 49	PGU 50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PGU56	PGU57	PGU 58	PGU 59	PGU 60
1	10078.25	8204.36	0	0	0	0	0	0	0	0	10078.25	8204.36	0	0	0	0	0	0	0	0
2	10010	7357.166667	0	0	0	0	0	0	0	0	10010	7357.166667	2860	2860	0	0	0	0	0	0
3	10510.5	10510.5	0	0	0	0	0	0	0	0	10510.5	10510.5	3003	3003	0	625.548	0	0	0	0
4	10305.75	10305.75	0	0	0	453	0	0	0	0	10305.75	10305.75	2944.5	2944.5	1452.2425	453	0	0	0	0
5	10578.75	10578.75	0	0	3766.5	557.966786	0	0	0	0	10578.75	10578.75	3022.5	3022.5	3766.5	557.966786	0	0	0	0
6	10442.25	10442.25	0	2983.5	3259.686857	459	0	0	0	0	10442.25	10442.25	2983.5	2983.5	3259.686857	459	0	0	0	0
7	10237.5	10237.5	2925	2925	2233.85	0	0	0	0	0	10237.5	10237.5	2925	2925	2233.85	450	0	0	0	0
8	10078.25	10078.25	2879.5	2879.5	1814.3508	0	0	0	0	0	10078.25	10078.25	2879.5	2879.5	1814.3508	0	0	0	0	0
9	10374	10208.8596	2964	2964	570	0	0	0	0	0	10374	10208.8596	2964	2964	570	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	1521.3866	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	1614.25	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	1486.998	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	1658.25	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	1594.157722	0	0	316.500057	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	316.500057
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	3985.2	1968	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	0	0	0	11147.5	11147.5	3185	3185	0	1960	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	1158.225	10237.5	10237.5	2925	2925	0	0	1912.5	0	0	1158.225
16	10146.5	10146.5	2899	0	0	0	0	0	0	0	10146.5	10146.5	2899	0	0	0	557.5	0	0	0
17	10123.75	9894.486	0	0	0	445	0	0	0	0	10123.75	9894.486	2892.5	0	0	0	556.25	0	0	0
18	10032.75	10032.75	0	0	0	1451.478	551.25	0	0	0	10032.75	10032.75	2866.5	0	0	0	0	0	0	0
19	10101	10101	0	0	0	1776	1773.891	0	0	0	10101	10101	0	0	0	0	0	0	0	0
20	10305.75	10305.75	0	0	0	1812	1914.0609	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
21	10510.5	10510.5	0	0	3742.2	0	0	0	0	0	10510.5	10510.5	0	0	0	0	0	0	0	0
22	10442.25	10442.25	0	0	3717.9	0	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	10351.25	2957.5	0	3685.5	0	0	0	0	0	10351.25	0	0	0	3685.5	0	1933.75	0	0	785.785
24	10260.25	0	2931.5	0	3653.1	0	0	0	0	0	10260.25	0	2931.5	2931.5	3653.1	0	1246.90225	0	0	0

Table-6.72d: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 61-80) with PEVs and solar during summer

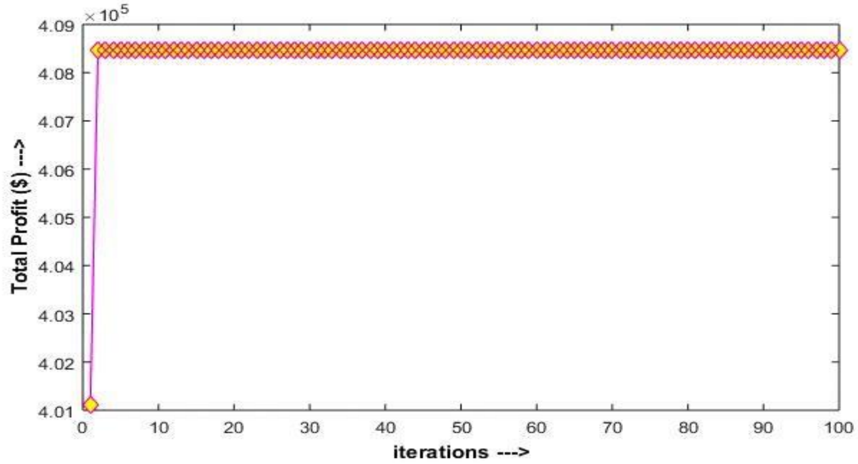
Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	10078.25	0	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	0	0	0	0	0	0	0	0	0	10010	0	2860	0	0	0	0	0	0	0
3	10510.5	0	0	0	0	0	0	0	0	0	10510.5	0	3003	0	0	0	577.5	0	0	0
4	10305.75	0	0	0	0	453	0	0	0	0	10305.75	0	2944.5	0	1452.2425	453	566.25	0	0	0
5	10578.75	0	3022.5	0	0	557.966786	0	0	0	0	10578.75	0	3022.5	3022.5	3766.5	557.966786	581.25	0	0	0
6	10442.25	0	2983.5	2983.5	0	459	0	0	0	0	10442.25	0	2983.5	2983.5	3259.686857	459	0	0	0	0
7	10237.5	0	2925	2925	0	450	0	0	0	0	10237.5	0	2925	2925	2233.85	450	0	0	0	0
8	10078.25	0	2879.5	2879.5	1814.3508	0	0	0	0	0	10078.25	0	2879.5	2879.5	1814.3508	0	0	0	0	0
9	10374	10208.8596	2964	2964	570	0	0	0	0	0	10374	10208.8596	2964	2964	570	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	1521.3866	0	1614.25	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	1658.25	0	13718.25	13718.25	3919.5	3919.5	4884.3	0	1486.998	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	0	1594.157722	0	0	316.500057
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	0	0	0	11147.5	11147.5	3185	3185	3969	1960	0	0	0	0
15	10237.5	10237.5	2925	2925	0	1800	1912.5	0	0	0	10237.5	10237.5	0	2925	0	1800	0	0	0	0
16	10146.5	10146.5	0	2899	0	494.837	557.5	0	0	0	10146.5	10146.5	0	0	0	494.837	0	0	0	0
17	10123.75	9894.486	0	2892.5	0	445	556.25	0	0	0	10123.75	9894.486	0	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	0	0	0	0	0	10032.75	10032.75	0	0	0	0	0	0	0	0
19	10101	10101	0	0	0	0	0	0	0	0	10101	10101	0	0	0	0	1773.891	0	0	0
20	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	0	0	0	1812	1914.0609	0	0	0
21	10510.5	10510.5	0	0	0	0	1809.0765	0	0	0	10510.5	10510.5	0	0	3742.2	1848	1809.0765	0	0	0
22	10442.25	10442.25	0	0	0	0	1544.076	0	0	0	10442.25	10442.25	0	2983.5	3717.9	1836	0	0	0	0
23	10351.25	0	0	0	0	0	1933.75	0	0	0	10351.25	0	0	2957.5	3685.5	1820	0	0	0	0
24	10260.25	0	0	0	0	0	0	0	0	0	10260.25	0	2931.5	2931.5	3653.1	0	0	0	0	0

Table-6.72e: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 81-100) with PEVs and solar during summer

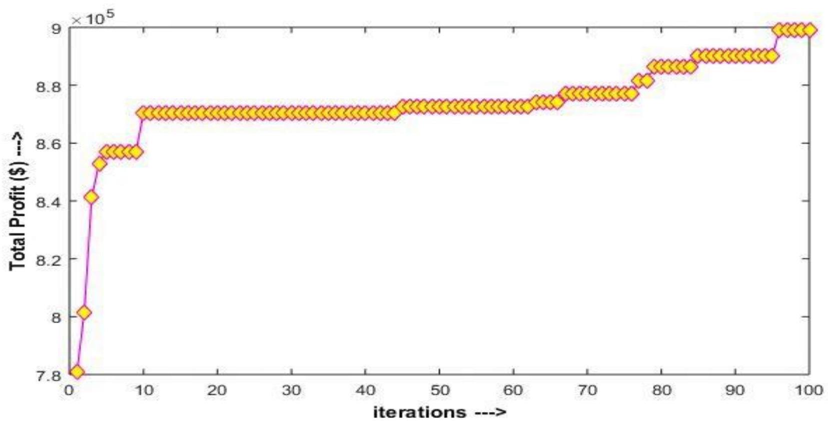
Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	10078.25	0	2879.5	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	0	2860	0	0	0	550	0	0	220	10010	0	2860	0	0	0	0	0	0	0
3	10510.5	0	3003	0	0	0	577.5	231	0	0	10510.5	0	3003	0	0	0	577.5	0	0	0
4	10305.75	0	2944.5	2944.5	0	0	566.25	0	0	0	10305.75	0	2944.5	0	1452.2425	0	566.25	0	0	0
5	10578.75	0	3022.5	3022.5	0	0	0	0	0	0	10578.75	0	3022.5	0	3766.5	0	581.25	0	0	0
6	10442.25	0	2983.5	2983.5	0	0	0	0	0	0	10442.25	0	2983.5	0	3259.686857	459	0	0	0	0
7	10237.5	0	2925	2925	2233.85	0	0	0	0	0	10237.5	0	2925	0	2233.85	450	0	0	0	0
8	10078.25	0	2879.5	2879.5	1814.3508	0	0	0	0	0	10078.25	0	2879.5	0	1814.3508	443	0	0	0	0
9	10374	10208.8596	2964	2964	570	0	0	0	0	0	10374	10208.8596	2964	0	570	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	1521.3866	0	0	0	13354.25	13354.25	3815.5	3815.5	0	0	1521.3866	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	1486.998	0	0	0	13718.25	13718.25	3919.5	3919.5	0	0	1486.998	0	1658.25	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	1594.157722	0	0	0	14400.75	14400.75	4114.5	4114.5	0	0	1594.157722	0	0	0
13	11193	11193	3198	3198	0	1968	0	0	0	0	11193	11193	3198	3198	0	0	0	0	0	0
14	11147.5	11147.5	3185	3185	0	0	0	0	0	0	11147.5	11147.5	3185	3185	0	1960	0	0	0	0
15	10237.5	10237.5	0	2925	0	0	0	0	0	0	10237.5	10237.5	0	2925	0	1800	0	1237.5	0	0
16	10146.5	10146.5	0	0	0	0	0	0	0	0	10146.5	10146.5	0	0	3612.6	494.837	0	0	0	0
17	10123.75	9894.486	0	0	0	445	0	0	0	0	10123.75	9894.486	0	0	556.25	0	0	0	0	0
18	10032.75	10032.75	0	0	0	1451.478	551.25	0	0	0	10032.75	10032.75	0	0	3572.1	0	0	0	0	0
19	10101	10101	0	0	0	1776	1773.891	0	0	0	10101	10101	0	0	3596.4	0	0	0	0	0
20	10305.75	10305.75	0	0	3669.3	0	1914.0609	0	0	0	10305.75	10305.75	0	0	3669.3	0	0	0	0	0
21	10510.5	10510.5	0	0	3742.2	0	0	0	0	0	10510.5	10510.5	0	0	3742.2	0	0	0	0	0
22	10442.25	10442.25	0	0	3717.9	0	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	0	0	0	3685.5	0	0	0	0	0	10351.25	0	2957.5	0	0	1820	0	0	0	0
24	10260.25	0	0	0	3653.1	0	0	0	0	0	10260.25	0	2931.5	0	0	1804	0	0	0	0



(a) 10-Unit system



(b) 40-Unit system



(c) 100-Unit system

Fig.6.21: Convergence curve for 10-, 40 and 100-generating unit system using hCSMA-SCA optimization algorithm with PEVs and solar during summer

Table.6.73: Statistical analysis of results for hCHHO-SCA & hCSMA-SCA optimization algorithms with PEVs and solar during summer for PBUCP

Test Systems	**10 Unit System**		**40 Unit System**		**100 Unit System**	
Methods	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**
Best Profit	**101298.9838**	101131.6453	**407653.112**	400084.916	**993567.629**	896905.041
Average Profit	100391.3352	100392.3751	384539.001	357417.256	892776.679	834748.895
Worst Profit	99709.68569	99567.84371	358217.559	342990.61	837681.978	791104.008
Std.	382.1893966	337.1761769	14413.9354	11202.5492	45586.3615	23161.4793
Median	100298.387	100308.1526	385386.656	355187.621	875433.237	830451.297

Table.6.74: Hypothetical testing of hCHHO-SCA & hCSMA-SCA optimization algorithms with PEVs and solar during summer for PBUCP

Test Systems		**10 Unit System**		**40 Unit System**		**100 Unit System**	
Methods		**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**
Wilcoxon-rank sum test [p-value]		1.50584E-06	1.69548E-06	1.7344E-06	1.7344E-06	1.7344E-06	1.7344E-06
t-test	**p-value**	6.17042E-72	1.62919E-73	3.8607E-43	2.1668E-45	2.9706E-39	6.3399E-47
	h-value	1	1	1	1	1	1

Table.6.75: Comparison of computational time for hCHHO-SCA & hCSMA-SCA optimization algorithms with PEVs and solar during summer for PBUCP

Test Systems	**10 Unit System**		**40 Unit System**		**100 Unit System**	
Methods	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**
Best time (sec.)	0.125	0.0105478	0.21875	0.015625	0.46875	0.015625
Average time (sec.)	0.400520833	0.013020833	1.36041667	0.0171875	2.50885417	0.03802083
Worst time (sec.)	0.8125	0.015625	3	0.046875	5.015625	0.0625

6.6.9 Hybrid Chaotic Harris Hawks-Sine Cosine Optimization Algorithm with PEVs and solar PV during Winter

The proposed hCHHO-SCA include exploratory as well as exploitative phase that is stimulated by surprise attacks, the natures of explorations of prey and various strategies are based upon aggressive attacked phenomenon of the Harris hawks birds. This is one of the gradient-free with consideration of inhabitants based calculations for the new optimization strategy, which will be helpful to detail on any kinds of optimization issues. The number of populations are 40 for 10-, 40- and 100-generating unit systems.

6.6.9.1 Ten Generating Unit System

This test system is used to check the efficiency of the proposed hCHHO-SCA optimizer. The system contains of 10-generating unit system having a 24-hour electricity demand. The hCHHO-SCA technique is evaluated for 100 iterations. The hCHHO- SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.22**. The commitment status, the optimal scheduling and the profit table of the 10-generating unit system have been shown in Table-6.76a and Table-6.76b respectively.

The Table-6.76a presents the commitment status and optimum scheduling of the generators during 24 hours. The power generating units are represented as PGU. Here, in this case, the PGU1 and PGU2 are on for 24 hours. From 10 to 14 hours, the PGU3 is on. When then unit is on, it is denoted as ‘1’ and when the unit is off, then it is denoted as ‘0’. The PGU7 to PGU10 are remained off for 24 hours.

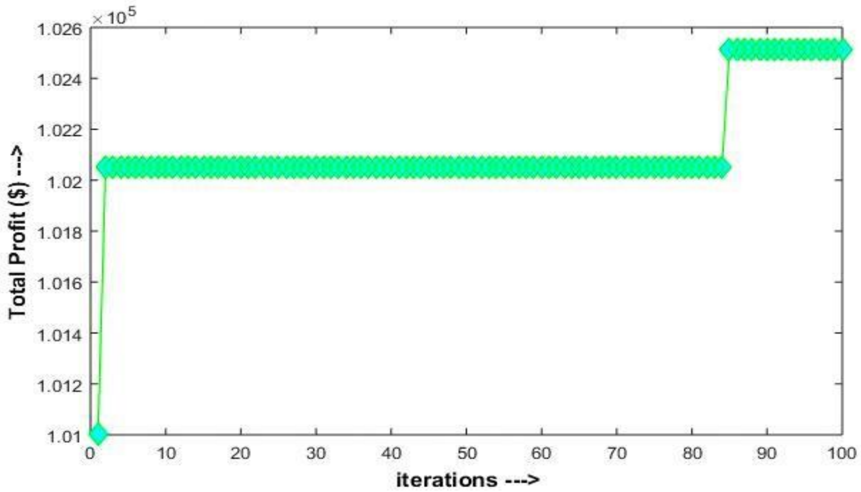
The Table-6.76b shows PGU1 generates 455 MW of power for 24 hours. The PGU3 generates 130 MGW of power for 10th, 11th, 12th, 13th and 14th hours. Further, the PGU4 is remain off for 6^{th} to 22^{nd} hours. In those time, for which the PFU4 is on, it generates 130 MW power for each hour.

Table-6.76a: Commitment status and scheduling for 10-generating unit system using hCHHO-SCA optimization algorithm with PEVs and solar during winter

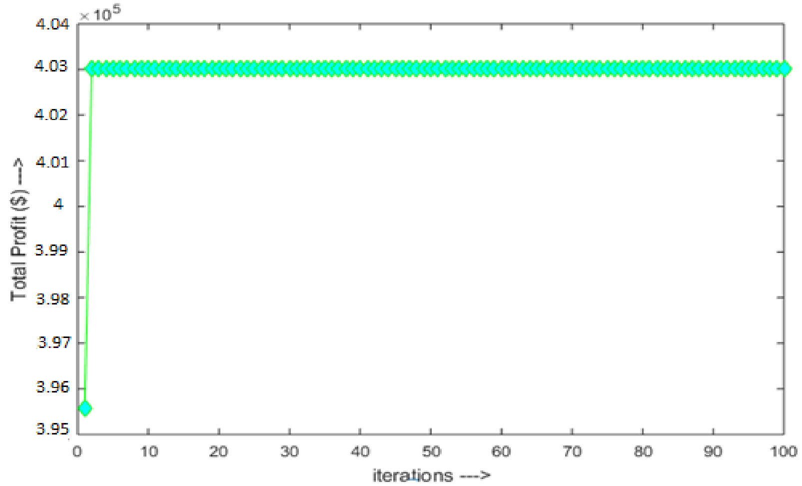
Commitment status of thermal units								Scheduling of the committed generating units						
HOURS	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**
1	1	1	0	0	0	0	0	455	277.4	0	0	0	0	0
2	1	1	0	0	0	0	0	455	316.5	0	0	0	0	0
3	1	1	0	0	0	0	0	455	416.24	0	0	0	0	0
4	1	1	0	0	1	0	0	455	455	0	0	42.35	0	0
5	1	1	0	0	1	0	0	455	455	0	0	112.99	0	0
6	1	1	0	1	1	0	0	455	455	0	130	39.24	0	0
7	1	1	0	1	1	0	0	455	443.54	0	130	25	0	0
8	1	1	0	1	1	0	0	455	433.67	0	130	25	0	0
9	1	1	0	1	1	0	0	455	455	0	130	82.6671	0	0
10	1	1	1	1	1	1	0	455	455	130	130	160.96	20	0
11	1	1	1	1	1	1	0	455	455	130	130	162	40.1700002	0
12	1	1	1	1	1	1	0	455	455	130	130	155.23	20	0
13	1	1	1	1	1	0	0	455	455	130	130	93.28	0	0
14	1	1	1	1	1	0	0	455	455	130	130	111.01	0	0
15	1	1	0	1	1	0	0	455	455	0	130	156.9	0	0
16	1	1	0	1	0	0	0	455	433.21	0	130	0	0	0
17	1	1	0	1	0	0	0	455	426.71	0	130	0	0	0
18	1	1	0	1	0	1	0	455	455	0	130	0	22.24	0
19	1	1	0	1	0	1	0	455	455	0	130	0	33.23	0
20	1	1	0	1	0	1	0	455	387.86	0	130	0	20	0
21	1	1	0	1	0	0	0	455	438.42	0	130	0	0	0
22	1	1	0	1	0	0	0	455	407.56	0	130	0	0	0
23	1	1	0	0	0	0	0	455	409.08	0	0	0	0	0
24	1	1	0	0	0	0	0	455	300.59	0	0	0	0	0

Table-6.76b: Hourly profit for 10-generating unit system using hCHHO-SCA optimization algorithm with PEVs and solar during winter

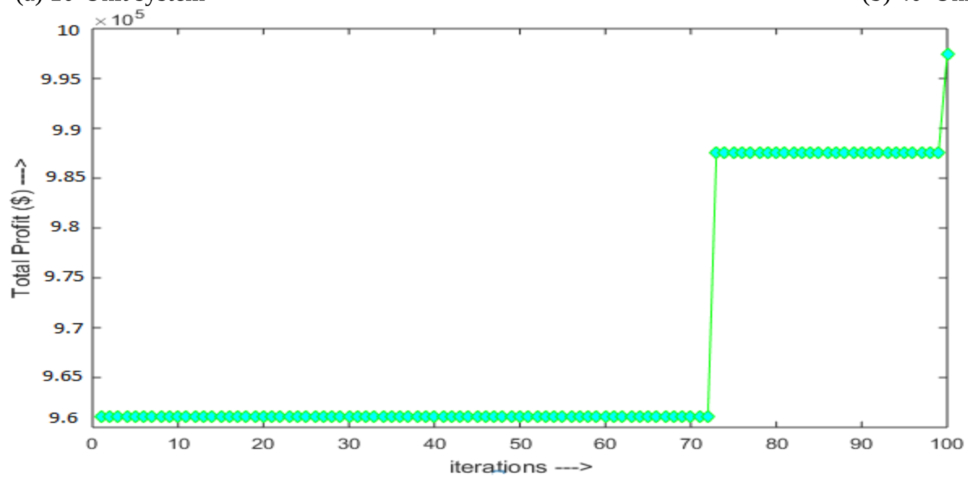
HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7 to PG10	Start-up Cost	Hourly Profit
1	10078.25	6144.41	0	0	0	0	0	870	16222.66
2	10010	6963	0	0	0	0	0	560	16973
3	10510.5	9615.144	0	0	0	0	0	170	20125.644
4	10305.75	10305.75	0	0	959.2275	0	0	900	21570.7275
5	10578.75	10578.75	0	0	2627.0175	0	0	0	23784.5175
6	10442.25	10442.25	0	2983.5	900.558	0	0	0	24768.558
7	10237.5	9979.65	0	2925	562.5	0	0	0	23704.65
8	10078.25	9605.7905	0	2879.5	553.75	0	0	0	23117.2905
9	10374	10374	0	2964	1884.80988	0	0	0	25596.8099
10	13354.25	13354.25	3815.5	3815.5	4724.176	587	0	60	39650.676
11	13718.25	13718.25	3919.5	3919.5	4884.3	1211.12551	0	170	41370.9255
12	14400.75	14400.75	4114.5	4114.5	4913.0295	633	0	520	42576.5295
13	11193	11193	3198	3198	2294.688	0	0	0	31076.688
14	11147.5	11147.5	3185	3185	2719.745	0	0	0	31384.745
15	10237.5	10237.5	0	2925	3530.25	0	0	0	26930.25
16	10146.5	9660.583	0	2899	0	0	0	0	22706.083
17	10123.75	9494.2975	0	2892.5	0	0	0	0	22510.5475
18	10032.75	10032.75	0	2866.5	0	490.392	0	0	23422.392
19	10101	10101	0	2886	0	737.706	0	60	23825.706
20	10305.75	8785.029	0	2944.5	0	453	0	0	22488.279
21	10510.5	10127.502	0	3003	0	0	0	900	23641.002
22	10442.25	9353.502	0	2983.5	0	0	0	0	22779.252
23	10351.25	9306.57	0	0	0	0	0	0	19657.82
24	10260.25	6778.3045	0	0	0	0	0	0	17038.5545



(a) 10-Unit system



(b) 40-Unit system



(c) 100-Unit system

Fig.6.22: Convergence curve for 10-, 40- and 100-generating unit system using hCHHO-SCA optimization algorithm with PEVs and solar during winter

6.6.9.2 Forty Generating Unit System

The test system is used to check the efficiency of the proposed hCHHO-SCA optimizer. The system contains of 40-generating unit system having a 24-hour electricity demand. The hCHHO-SCA technique is evaluated for 100 iterations. PEVs are fit for supporting the network with enormous combination of RES by charging the excess amount of energy and by discharging i.e. returning this to the power grid when it's required. A profit based analysis on this stochastic method for optimization of hourly profit, fuel costs, startup costs are formulated by minimizing the total operating costs including the uncertainty of solar PV with PEVs during winter for the proposed hybrid system. The hCHHO-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.22**. The hourly profit with fuel cost are given in Table-6.77. The optimal scheduling of 40-generating unit systems are shown in Table-6.78a and Table-6.78b. The hourly profit table for this system is shown in Table-6.79a and Table-6.79b respectively.

Table-6.77: Hourly profit with startup cost and fuel cost for 40-generating unit system using hCHHO-SCA optimization algorithm with PEVs and solar during winter

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	62737.66	2450	54353.2239	**13**	129378.288	180	106998.462
2	66473	610	57660.3502	**14**	126934.745	410	104842.711
3	79030.644	4770	65830.2973	**15**	107930.25	60	95633.9638
4	83405.2275	900	71571.0817	**16**	92282.083	0	80535.9114
5	93534.5175	0	79357.7444	**17**	89260.5475	260	79418.5039
6	96372.558	2620	83190.5318	**18**	92218.392	2020	83376.7681
7	93904.65	510	82665.546	**19**	93089.706	260	83694.6256
8	92225.2905	270	82465.3242	**20**	93156.279	1360	80432.0703
9	105624.81	5380	91636.9756	**21**	95713.002	1510	80761.8901
10	162920.676	490	113597.51	**22**	94383.252	2730	80129.8773
11	169086.326	30	115262.745	**23**	81082.82	560	70422.6366
12	176645.93	490	114637.483	**24**	71158.5545	1800	62614.4157

Table-6.78a: Generation scheduling for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with PEVs and solar during winter

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU 7-10	PGU 11	PGU-12	PGU-13	PGU-14	PGU-15	PGU-16	PGU-17	PGU-18-20
1	455	337.46667	0	0	0	0	0	455	337.46667	0	0	0	0	0	0
2	455	400.5	0	0	0	0	0	455	400.5	0	0	0	0	0	0
3	455	447.08	0	130	0	0	0	455	447.08	0	130	0	0	0	0
4	455	447.45	0	130	0	0	0	455	447.45	0	130	0	0	0	0
5	455	455	0	130	57.99	0	0	455	455	130	130	0	0	0	0
6	455	455	130	130	104.24	0	0	455	455	130	130	0	0	0	0
7	455	455	130	130	78.54	0	0	455	455	130	130	0	0	0	0
8	455	455	130	130	68.670001	0	0	455	455	130	130	0	0	0	0
9	455	455	130	130	82.6671	0	0	455	455	130	130	0	0	0	0
10	455	455	130	130	162	74.32	0	455	455	130	130	162	74.32	0	0
11	455	455	130	130	162	70.0425	0	455	455	130	130	162	70.0425	0	0
12	455	455	130	130	162	63.3075	0	455	455	130	130	162	63.3075	0	0
13	455	455	130	130	0	74.426667	0	455	455	130	0	162	0	0	0
14	455	455	130	130	0	0	0	455	455	130	0	162	0	0	0
15	455	455	130	130	0	0	0	455	455	130	0	125.63333	0	0	0
16	455	449.5525	130	130	0	0	0	455	449.5525	130	0	0	0	0	0
17	455	455	0	130	0	80	0	455	455	0	0	0	80	81.71	0
18	455	455	0	130	0	80	0	455	455	0	130	0	80	42.24	0
19	455	455	0	0	162	78.743333	0	455	455	0	130	0	78.743333	25	0
20	455	455	0	0	162	0	0	455	455	0	130	0	0	0	0
21	455	455	0	0	113.42	0	0	455	455	0	130	0	0	0	0
22	455	455	0	0	82.56	0	0	455	455	0	130	0	0	0	0
23	455	0	130	0	54.08	0	0	455	455	0	130	0	0	0	0
24	455	0	130	0	25	0	0	455	330.295	0	0	0	0	0	0

The optimal power generation scheduling for 40-generating unit system using hCHHO-SCA optimizer have been shown in Table-6.78a and Table-6.78b. Out of 40-generating units Table-6.82a represent PGU1 to PGU20 for 24 hours considering PEVs and solar in winter. The optimal scheduling have been obtained 455 MW from PGU1 and PGU11. The PGU7 to PGU10 and PGU18 to PGU20 remain off during 24 hours. So, the output power is became '0'. The PGU4 and PGU13 have been on for few hours. Thus the optimum scheduling can be obtain for that particular hour.

Table-6.78b: Generation scheduling for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40) with PEVS and solar during winter

HOURS	PGU 21	PGU 22	PGU 23	PGU 24	PGU 25	PGU 26	PGU 27-30	PGU 31	PGU 32	PGU 33	PGU 34	PGU 35	PGU 36	PGU 37-40
1	455	337.46667	0	0	0	0	0	455	0	0	0	0	0	0
2	455	400.5	0	0	0	0	0	455	0	0	0	0	0	0
3	455	447.08	0	0	0	0	0	455	0	0	0	0	0	0
4	455	447.45	0	130	0	0	0	455	0	0	130	0	0	0
5	455	455	0	130	0	0	0	455	0	130	130	0	0	0
6	455	455	0	130	0	0	0	455	0	130	130	0	0	0
7	455	455	0	130	0	0	0	455	0	130	130	0	0	0
8	455	455	0	130	0	0	0	455	0	130	130	0	0	0
9	455	455	0	130	0	0	0	455	455	130	130	0	0	0
10	455	455	130	130	162	0	0	455	455	130	130	162	74.32	0
11	455	455	130	130	162	70.0425	0	455	455	130	130	162	70.0425	0
12	455	455	130	130	162	63.3075	0	455	455	130	130	162	63.3075	0
13	455	455	130	130	162	74.426667	0	455	455	130	130	162	74.426667	0
14	455	455	130	130	162	72.505	0	455	455	130	130	162	72.505	0
15	455	455	0	130	125.63333	0	0	455	455	130	130	125.63333	0	0
16	455	449.5525	0	130	0	0	0	455	449.5525	0	0	0	0	0
17	455	455	0	0	0	0	0	455	455	0	0	0	0	0
18	455	455	0	0	0	80	0	455	455	0	0	0	0	0
19	455	455	0	0	0	78.743333	0	455	455	0	0	0	0	0
20	455	455	130	0	0	50.86	0	455	455	0	0	0	0	0
21	455	455	130	0	0	0	0	455	455	0	130	0	0	0
22	455	455	130	0	0	0	0	455	455	0	130	0	0	0
23	455	0	130	130	0	0	0	455	455	130	130	0	0	0
24	455	0	130	130	0	0	0	455	330.295	130	130	0	0	0

The suggested hCHHO-SCA optimization algorithm is used to solve PBUCP for 40-unit test system with PEVs and solar in winter. The Table-6.78b represents the optimum scheduling of PGU21 to PGU40. The power scheduling for PGU21 and PGU31 is 455 MW for 24 hours. Further, PGU27 to PGU30 and PGU37 to PGU40 has been off throughout the 24 hours. For 4^{th} to 16^{th} hours and 23^{rd} to 24^{th} hours, the PGU24 have been on. The optimal power generation is 130 MW for that particular hour.

Table-6.79a and Table-6.79b represents the hourly profit for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with PEVs and solar during winter.

Table-6.79a: Hourly profit for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with PEVs and solar during winter

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	GPU16	PGU17	PGU 18	PGU19	PGU 20
1	10078.25	7474.88667	0	0	0	0	0	0	0	0	10078.25	7474.88667	0	0	0	0	0	0	0	0
2	10010	8811	0	0	0	0	0	0	0	0	10010	8811	0	0	0	0	0	0	0	0
3	10510.5	10327.548	0	3003	0	0	0	0	0	0	10510.5	10327.548	0	3003	0	0	0	0	0	0
4	10305.75	10134.7425	0	2944.5	0	0	0	0	0	0	10305.75	10134.7425	0	2944.5	0	0	0	0	0	0
5	10578.75	10578.75	0	3022.5	1348.2675	0	0	0	0	0	10578.75	10578.75	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	10442.25	2983.5	2983.5	2392.308	0	0	0	0	0	10442.25	10442.25	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	10237.5	2925	2925	1767.15001	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
8	10078.25	10078.25	2879.5	2879.5	1521.04051	0	0	0	0	0	10078.25	10078.25	2879.5	2879.5	0	0	0	0	0	0
9	10374	10374	2964	2964	1884.80988	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2181.292	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2181.292	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2111.78138	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2111.78138	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2003.68238	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2003.68238	0	0	0	0
13	11193	11193	3198	3198	0	1830.896	0	0	0	0	11193	11193	3198	0	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	0	0	0	0	0	0	11147.5	11147.5	3185	0	3969	0	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	0	2826.75	0	0	0	0	0
16	10146.5	10025.0208	2899	2899	0	0	0	0	0	0	10146.5	10025.0208	2899	0	0	0	0	0	0	0
17	10123.75	10123.75	0	2892.5	0	1780	0	0	0	0	10123.75	10123.75	0	0	0	1780	1818.0475	0	0	0
18	10032.75	10032.75	0	2866.5	0	1764	0	0	0	0	10032.75	10032.75	0	2866.5	0	1764	931.392007	0	0	0
19	10101	10101	0	0	3596.4	1748.102	0	0	0	0	10101	10101	0	2886	0	1748.102	555	0	0	0
20	10305.75	10305.75	0	0	3669.3	0	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	0	0	0	0
21	10510.5	10510.5	0	0	2620.002	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	0	0	1894.752	0	0	0	0	0	10442.25	10442.25	0	2983.5	0	0	0	0	0	0
23	10351.25	0	2957.5	0	1230.32	0	0	0	0	0	10351.25	10351.25	0	2957.5	0	0	0	0	0	0
24	10260.25	8913.90225	2931.5	0	563.75	0	0	0	0	0	10260.25	8913.90225	2931.5	0	0	0	0	0	0	0

Table-6.79b: Hourly profit for 40-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40) with PEVs and solar during winter

HOURS	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PG34	PGU35	GPU36	PGU37	PGU 38	PGU39	PGU 40
1	10078.25	7474.88667	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	8811	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	10327.548	0	0	0	0	0	0	0	0	10510.5	0	0	0	0	0	0	0	0	0
4	10305.75	10134.7425	0	2944.5	0	0	0	0	0	0	10305.75	0	0	2944.5	0	0	0	0	0	0
5	10578.75	10578.75	0	3022.5	0	0	0	0	0	0	10578.75	0	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	10442.25	0	2983.5	0	0	0	0	0	0	10442.25	0	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	10237.5	0	2925	0	0	0	0	0	0	10237.5	0	2925	2925	0	0	0	0	0	0
8	10078.25	10078.25	0	2879.5	0	0	0	0	0	0	10078.25	0	2879.5	2879.5	0	0	0	0	0	0
9	10374	10374	0	2964	0	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2181.292	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2111.78138	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2111.78138	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2003.68238	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2003.68238	0	0	0	0
13	11193	11193	3198	3198	3985.2	1830.896	0	0	0	0	11193	11193	3198	3198	3985.2	1830.896	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	1776.3725	0	0	0	0	11147.5	11147.5	3185	3185	3969	1776.3725	0	0	0	0
15	10237.5	10237.5	0	2925	2826.75	0	0	0	0	0	10237.5	10237.5	2925	2925	2826.75	0	0	0	0	0
16	10146.5	10025.0208	0	2899	0	0	0	0	0	0	10146.5	10025.0208	0	0	0	0	0	0	0	0
17	10123.75	10123.75	0	0	0	0	0	0	0	0	10123.75	10123.75	0	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	1764	0	0	0	0	10032.75	10032.75	0	0	0	0	0	0	0	0
19	10101	10101	0	0	0	1748.102	0	0	0	0	10101	10101	0	0	0	0	0	0	0	0
20	10305.75	10305.75	2944.5	0	0	1151.97901	0	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
21	10510.5	10510.5	3003	0	0	0	0	0	0	0	10510.5	10510.5	0	3003	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	0	0	0	0	0	0	0	10442.25	10442.25	0	2983.5	0	0	0	0	0	0
23	10351.25	0	2957.5	2957.5	0	0	0	0	0	0	10351.25	10351.25	2957.5	2957.5	0	0	0	0	0	0
24	10260.25	0	2931.5	2931.5	0	0	0	0	0	0	10260.25	7448.15225	2931.5	2931.5	0	0	0	0	0	0

6.6.9.3 Hundred Generating Unit System

The test system is used to check the efficiency of the proposed hCHHO-SCA optimizer. The system contains of 100-generating unit system having a 24-hour electricity demand. The hCHHO-SCA technique is evaluated for 100 iterations. The hCHHO-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.22**. The optimal scheduling of 100-generating unit systems are shown in Table-6.81a to Table-6.81e. The hourly profit table for this system is shown in Table-6.82a to Table-6.82e respectively. The profit with start-up cost and fuel cost of 24 hours are shown in Table-6.80.

Table-6.80: Hourly profit with start-up cost and fuel cost for100-generating unit system using hCHHO-SCA optimization algorithm with PEVs and solar during winter

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	155767.66	5800	137395.48	**13**	325981.49	1030	271865.3
2	165473	3910	145920.03	**14**	318034.75	1170	263650.48
3	196840.64	5670	165149.98	**15**	269930.25	2780	240874.16
4	207074.23	2760	176634.86	**16**	231434.08	1200	203226.18
5	233034.52	3120	194459.52	**17**	222760.55	700	195904.98
6	239580.56	2040	203501.8	**18**	229810.39	580	204660.52
7	234304.65	2390	204646.5	**19**	231617.71	2060	210086
8	230441.29	2760	205703.23	**20**	234492.28	5110	205388.6
9	265680.81	16270	230453.53	**21**	239857	4630	204550.59
10	409460.68	2240	290657.44	**22**	237591.25	3230	202176.71
11	424517.13	1000	292598.2	**23**	203932.82	3160	174623.51
12	444784.73	590	291856.51	**24**	179398.55	2910	163376.24

Table-6.81a: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 1-20) with PEVs and solar during winter

HOUR	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	455	248.24	0	0	0	0	0	0	0	0	455	248.24	0	0	0	0	0	0	0	0
2	455	297.15	0	0	0	0	0	0	0	0	455	297.15	0	0	0	0	0	0	0	0
3	455	358.124	0	0	0	0	0	0	0	0	455	358.124	0	0	0	0	0	0	0	0
4	455	407.235	0	0	0	0	0	0	0	0	455	407.235	0	0	0	0	0	0	0	0
5	455	443.299	0	130	0	0	0	0	0	0	455	443.299	0	130	0	0	0	0	0	0
6	455	445.924	0	130	0	0	0	0	0	0	455	445.924	0	130	0	0	0	0	0	0
7	455	425.354	0	130	0	0	0	0	0	0	455	425.354	0	130	0	0	0	0	0	0
8	455	398.367	130	130	0	0	0	0	0	0	455	398.367	130	130	0	0	0	0	0	0
9	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
10	455	455	130	130	162	0	0	0	55	40.48	455	455	130	130	162	0	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	82.5425	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	76.646	0	0	0
13	455	455	130	130	162	78.056	0	0	0	0	455	455	130	130	162	78.056	25	0	0	0
14	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
15	455	455	0	130	162	0	0	0	55	0	455	455	0	130	162	0	0	0	0	0
16	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
17	455	436.671	0	130	0	0	0	0	0	0	455	436.671	0	130	0	0	0	0	0	0
18	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	80	0	0	0	0
19	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	80	0	0	0	0
20	455	455	0	130	0	80	0	0	0	0	455	455	0	130	0	80	0	0	0	0
21	455	455	0	0	0	71.105	0	0	0	0	455	455	0	0	0	0	0	0	0	0
22	455	455	0	0	0	20	0	0	0	0	455	455	0	0	0	0	0	0	0	0
23	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
24	455	455	0	0	162	0	0	0	0	0	455	455	0	0	0	0	66.795	0	0	0

Table-6.81b: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 21-40) with PEVs and solar during winter

HOUR	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	248.24	0	0	0	0	0	0	0	0	455	248.24	0	0	0	0	0	0	0	0
2	455	297.15	0	0	0	0	0	0	0	0	455	297.15	0	0	0	0	0	0	0	0
3	455	358.124	0	0	0	0	0	0	0	0	455	358.124	0	130	0	0	0	0	0	0
4	455	407.235	130	0	0	0	0	0	0	0	455	407.235	0	130	0	0	0	0	0	0
5	455	443.299	130	0	0	0	0	0	0	0	455	443.299	0	130	0	0	0	0	0	0
6	455	445.924	130	130	0	0	0	0	0	0	455	445.924	0	130	0	0	0	0	0	0
7	455	425.354	130	130	25	0	0	0	0	0	455	425.354	0	130	25	0	0	0	0	0
8	455	398.367	130	130	25	0	0	0	0	0	455	398.367	0	130	25	0	0	0	0	0
9	455	455	130	130	106.33355	0	0	0	0	0	455	455	130	130	106.33355	0	0	0	0	0
10	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	55	0	40.48
11	455	455	130	130	162	0	0	55	0	0	455	455	130	130	162	0	0	0	0	0
12	455	455	130	130	162	0	76.646	0	0	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	0	0	25	0	0	0	455	455	130	130	0	78.056	0	0	0	0
14	455	455	130	130	0	0	67.505	0	0	0	455	455	130	130	0	80	0	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
16	455	455	130	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
17	455	436.671	0	130	0	0	0	0	0	0	455	436.671	0	130	0	0	0	0	0	0
18	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
19	455	455	0	130	0	80	0	0	0	0	455	455	0	130	0	0	0	0	0	0
20	455	455	0	130	0	80	0	0	0	0	455	455	0	130	0	0	0	0	0	0
21	455	455	0	0	162	71.105	0	0	0	0	455	455	0	0	162	0	0	0	0	0
22	455	455	0	0	150.85333	0	0	0	0	0	455	455	0	0	150.85333	0	0	0	0	0
23	455	455	0	0	149.69333	0	0	0	0	0	455	455	0	0	149.69333	0	0	0	0	0
24	455	0	0	0	162	0	0	0	0	0	455	0	0	0	162	80	0	55	0	0

Table-6.81c: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 41-60) with PEVs and solar during winter

Hour	PGU41	PGU42	PGU43	PGU44	PGU45	PGU46	PGU47	PGU48	PGU49	PGU50	PGU51	PGU52	PGU53	PGU54	PGU55	PGU56	PGU57	PGU58	PGU59	PGU60
1	455	248.24	0	0	0	0	0	0	0	0	455	248.24	0	0	0	0	0	0	0	0
2	455	297.15	0	0	0	0	0	0	0	0	455	297.15	0	0	0	0	0	0	0	0
3	455	358.124	0	130	0	0	0	0	0	0	455	358.124	0	0	0	0	0	0	0	0
4	455	407.235	0	130	0	0	0	0	0	0	455	407.235	0	0	0	0	0	0	0	0
5	455	443.299	0	130	0	0	0	0	0	0	455	443.299	0	0	0	0	0	0	0	0
6	455	445.924	0	130	0	0	0	0	0	0	455	445.924	0	130	0	0	0	0	0	0
7	455	425.354	0	130	0	0	0	0	0	0	455	425.354	0	130	0	0	0	0	0	0
8	455	398.367	0	130	0	0	0	0	0	0	455	398.367	0	130	0	0	0	0	0	0
9	455	455	130	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
10	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	55	0	0
11	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	55	0	0
12	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
15	455	455	0	130	162	0	0	0	0	0	455	455	0	130	162	0	0	0	0	0
16	455	455	0	130	29.403333	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
17	455	436.671	0	130	0	0	0	0	0	0	455	436.671	0	130	0	0	0	0	0	0
18	455	455	0	130	0	80	0	0	0	0	455	455	0	130	0	0	42.24	0	0	0
19	455	455	0	0	0	80	0	55	0	0	455	455	0	0	0	80	84.115	55	0	0
20	455	455	0	0	0	80	0	0	0	0	455	455	0	0	0	80	61.43	0	0	0
21	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	71.105	0	0	0	0
22	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
23	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
24	455	0	0	130	0	80	0	0	0	0	455	0	0	130	162	0	0	55	0	0

The Table-6.81a represents the generation scheduling of 100-generating unit system with effect of PEVs and solar PV in winter using hCHHO-SCA optimization algorithm for PGU1 to PGU20. Where PGU1, PGU2, PGU11 and PGU12 are remain on for 24 hours. The 455 MW power output can be measured from PGU1 and PGU11 for 24 hours. PGU7 to PGU8 and PGU18 to PGU20 is totally off for 24 hours. So, no power generation can be obtained from those units. Further others unit are on for some few hours and off some few hours. Thus the optimal generation can be taken only those are in on condition.

Table-6.81b gives the optimal power scheduling of 100-uniut system with effect of PEVs and solar PV in winter by suggested hCHHO-SCA method for PGU21 to PGU40. The PGU21 and PGU31 are in on condition for 24 hours. And other PGU are sometimes on and sometimes off. PGU29 to PGU39 are off during 24 hours.

Table-6.81c presents the generation scheduling of 100-unit system with effect of PEVs and solar PV in winter using proposed hCHHO-SCA optimization algorithm for PGU41 to PGU60. Here, PGU41 and PGU51 are on for 24 hours. The 455 MW power can be generated from PGU41 and PGU51. The output power is ‘0’ for PGU49 to PGU50 and PGU59 to PGU60. The PGU46 generate 80 MW power for 18th to 20th hours and 24th hour also. The other PGU are on and off for few hours and output power generation can be measured through the table.

Thable-6.81d signifies the generation scheduling of 100-generating unit by hCHHO-SCA algorithm for PGU61 to PGU80 considering the effect of PEVs and solar PV in winter. The PGU61 and PGU71 is on for 24 hours. The 455 MW power output can be shown from PGU61 and PGU71 for 24 hours. The power output from PGU70, PGU79 and PGU80 is ‘0’ for 24 hours.

Table-6.81d: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 61-80) with PEVs and solar during winter

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	455	248.24	0	0	0	0	0	0	0	0	455	248.24	0	0	0	0	0	0	0	0
2	455	297.15	0	0	0	0	0	0	0	0	455	297.15	0	0	0	0	0	0	0	0
3	455	358.124	0	130	0	0	0	0	0	0	455	358.124	0	0	0	0	0	0	0	0
4	455	407.235	0	130	0	0	0	0	0	0	455	407.235	0	0	0	0	0	0	0	0
5	455	443.299	0	130	0	0	0	0	0	0	455	443.299	0	0	0	0	0	0	0	0
6	455	445.924	0	130	0	0	0	0	0	0	455	445.924	0	130	0	0	0	0	0	0
7	455	425.354	0	130	0	0	0	0	0	0	455	425.354	0	130	0	0	0	0	0	0
8	455	398.367	0	130	0	0	0	0	0	0	455	398.367	0	130	0	0	0	0	0	0
9	455	455	130	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
10	455	455	130	130	162	0	0	55	0	0	455	455	130	130	162	0	85	0	0	0
11	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	82.5425	0	0	0
12	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	80	76.646	0	0	0
13	455	455	130	130	162	78.056	25	0	0	0	455	455	130	130	162	78.056	25	0	0	0
14	455	455	0	130	162	80	67.505	0	0	0	455	455	130	130	162	80	0	0	0	0
15	455	455	0	130	162	80	35.9	0	0	0	455	455	0	130	162	0	0	0	0	0
16	455	455	0	130	0	20	0	0	0	0	455	455	0	130	29.403333	0	0	0	0	0
17	455	436.671	0	130	0	0	0	0	10	0	455	436.671	0	130	25	0	0	0	0	0
18	455	455	0	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
19	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	80	0	55	0	0
20	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	80	0	0	0	0
21	455	455	130	0	0	0	0	0	0	0	455	455	130	0	0	71.105	0	0	0	0
22	455	455	130	0	150.85333	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
23	455	0	130	0	149.69333	0	0	0	0	0	455	0	130	0	0	0	0	0	0	0
24	455	0	130	0	162	80	0	0	0	0	455	0	130	0	0	0	66.795	0	0	0

Table-6.81e: Generation scheduling for 100-generating unit system using hCHHO-SCA optimization algorithm (Units 81-100) with PEVs and solar during winter

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	455	248.24	0	0	0	0	0	0	0	0	455	248.24	0	0	0	0	0	0	0	0
2	455	297.15	0	0	0	0	0	0	0	0	455	297.15	0	0	0	0	0	0	0	0
3	455	358.124	0	0	0	0	0	0	0	0	455	358.124	0	0	0	0	0	0	0	0
4	455	407.235	0	0	0	0	0	0	0	0	455	407.235	0	0	0	0	0	0	0	0
5	455	443.299	130	0	0	0	0	0	0	0	455	443.299	130	0	0	0	0	0	0	0
6	455	445.924	130	0	0	0	0	0	0	0	455	445.924	130	0	0	0	0	0	0	0
7	455	425.354	130	130	0	0	0	0	0	0	455	425.354	130	0	0	0	0	0	0	0
8	455	398.367	130	130	0	0	0	0	0	0	455	398.367	130	0	0	0	0	0	0	0
9	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
10	455	455	130	130	162	0	85	0	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	0	82.5425	0	0	0	455	455	130	130	162	80	82.5425	0	0	0
12	455	455	130	130	162	0	76.646	0	0	0	455	455	0	130	162	80	76.646	0	0	0
13	455	455	0	130	162	0	0	0	0	0	455	455	0	130	162	0	25	0	0	0
14	455	455	0	130	162	0	0	0	0	0	455	455	0	130	162	0	0	0	0	0
15	455	455	0	0	162	0	0	0	0	0	455	455	0	130	162	0	0	0	0	0
16	455	455	0	0	0	0	0	0	0	0	455	455	0	0	29.403333	0	0	0	0	0
17	455	436.671	0	0	0	0	0	0	0	0	455	436.671	0	0	0	20	0	0	0	0
18	455	455	0	0	0	0	0	0	0	0	455	455	0	0	0	80	0	0	0	0
19	455	455	0	0	0	0	84.115	0	0	0	455	455	0	0	0	80	0	0	0	0
20	455	455	0	130	0	0	61.43	0	0	0	455	455	0	0	0	0	0	0	0	0
21	455	455	0	130	0	0	25	0	0	0	455	455	130	130	0	0	0	0	0	0
22	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
23	455	0	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
24	455	0	130	130	162	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0

Table-6.81e gives the optimal power scheduling of 100-unit system by suggested hCHHO-SCA method for PGU81 to PGU100 considering the effect of PEVs and solar PV in winter. PGU88, PGU89, PGU90 and PGU98 to PGU100 is totally off throughout the day. So, no power generation can be obtained from those units. Further others unit are on for some few hours and off some few hours. Thus the optimal generation can be taken only those are in on condition.

Table-6.82a shows the best profit of PGU1 to PGU20 for each unit for particular hours considering the effect of PEVs and solar PV in winter. The duration of total hour is 24 hours. The suggested hCHHO-SCA optimizer is tested on 100-unit system.

Table-6.82b represents the hourly profit for 100-generating unit system by hCHHO-SCA optimizer for PGU21 to PGU40 with PEVs and solar PV in winter. The PGU21 and PGU31 are on throughout 24 hours. So, for those units the profit values are obtained in each hour. The PGU28 is on only for 11^{th} hours and the profit can be obtained as 1658.25 $ for 11^{th} hour, and for other time period it will be off throughout the day.

The Table-6.82c is presented the hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm for units 41 to unit 60 with PEVs and solar PV in winter. The PGU41 and PGU51 remain on for 24 hours. The PGU49 to PGU50 and PGU59 to PGU60 remain close throughout the whole day. That’s why no profit come from those units, the output is ‘0’.

The Table-6.82d and Table-6.62e is presented the hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm for PGU61 to PGU80 and PGU81 to PGU100 with PEVs and solar PV in winter. The PGU61, PGU71, PGU81 and PGU91 remain on for 24 hours. The PGU70, PGU79, PGU80, PGU88, PGU98 to PGU100 as remain close throughout the whole day. That’s why no profit come from those units, the output is ‘0’.

Table-6.82a: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 1-20) with PEVs and solar during winter

Hour	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	10078.25	5498.516	0	0	0	0	0	0	0	0	10078.25	5498.516	0	0	0	0	0	0	0	0
2	10010	6537.3	0	0	0	0	0	0	0	0	10010	6537.3	0	0	0	0	0	0	0	0
3	10510.5	8272.6644	0	0	0	0	0	0	0	0	10510.5	8272.6644	0	0	0	0	0	0	0	0
4	10305.75	9223.8728	0	0	0	0	0	0	0	0	10305.75	9223.8728	0	0	0	0	0	0	0	0
5	10578.75	10306.702	0	3022.5	0	0	0	0	0	0	10578.75	10306.702	0	3022.5	0	0	0	0	0	0
6	10442.25	10233.956	0	2983.5	0	0	0	0	0	0	10442.25	10233.956	0	2983.5	0	0	0	0	0	0
7	10237.5	9570.465	0	2925	0	0	0	0	0	0	10237.5	9570.465	0	2925	0	0	0	0	0	0
8	10078.25	8823.8291	2879.5	2879.5	0	0	0	0	0	0	10078.25	8823.8291	2879.5	2879.5	0	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	1614.25	1188.088	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	2488.6564	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2425.8459	0	0	0
13	11193	11193	3198	3198	3985.2	1920.1776	0	0	0	0	11193	11193	3198	3198	3985.2	1920.1776	615	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	0	0	0	11147.5	11147.5	3185	3185	3969	0	0	0	0	0
15	10237.5	10237.5	0	2925	3645	0	0	0	1237.5	0	10237.5	10237.5	0	2925	3645	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	9715.9298	0	2892.5	0	0	0	0	0	0	10123.75	9715.9298	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	1764	0	0	0	0
19	10101	10101	0	2886	0	0	0	0	0	0	10101	10101	0	2886	0	1776	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	1812	0	0	0	0	10305.75	10305.75	0	2944.5	0	1812	0	0	0	0
21	10510.5	10510.5	0	0	0	1642.5255	0	0	0	0	10510.5	10510.5	0	0	0	0	0	0	0	0
22	10442.25	10442.25	0	0	0	459	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	10351.25	0	0	0	0	0	0	0	0	10351.25	10351.25	0	0	0	0	0	0	0	0
24	10260.25	10260.25	0	0	3653.1	0	0	0	0	0	10260.25	10260.25	0	0	0	0	1506.2273	0	0	0

Table-6.82b: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 21-40) with PEVs and solar during winter

Hour	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU 29	PGU 30	PGU31	PGU32	PGU33	PGU 34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	10078.25	5498.516	0	0	0	0	0	0	0	0	10078.25	5498.516	0	0	0	0	0	0	0	0
2	10010	6537.3	0	0	0	0	0	0	0	0	10010	6537.3	0	0	0	0	0	0	0	0
3	10510.5	8272.6644	0	0	0	0	0	0	0	0	10510.5	8272.6644	0	3003	0	0	0	0	0	0
4	10305.75	9223.8728	2944.5	0	0	0	0	0	0	0	10305.75	9223.8728	0	2944.5	0	0	0	0	0	0
5	10578.75	10306.702	3022.5	0	0	0	0	0	0	0	10578.75	10306.702	0	3022.5	0	0	0	0	0	0
6	10442.25	10233.956	2983.5	2983.5	0	0	0	0	0	0	10442.25	10233.956	0	2983.5	0	0	0	0	0	0
7	10237.5	9570.465	2925	2925	562.5	0	0	0	0	0	10237.5	9570.465	0	2925	562.5	0	0	0	0	0
8	10078.25	8823.8291	2879.5	2879.5	553.75	0	0	0	0	0	10078.25	8823.8291	0	2879.5	553.75	0	0	0	0	0
9	10374	10374	2964	2964	2424.4049	0	0	0	0	0	10374	10374	2964	2964	2424.4049	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	1614.25	0	1188.088
11	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	1658.25	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	0	2425.8459	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	0	0	615	0	0	0	11193	11193	3198	3198	0	1920.1776	0	0	0	0
14	11147.5	11147.5	3185	3185	0	0	1653.8725	0	0	0	11147.5	11147.5	3185	3185	0	1960	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
16	10146.5	10146.5	2899	2899	0	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	9715.9298	0	2892.5	0	0	0	0	0	0	10123.75	9715.9298	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	0	0	0	0
19	10101	10101	0	2886	0	1776	0	0	0	0	10101	10101	0	2886	0	0	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	1812	0	0	0	0	10305.75	10305.75	0	2944.5	0	0	0	0	0	0
21	10510.5	10510.5	0	0	3742.2	1642.5255	0	0	0	0	10510.5	10510.5	0	0	3742.2	0	0	0	0	0
22	10442.25	10442.25	0	0	3462.084	0	0	0	0	0	10442.25	10442.25	0	0	3462.084	0	0	0	0	0
23	10351.25	10351.25	0	0	3405.5233	0	0	0	0	0	10351.25	10351.25	0	0	3405.5233	0	0	0	0	0
24	10260.25	0	0	0	3653.1	0	0	0	0	0	10260.25	0	0	0	3653.1	1804	0	1240.25	0	0

Table-6.82c: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 41-60) with PEVs and solar during winter

Hour	PGU41	PGU42	PGU43	PGU 44	PGU45	PGU46	PGU 47	PGU48	PGU49	PGU50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PGU56	PGU57	PGU 58	PGU 59	PGU 60
1	10078.25	5498.516	0	0	0	0	0	0	0	0	10078.25	5498.516	0	0	0	0	0	0	0	0
2	10010	6537.3	0	0	0	0	0	0	0	0	10010	6537.3	0	0	0	0	0	0	0	0
3	10510.5	8272.6644	0	3003	0	0	0	0	0	0	10510.5	8272.6644	0	0	0	0	0	0	0	0
4	10305.75	9223.8728	0	2944.5	0	0	0	0	0	0	10305.75	9223.8728	0	0	0	0	0	0	0	0
5	10578.75	10306.702	0	3022.5	0	0	0	0	0	0	10578.75	10306.702	0	0	0	0	0	0	0	0
6	10442.25	10233.956	0	2983.5	0	0	0	0	0	0	10442.25	10233.956	0	2983.5	0	0	0	0	0	0
7	10237.5	9570.465	0	2925	0	0	0	0	0	0	10237.5	9570.465	0	2925	0	0	0	0	0	0
8	10078.25	8823.8291	0	2879.5	0	0	0	0	0	0	10078.25	8823.8291	0	2879.5	0	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	0	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	1614.25	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	1658.25	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	3198	3985.2	0	0	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	0	0	0	0	0	11147.5	11147.5	3185	3185	3969	0	0	0	0	0
15	10237.5	10237.5	0	2925	3645	0	0	0	0	0	10237.5	10237.5	0	2925	3645	0	0	0	0	0
16	10146.5	10146.5	0	2899	655.69433	0	0	0	0	0	10146.5	10146.5	0	2899	0	0	0	0	0	0
17	10123.75	9715.9298	0	2892.5	0	0	0	0	0	0	10123.75	9715.9298	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	1764	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	931.392	0	0	0
19	10101	10101	0	0	0	1776	0	1221	0	0	10101	10101	0	0	0	1776	1867.353	1221	0	0
20	10305.75	10305.75	0	0	0	1812	0	0	0	0	10305.75	10305.75	0	0	0	1812	1391.3895	0	0	0
21	10510.5	10510.5	0	0	0	0	0	0	0	0	10510.5	10510.5	0	0	0	1642.5255	0	0	0	0
22	10442.25	10442.25	0	0	0	0	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	10351.25	0	0	0	0	0	0	0	0	10351.25	10351.25	0	0	0	0	0	0	0	0
24	10260.25	0	0	2931.5	0	1804	0	0	0	0	10260.25	0	0	2931.5	3653.1	0	0	1240.25	0	0

Table-6.82d: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 61-80) with PEVs and solar during winter

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	10078.25	5498.516	0	0	0	0	0	0	0	0	10078.25	5498.516	0	0	0	0	0	0	0	0
2	10010	6537.3	0	0	0	0	0	0	0	0	10010	6537.3	0	0	0	0	0	0	0	0
3	10510.5	8272.6644	0	3003	0	0	0	0	0	0	10510.5	8272.6644	0	0	0	0	0	0	0	0
4	10305.75	9223.8728	0	2944.5	0	0	0	0	0	0	10305.75	9223.8728	0	0	0	0	0	0	0	0
5	10578.75	10306.702	0	3022.5	0	0	0	0	0	0	10578.75	10306.702	0	0	0	0	0	0	0	0
6	10442.25	10233.956	0	2983.5	0	0	0	0	0	0	10442.25	10233.956	0	2983.5	0	0	0	0	0	0
7	10237.5	9570.465	0	2925	0	0	0	0	0	0	10237.5	9570.465	0	2925	0	0	0	0	0	0
8	10078.25	8823.8291	0	2879.5	0	0	0	0	0	0	10078.25	8823.8291	0	2879.5	0	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	0	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	1614.25	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	2494.75	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	0	2488.6564	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	0	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2425.8459	0	0	0
13	11193	11193	3198	3198	3985.2	1920.1776	615	0	0	0	11193	11193	3198	3198	3985.2	1920.1776	615	0	0	0
14	11147.5	11147.5	0	3185	3969	1960	1653.8725	0	0	0	11147.5	11147.5	3185	3185	3969	1960	0	0	0	0
15	10237.5	10237.5	0	2925	3645	1800	807.75	0	0	0	10237.5	10237.5	0	2925	3645	0	0	0	0	0
16	10146.5	10146.5	0	2899	0	446	0	0	0	0	10146.5	10146.5	0	2899	655.69433	0	0	0	0	0
17	10123.75	9715.9298	0	2892.5	0	0	0	0	222.5	0	10123.75	9715.9298	0	2892.5	556.25	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	0	0	0	0
19	10101	10101	0	0	0	0	0	0	0	0	10101	10101	0	0	0	1776	0	1221	0	0
20	10305.75	10305.75	0	0	0	0	0	0	0	0	10305.75	10305.75	0	0	0	1812	0	0	0	0
21	10510.5	10510.5	3003	0	0	0	0	0	0	0	10510.5	10510.5	3003	0	0	1642.5255	0	0	0	0
22	10442.25	10442.25	2983.5	0	3462.084	0	0	0	0	0	10442.25	10442.25	2983.5	0	0	0	0	0	0	0
23	10351.25	0	2957.5	0	3405.5233	0	0	0	0	0	10351.25	0	2957.5	0	0	0	0	0	0	0
24	10260.25	0	2931.5	0	3653.1	1804	0	0	0	0	10260.25	0	2931.5	0	0	0	1506.2273	0	0	0

Table-6.82e: Hourly profit for 100-generating unit system using hCHHO-SCA optimization algorithm (Unit 81-100) with PEVs and solar during winter

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	10078.25	5498.516	0	0	0	0	0	0	0	0	10078.25	5498.516	0	0	0	0	0	0	0	0
2	10010	6537.3	0	0	0	0	0	0	0	0	10010	6537.3	0	0	0	0	0	0	0	0
3	10510.5	8272.6644	0	0	0	0	0	0	0	0	10510.5	8272.6644	0	0	0	0	0	0	0	0
4	10305.75	9223.8728	0	0	0	0	0	0	0	0	10305.75	9223.8728	0	0	0	0	0	0	0	0
5	10578.75	10306.702	3022.5	0	0	0	0	0	0	0	10578.75	10306.702	3022.5	0	0	0	0	0	0	0
6	10442.25	10233.956	2983.5	0	0	0	0	0	0	0	10442.25	10233.956	2983.5	0	0	0	0	0	0	0
7	10237.5	9570.465	2925	2925	0	0	0	0	0	0	10237.5	9570.465	2925	0	0	0	0	0	0	0
8	10078.25	8823.8291	2879.5	2879.5	0	0	0	0	0	0	10078.25	8823.8291	2879.5	0	0	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	2494.75	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	0	2488.6564	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	2488.6564	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	0	2425.8459	0	0	0	14400.75	14400.75	0	4114.5	5127.3	2532	2425.8459	0	0	0
13	11193	11193	0	3198	3985.2	0	0	0	0	0	11193	11193	0	3198	3985.2	0	615	0	0	0
14	11147.5	11147.5	0	3185	3969	0	0	0	0	0	11147.5	11147.5	0	3185	3969	0	0	0	0	0
15	10237.5	10237.5	0	0	3645	0	0	0	0	0	10237.5	10237.5	0	2925	3645	0	0	0	0	0
16	10146.5	10146.5	0	0	0	0	0	0	0	0	10146.5	10146.5	0	0	655.69433	0	0	0	0	0
17	10123.75	9715.9298	0	0	0	0	0	0	0	0	10123.75	9715.9298	0	0	0	445	0	0	0	0
18	10032.75	10032.75	0	0	0	0	0	0	0	0	10032.75	10032.75	0	0	0	1764	0	0	0	0
19	10101	10101	0	0	0	0	1867.353	0	0	0	10101	10101	0	0	0	1776	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	0	1391.3895	0	0	0	10305.75	10305.75	0	0	0	0	0	0	0	0
21	10510.5	10510.5	0	3003	0	0	577.5	0	0	0	10510.5	10510.5	3003	3003	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	2983.5	0	0	0	0	0	0	10442.25	10442.25	2983.5	2983.5	0	0	0	0	0	0
23	10351.25	0	2957.5	2957.5	0	0	0	0	0	0	10351.25	10351.25	2957.5	2957.5	0	0	0	0	0	0
24	10260.25	0	2931.5	2931.5	3653.1	0	0	0	0	0	10260.25	0	2931.5	2931.5	0	0	0	0	0	0

6.6.10 Hybrid Chaotic Slime Mould-Sine Cosine Optimization Algorithm with PEVs and solar PV during Winter

The proposed hybrid algorithm, hCSMA-SCA is established to increase the penetrating capability through the entire search region. The alteration with input boundaries with chaotic map is thought about to make the hybridization SMA enhancer with SCA technique which is especially proficient to track down the ideal arrangement over the hunt locale. This technique is unrivaled as the populace based enhancers are more reasonable to tackle ongoing issue since they can ready to stay away from the caught into nearby optima and investigate the pursuit district just as take advantage of worldwide ideal arrangement more steady than the individual based analyzer. The number of population is 40 for 10-, 40- and 100-generating unit systems.

6.6.10.1 Ten Generating Unit System

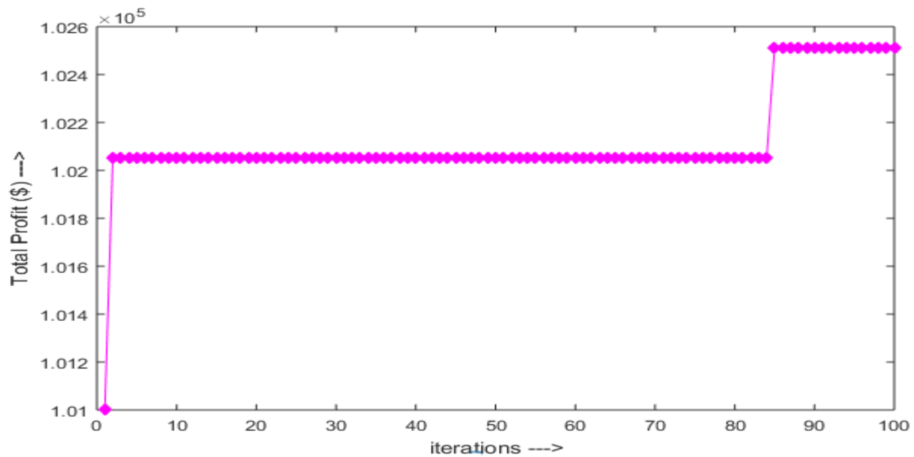
The system contains of 10-generating unit system having a 24-hour electricity demand. The hCSMA-SCA technique is evaluated for 100 iterations with considering the effect of PEVs in winter days. The hCSMA-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.23**. Thecommitment status and the optimal scheduling for this unit system are shown in Table-6.83a and the hourly profit of the 10-generating unit system have been shown in Table-6.83b. The ‘Best’, ‘Average’ and ‘Worst’ values for profit with standard deviation and medianvalue of solutions have been stated for 30 trial result for PBUCP of power systems that are shown in Table-6.90. The hypothesis tests are also taken into consideration. The p-value for wilcoxon-rank sum test and t-test and h-value for t-test is used to verify the efficiency of hCSMA-SCA optimizer that are shown in Table-6.91. The best, average and worst time are also taken into consideration, are shown in Table-6.92.

Table-6.83a: Commitment status and scheduling for 10-generating unit system using hCSMA-SCA optimization algorithm with PEVs and solar during winter

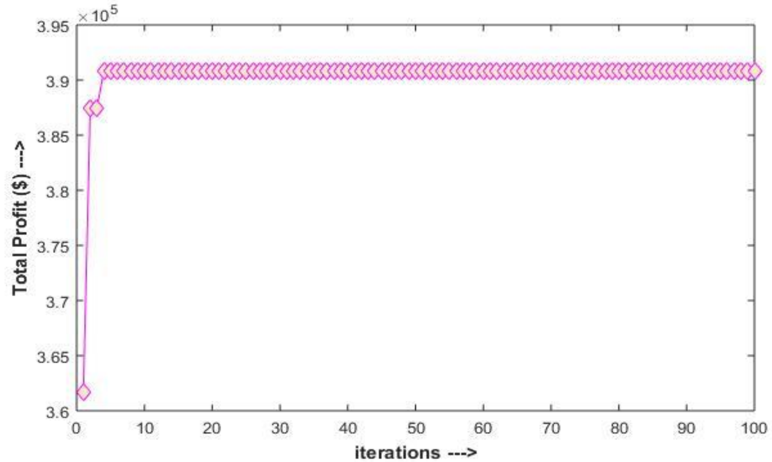
Commitment status of thermal units								Scheduling of the committed generating units						
HOURS	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**	**PGU1**	**PGU2**	**PGU3**	**PGU4**	**PGU5**	**PGU6**	**PGU7 to PG10**
1	1	1	0	0	0	0	0	455	277.4	0	0	0	0	0
2	1	1	0	0	0	0	0	455	316.5	0	0	0	0	0
3	1	1	0	0	0	0	0	455	416.24	0	0	0	0	0
4	1	1	0	0	1	0	0	455	455	0	0	42.35	0	0
5	1	1	0	0	1	0	0	455	455	0	0	112.99	0	0
6	1	1	0	1	1	0	0	455	455	0	130	39.24	0	0
7	1	1	0	1	1	0	0	455	443.54	0	130	25	0	0
8	1	1	0	1	1	0	0	455	433.67	0	130	25	0	0
9	1	1	0	1	1	0	0	455	455	0	130	82.6671	0	0
10	1	1	1	1	1	1	0	455	455	130	130	160.96	20	0
11	1	1	1	1	1	1	0	455	455	130	130	162	40.17	0
12	1	1	1	1	1	1	0	455	455	130	130	155.23	20	0
13	1	1	1	1	1	0	0	455	455	130	130	93.28	0	0
14	1	1	1	1	1	0	0	455	455	130	130	111.01	0	0
15	1	1	0	1	1	0	0	455	455	0	130	156.9	0	0
16	1	1	0	1	0	0	0	455	433.21	0	130	0	0	0
17	1	1	0	1	0	0	0	455	426.71	0	130	0	0	0
18	1	1	0	1	0	1	0	455	455	0	130	0	22.24	0
19	1	1	0	1	0	1	0	455	455	0	130	0	33.23	0
20	1	1	0	1	0	1	0	455	387.86	0	130	0	20	0
21	1	1	0	1	0	0	0	455	438.42	0	130	0	0	0
22	1	1	0	1	0	0	0	455	407.56	0	130	0	0	0
23	1	1	0	0	0	0	0	455	409.08	0	0	0	0	0
24	1	1	0	0	0	0	0	455	300.59	0	0	0	0	0

Table-6.83b: Hourly profit for 10-generating unit system using hCSMA-SCA optimization algorithm with PEVs and solar during winter

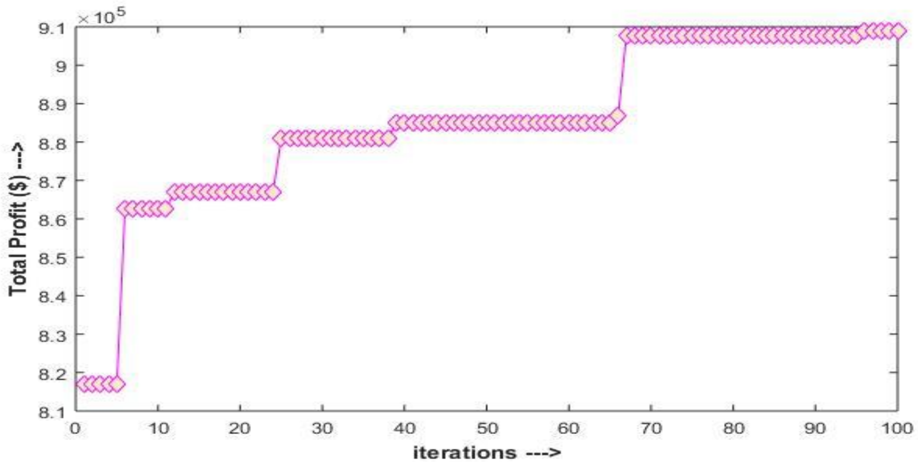
HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7 to PG10	Start-up Cost	Hourly Profit
1	10078.25	6144.41	0	0	0	0	0	2010	16222.66
2	10010	6963	0	0	0	0	0	0	16973
3	10510.5	9615.144	0	0	0	0	0	0	20125.644
4	10305.75	10305.75	0	0	959.2275	0	0	520	21570.7275
5	10578.75	10578.75	0	0	2627.0175	0	0	0	23784.5175
6	10442.25	10442.25	0	2983.5	900.558	0	0	0	24768.558
7	10237.5	9979.65	0	2925	562.5	0	0	0	23704.65
8	10078.25	9605.7905	0	2879.5	553.75	0	0	0	23117.2905
9	10374	10374	0	2964	1884.80988	0	0	400	25596.8099
10	13354.25	13354.25	3815.5	3815.5	4724.176	587	0	380	39650.676
11	13718.25	13718.25	3919.5	3919.5	4884.3	1211.1255	0	550	41370.9255
12	14400.75	14400.75	4114.5	4114.5	4913.0295	633	0	60	42576.5295
13	11193	11193	3198	3198	2294.688	0	0	30	31076.688
14	11147.5	11147.5	3185	3185	2719.745	0	0	0	31384.745
15	10237.5	10237.5	0	2925	3530.25	0	0	30	26930.25
16	10146.5	9660.583	0	2899	0	0	0	320	22706.083
17	10123.75	9494.2975	0	2892.5	0	0	0	0	22510.5475
18	10032.75	10032.75	0	2866.5	0	490.392	0	0	23422.392
19	10101	10101	0	2886	0	737.706	0	430	23825.706
20	10305.75	8785.029	0	2944.5	0	453	0	60	22488.279
21	10510.5	10127.502	0	3003	0	0	0	0	23641.002
22	10442.25	9353.502	0	2983.5	0	0	0	900	22779.252
23	10351.25	9306.57	0	0	0	0	0	700	19657.82
24	10260.25	6778.3045	0	0	0	0	0	560	17038.5545



(a) 10-Unit system



(b) 40-Unit system



(c) 100-Unit system

Fig.6.23: Convergence curve for 10-, 40- and 100-generating unit system using hCSMA-SCA optimization algorithm with PEVs and solar during winter

6.6.10.2 Forty Generating Unit System

The system contains of 40-generating unit system having a 24-hour electricity demand. The hCSMA-SCA technique is evaluated for 100 iterations considering the effect of PEVs in winter days. The hCHHO-SCA technique is evaluated for 100 iterations. The hCSMA-SCA algorithm is verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.23**. The optimal scheduling of 40-generating unit systems are shown in Table-6.85a and Table-6.85b. The hourly profit table for this system is shown in Table-6.86a and Table-6.86b respectively. The profit with start-up cost and fuel cost of 24 hours are shown in Table-6.84.

Table-6.84: Hourly profit with startup cost and fuel cost for 40-generating unit system using hCSMA-SCA optimization algorithm with PEVs and solar during winter

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	62737.66	2240	54353.2239	**13**	129378.288	440	106663.242
2	66473	4540	57660.3502	**14**	126934.745	30	106482.083
3	79030.644	230	65861.4383	**15**	107930.25	1190	97273.5917
4	83405.2275	0	71602.2227	**16**	92282.083	1070	81987.8687
5	93534.5175	2240	79381.0865	**17**	89260.5475	520	77705.4979
6	96372.558	2160	83083.7413	**18**	92218.392	410	83038.9732
7	93904.65	960	82633.1144	**19**	93089.706	520	83294.868
8	92225.2905	120	82460.0889	**20**	93156.279	620	81464.5723
9	105624.81	10460	92328.5633	**21**	95713.002	1370	80596.1493
10	162920.676	350	114028.817	**22**	94383.252	2560	81226.6906
11	169086.326	180	115591.134	**23**	81082.82	1200	71908.4629
12	176645.93	320	116320.598	**24**	71158.5545	520	63384.3304

Table-6.85a: Generation scheduling for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with PEVs and solar during winter

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU-10	PGU-11	PGU-12	PGU-13	PGU-14	PGU-15	PGU-16	PGU-17	PGU-18	PGU-19	PGU-20
1	455	337.46667	0	0	0	0	0	0	0	0	455	337.46667	0	0	0	0	0	0	0	0
2	455	400.5	0	0	0	0	0	0	0	0	455	400.5	0	0	0	0	0	0	0	0
3	455	447.08	130	0	0	0	0	0	0	0	455	447.08	0	130	0	0	0	0	0	0
4	455	447.45	130	130	0	0	0	0	0	0	455	447.45	0	130	0	0	0	0	0	0
5	455	430.99667	130	130	0	0	0	0	0	0	455	430.99667	130	130	0	0	0	0	0	0
6	455	446.41333	130	130	0	0	0	0	0	0	455	446.41333	130	130	0	0	0	0	0	0
7	455	437.84667	130	130	0	0	0	0	0	0	455	437.84667	130	130	0	0	0	0	0	0
8	455	434.55667	130	130	0	0	0	0	0	0	455	434.55667	130	130	0	0	0	0	0	0
9	455	436.91678	130	130	0	0	25	0	0	0	455	436.91678	130	130	0	0	0	0	0	0
10	455	455	130	130	162	80	62.96	0	0	0	455	455	130	130	162	80	0	0	0	0
11	455	455	130	130	162	80	40.17	0	0	0	455	455	130	130	162	80	0	0	0	0
12	455	455	130	0	162	80	0	0	10	0	455	455	130	130	162	80	0	0	0	0
13	455	455	130	0	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
14	455	455	130	0	162	0	0	0	0	0	455	455	0	130	162	0	0	0	0	0
15	455	455	0	0	162	0	0	0	0	0	455	455	0	130	162	0	0	0	0	0
16	455	455	0	0	0	0	0	0	0	0	455	455	0	130	162	0	0	0	0	0
17	455	450.4275	0	130	0	0	0	0	0	0	455	450.4275	0	130	0	0	0	0	0	0
18	455	455	0	130	0	70.56	0	0	0	0	455	455	0	130	0	70.56	0	0	0	0
19	455	455	0	130	0	73.3075	0	0	0	0	455	455	0	130	0	73.3075	0	0	0	0
20	455	455	0	130	0	53.215	0	0	0	0	455	455	130	0	0	53.215	0	0	0	0
21	455	450.855	0	130	0	0	0	0	0	0	455	450.855	130	0	0	0	0	0	0	0
22	455	455	130	130	147.56	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
23	455	455	130	130	126.36	0	0	0	0	0	455	0	130	0	126.36	0	0	0	0	0
24	455	455	130	0	33.53	0	0	0	0	0	455	0	130	0	33.53	0	0	0	0	0

Table-6.85b: Generation scheduling for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with PEVs and solar during winter

Hour	PGU21	PGU22	PGU23	PGU 24	PGU 25	PGU 26	PGU 27	PGU 28	PGU 29	PGU 30	PGU 31	PGU32	PGU 33	PGU 34	PGU 35	PGU 36	PGU 37	PGU 38	PGU 39	PGU 40
1	455	337.46667	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	400.5	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	447.08	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
4	455	447.45	0	130	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
5	455	430.99667	130	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
6	455	446.41333	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
7	455	437.84667	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
8	455	434.55667	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
9	455	436.91678	130	130	0	0	0	0	0	0	455	436.91678	130	130	0	0	0	0	0	0
10	455	455	130	130	162	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	0	0	0	0	0
12	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	0	53.23	0	0
13	455	455	130	130	162	30.64	0	0	0	0	455	455	130	130	162	30.64	0	0	0	0
14	455	455	130	0	162	0	81.505	0	0	0	455	455	130	130	162	80	81.505	0	0	0
15	455	455	130	0	162	0	59.45	0	0	0	455	455	0	130	162	0	59.45	0	0	0
16	455	455	130	0	0	0	38.105	0	0	0	455	455	0	0	0	0	38.105	0	0	0
17	455	450.4275	130	0	0	0	0	0	0	0	455	450.4275	0	0	0	0	0	0	0	0
18	455	455	0	0	0	70.56	0	0	0	0	455	455	0	0	0	70.56	0	0	0	0
19	455	455	0	0	0	73.3075	0	0	0	0	455	455	0	0	0	73.3075	0	0	0	0
20	455	455	0	0	0	53.215	0	0	0	0	455	455	0	0	0	53.215	0	0	0	0
21	455	450.855	0	130	0	0	0	0	0	0	455	450.855	0	130	0	0	0	0	0	0
22	455	0	0	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
23	455	0	130	130	126.36	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
24	455	0	130	130	33.53	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0

Table-6.85a shows the optimal scheduling of PGU1 to PGU20 for 40-generating unit test system considering the effect of PEVs and solar PV in winter using hCSMA-SCA optimizer. The PGU8, PGU10 and PGU17 to PGU20 is off for 24 hours. The PGU1 and PGU11 is always remain on throughout the whole day. PGU7 gives 62.96 MW power for 10^{th} hour and 40.17 MW for 11^{th} hour. Further, the PGU are sometimes remain on and off condition for optimum power generation scheduling.

In Table-6.85b represents the power scheduling of 21 to 40 unit for 40-unit system with PEVs and solar PV in winter using hCSMA-SCA optimizer. The PGU21 and PGU31 is continuing on for 24 hours. The PGU28 to PGU30 and PGU39 to PGU40 remain off throughout the whole day. The PGU26 is on for 11^{th} to 13^{th} hour only. For this the output is 80 MW for 11^{th} and 12^{th} hour, 30.64 MW for 13^{th} hour and 18^{th} to 20^{th} hour it give 70.56 MW power output for 18^{th} hour, 73.3075 MW for 19^{th} unit and 53.215 MW for 20^{th} unit.

The hourly profit for 40-test system is presented in Table-6.86a and Table-6.86b using hCSMA-SCA optimizer with PEVs and solar PV in winter. The Table-6.90a shows the hourly profit for PGU1 to PGU20 for whole day. The maximum number of profit can be obtained from the PGU1 and PGU11 as it was remain on for all hours.

Table-6.86b shows that the hourly profit for PGU21 to PGU40 for this test system for 24 hours. The PGU21 and PGU31 are on for 24 hours, so that the profit from these units are maximum. Moreover for the others hours as it remain off, no profit come from that hour when the generating unit remain off.

Table-6.86a: Hourly profit for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with PEVs and solar during winter

HOURS	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	GPU16	PGU17	PGU 18	PGU19	PGU 20
1	10078.25	7474.88667	0	0	0	0	0	0	0	0	10078.25	7474.88667	0	0	0	0	0	0	0	0
2	10010	8811	0	0	0	0	0	0	0	0	10010	8811	0	0	0	0	0	0	0	0
3	10510.5	10327.548	3003	0	0	0	0	0	0	0	10510.5	10327.548	0	3003	0	0	0	0	0	0
4	10305.75	10134.7425	2944.5	2944.5	0	0	0	0	0	0	10305.75	10134.7425	0	2944.5	0	0	0	0	0	0
5	10578.75	10020.6725	3022.5	3022.5	0	0	0	0	0	0	10578.75	10020.6725	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	10245.186	2983.5	2983.5	0	0	0	0	0	0	10442.25	10245.186	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	9851.55	2925	2925	0	0	0	0	0	0	10237.5	9851.55	2925	2925	0	0	0	0	0	0
8	10078.25	9625.43017	2879.5	2879.5	0	0	0	0	0	0	10078.25	9625.43017	2879.5	2879.5	0	0	0	0	0	0
9	10374	9961.70247	2964	2964	0	0	570	0	0	0	10374	9961.70247	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	1847.876	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	1211.1255	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0
12	14400.75	14400.75	4114.5	0	5127.3	2532	0	0	316.5	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0
13	11193	11193	3198	0	3985.2	0	0	0	0	0	11193	11193	3198	3198	3985.2	0	0	0	0	0
14	11147.5	11147.5	3185	0	3969	0	0	0	0	0	11147.5	11147.5	0	3185	3969	0	0	0	0	0
15	10237.5	10237.5	0	0	3645	0	0	0	0	0	10237.5	10237.5	0	2925	3645	0	0	0	0	0
16	10146.5	10146.5	0	0	0	0	0	0	0	0	10146.5	10146.5	0	2899	3612.6	0	0	0	0	0
17	10123.75	10022.0119	0	2892.5	0	0	0	0	0	0	10123.75	10022.0119	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	1555.848	0	0	0	0	10032.75	10032.75	0	2866.5	0	1555.848	0	0	0	0
19	10101	10101	0	2886	0	1627.4265	0	0	0	0	10101	10101	0	2886	0	1627.4265	0	0	0	0
20	10305.75	10305.75	0	2944.5	0	1205.31975	0	0	0	0	10305.75	10305.75	2944.5	0	0	1205.31975	0	0	0	0
21	10510.5	10414.7505	0	3003	0	0	0	0	0	0	10510.5	10414.7505	3003	0	0	0	0	0	0	0
22	10442.25	10442.25	2983.5	2983.5	3386.502	0	0	0	0	0	10442.25	10442.25	2983.5	0	0	0	0	0	0	0
23	10351.25	10351.25	2957.5	2957.5	2874.69	0	0	0	0	0	10351.25	0	2957.5	0	2874.69	0	0	0	0	0
24	10260.25	10260.25	2931.5	0	756.1015	0	0	0	0	0	10260.25	0	2931.5	0	756.1015	0	0	0	0	0

Table-6.86b: Hourly profit for 40-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with PEVs and solar during winter

HOURS	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PG34	PGU35	GPU36	PGU37	PGU 38	PGU39	PGU 40
1	10078.25	7474.88667	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	8811	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	10327.548	0	0	0	0	0	0	0	0	10510.5	0	0	0	0	0	0	0	0	0
4	10305.75	10134.7425	0	2944.5	0	0	0	0	0	0	10305.75	0	0	0	0	0	0	0	0	0
5	10578.75	10020.6725	3022.5	3022.5	0	0	0	0	0	0	10578.75	0	0	3022.5	0	0	0	0	0	0
6	10442.25	10245.186	2983.5	2983.5	0	0	0	0	0	0	10442.25	0	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	9851.55	2925	2925	0	0	0	0	0	0	10237.5	0	2925	2925	0	0	0	0	0	0
8	10078.25	9625.43017	2879.5	2879.5	0	0	0	0	0	0	10078.25	0	2879.5	2879.5	0	0	0	0	0	0
9	10374	9961.70247	2964	2964	0	0	0	0	0	0	10374	9961.70247	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	0	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	0	0	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	0	1684.7295	0	0
13	11193	11193	3198	3198	3985.2	753.744	0	0	0	0	11193	11193	3198	3198	3985.2	753.744	0	0	0	0
14	11147.5	11147.5	3185	0	3969	0	1996.8725	0	0	0	11147.5	11147.5	3185	3185	3969	1960	1996.8725	0	0	0
15	10237.5	10237.5	2925	0	3645	0	1337.625	0	0	0	10237.5	10237.5	0	2925	3645	0	1337.625	0	0	0
16	10146.5	10146.5	2899	0	0	0	849.7415	0	0	0	10146.5	10146.5	0	0	0	0	849.7415	0	0	0
17	10123.75	10022.0119	2892.5	0	0	0	0	0	0	0	10123.75	10022.0119	0	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	1555.848	0	0	0	0	10032.75	10032.75	0	0	0	1555.848	0	0	0	0
19	10101	10101	0	0	0	1627.4265	0	0	0	0	10101	10101	0	0	0	1627.4265	0	0	0	0
20	10305.75	10305.75	0	0	0	1205.31975	0	0	0	0	10305.75	10305.75	0	0	0	1205.31975	0	0	0	0
21	10510.5	10414.7505	0	3003	0	0	0	0	0	0	10510.5	10414.7505	0	3003	0	0	0	0	0	0
22	10442.25	0	0	2983.5	0	0	0	0	0	0	10442.25	10442.25	2983.5	2983.5	0	0	0	0	0	0
23	10351.25	0	2957.5	2957.5	2874.69	0	0	0	0	0	10351.25	0	2957.5	2957.5	0	0	0	0	0	0
24	10260.25	0	2931.5	2931.5	756.1015	0	0	0	0	0	10260.25	0	2931.5	2931.5	0	0	0	0	0	0

6.6.10.3 Hundred Generating Unit System

The system contains of 100-generating unit system having a 24-hour electricity demand. The hCSMA-SCA technique is evaluated for 100 iterations considering solar as solar PV with effect of PEVs in winter days. The hCSMA-SCA technique is evaluated for 100 iterations. The hCSMA-SCA algorithmis verified for 30 trial runs. The convergence graph of total profit is shown in **Fig.6.23**.The optimal scheduling of 100-generating unit systems are shown in Table-6.88a to Table-6.88e. The hourly profit table for this system is shown in Table-6.89a to Table-6.89e respectively. The profit with start-up cost and fuel cost of 24 hours are shown in Table-6.87.

Table-6.87: Hourly profit with start-up cost and fuel cost for 100-generating unit system using hCSMA-SCA optimization algorithm with PEVs and solar during winter

HOURS	Hourly Profit	Start-up Cost	Fuel Cost	HOURS	Hourly Profit	Start-up Cost	Fuel Cost
1	155767.66	9640	141334.25	**13**	325981.49	1620	274230
2	165473	4720	155245.13	**14**	318034.75	1080	266880.33
3	196840.64	7870	174647.05	**15**	269930.25	2290	241374.23
4	207074.23	2380	190099.64	**16**	231434.08	1190	207275.73
5	233034.52	790	207489.03	**17**	222760.55	1570	197635.26
6	239580.56	430	214595.18	**18**	229810.39	530	208107.72
7	234304.65	1280	214751.5	**19**	231617.71	3190	212681.34
8	230441.29	2870	213846.78	**20**	234492.28	6230	211846.55
9	265680.81	10300	236726.91	**21**	239857	4310	212932.33
10	409460.68	2140	291015.22	**22**	237591.25	4360	213600.37
11	424517.13	750	299041.14	**23**	203932.82	1990	182508.92
12	444784.73	420	294296.53	**24**	179398.55	930	164034.79

Table-6.88a: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with PEVs and solar during winter

HOUR	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	455	413.73333	0	0	0	0	0	0	0	0	455	413.73333	0	0	0	0	0	0	0	0
2	455	451.91667	0	130	0	0	0	0	0	0	455	451.91667	0	130	0	0	0	0	0	0
3	455	430.248	130	130	0	0	0	0	0	0	455	430.248	130	130	0	0	0	0	0	0
4	455	450.47	130	130	0	0	0	0	0	0	455	450.47	130	130	0	0	0	0	0	0
5	455	455	130	130	149.4975	0	0	0	0	0	455	455	130	130	149.4975	0	0	0	0	0
6	455	455	130	130	144.89143	0	0	0	0	0	455	455	130	130	144.89143	0	0	0	0	0
7	455	455	130	130	141.22	0	0	0	0	0	455	455	130	130	141.22	0	0	0	0	0
8	455	455	130	130	158.38143	0	0	0	0	0	455	455	130	130	158.38143	0	0	0	0	0
9	455	455	130	130	151.0953	0	0	0	0	0	455	455	130	130	151.0953	0	0	0	0	0
10	455	455	130	130	162	80	78.245	55	55	0	455	455	130	130	162	0	0	55	55	0
11	455	455	0	130	162	80	78.907778	55	0	0	455	455	130	130	162	80	78.907778	55	0	0
12	455	455	0	130	162	80	81.723	55	0	0	455	455	130	130	162	80	81.723	55	0	0
13	455	455	0	130	162	0	79.213333	0	0	0	455	455	130	130	162	80	79.213333	0	0	0
14	455	455	0	130	162	0	0	0	0	0	455	455	130	130	162	80	0	0	0	0
15	455	455	0	130	157.81667	0	0	0	0	0	455	455	130	130	157.81667	0	0	0	0	0
16	455	452.821	0	130	0	0	0	0	0	0	455	452.821	0	130	0	0	0	0	0	0
17	455	442.171	0	130	0	0	0	0	0	0	455	442.171	0	130	0	0	0	0	0	0
18	455	455	130	130	0	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
19	455	455	130	0	0	80	47.115	0	0	0	455	455	0	130	0	80	0	0	0	0
20	455	455	130	0	0	80	75.62	0	0	0	455	455	0	0	0	80	75.62	0	0	0
21	455	455	130	0	0	80	42.473333	0	0	0	455	455	130	0	0	80	42.473333	0	0	0
22	455	455	130	0	162	0	0	0	0	0	455	455	130	0	162	0	25	0	0	0
23	455	0	130	0	147.72571	0	0	0	0	0	455	455	130	0	147.72571	0	0	0	0	0
24	455	0	0	130	155.93167	0	0	0	0	0	455	455	130	0	155.93167	0	0	0	0	0

Table-6.88b: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with PEVs and solar during winter

HOUR	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	455	413.73333	0	0	0	0	0	0	0	0	455	413.73333	0	0	0	0	0	0	0	0
2	455	451.91667	0	0	0	0	0	0	0	0	455	451.91667	0	0	0	0	0	0	0	0
3	455	0	130	130	0	0	0	0	0	0	455	430.248	130	130	0	0	0	0	0	0
4	455	0	130	130	0	0	0	0	0	0	455	450.47	130	130	0	0	0	0	0	0
5	455	0	130	130	149.4975	0	0	0	0	0	455	455	130	130	149.4975	0	0	0	0	0
6	455	0	130	130	144.89143	0	0	0	0	0	455	455	130	130	144.89143	0	0	0	0	0
7	455	0	130	130	141.22	0	0	0	0	0	455	455	130	130	141.22	0	0	0	0	0
8	455	0	130	0	158.38143	0	0	0	0	0	455	455	130	130	158.38143	0	0	0	0	0
9	455	0	130	0	151.0953	0	0	0	0	0	455	455	130	130	151.0953	0	0	0	0	0
10	455	0	130	0	162	80	78.245	0	0	0	455	455	130	130	162	0	78.245	55	55	0
11	455	455	130	0	162	80	78.907778	0	0	0	455	455	130	130	162	0	78.907778	0	0	0
12	455	455	130	0	162	80	81.723	55	0	0	455	455	130	130	162	80	81.723	55	0	0
13	455	455	130	130	162	80	79.213333	0	0	0	455	455	130	130	162	80	0	0	0	0
14	455	455	0	130	162	80	0	0	0	0	455	455	130	130	0	80	0	0	0	0
15	455	455	0	130	157.81667	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
16	455	452.821	0	130	0	0	0	0	0	0	455	452.821	0	130	0	0	0	0	0	0
17	455	442.171	0	130	0	0	0	0	0	0	455	442.171	0	130	0	0	0	0	0	0
18	455	455	0	130	0	0	0	0	0	0	455	455	0	0	0	0	0	0	0	0
19	455	455	0	0	0	80	47.115	0	0	0	455	455	0	0	0	80	0	0	0	0
20	455	455	130	0	0	80	75.62	0	0	0	455	455	0	0	162	80	0	0	0	0
21	455	455	130	0	0	80	42.473333	0	0	0	455	455	0	0	162	80	0	0	0	0
22	455	455	130	0	162	0	0	0	0	0	455	455	130	0	162	0	0	0	0	0
23	455	455	130	0	147.72571	0	0	0	0	0	455	455	130	130	147.72571	0	0	0	0	0
24	455	455	130	0	155.93167	0	0	0	0	0	455	0	130	130	155.93167	0	0	0	0	0

Table-6.88c: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 41-60) with PEVs and solar during winter

Hour	PG U41	PGU42	PGU 43	PGU 44	PGU45	PGU46	PGU 47	PGU 48	PGU49	PGU50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PGU56	PGU57	PGU58	PGU59	PGU60
1	455	413.73333	0	0	0	0	0	0	0	0	455	413.73333	0	0	0	0	0	0	0	0
2	455	451.91667	0	0	0	0	0	0	0	0	455	451.91667	0	0	0	0	0	0	0	0
3	455	430.248	0	130	0	0	0	0	0	0	455	430.248	0	130	0	0	0	0	0	0
4	455	450.47	130	130	0	0	0	0	0	0	455	450.47	130	130	0	0	0	0	0	0
5	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
6	455	455	130	130	144.89143	0	0	0	0	0	455	455	130	130	144.89143	0	0	0	0	0
7	455	455	130	130	141.22	0	0	0	0	0	455	455	130	130	141.22	0	0	0	0	0
8	455	455	130	130	158.38143	0	0	0	0	0	455	455	130	130	158.38143	0	0	0	0	0
9	455	455	0	130	151.0953	0	0	0	0	0	455	455	0	130	151.0953	0	0	0	0	0
10	455	455	0	130	162	80	78.245	0	0	0	455	455	0	130	162	80	78.245	55	0	0
11	455	455	0	130	162	80	78.907778	0	0	0	455	455	0	130	162	80	78.907778	0	0	0
12	455	455	0	130	162	80	81.723	0	0	0	455	455	0	130	0	80	81.723	0	0	0
13	455	455	0	130	162	80	79.213333	0	0	0	455	455	0	130	0	0	0	0	0	0
14	455	455	130	130	162	80	0	0	0	0	455	455	130	130	0	0	0	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
16	455	452.821	130	130	0	0	0	0	0	0	455	452.821	130	0	0	0	0	0	0	0
17	455	442.171	130	0	0	0	0	0	0	0	455	442.171	130	0	0	0	0	0	0	0
18	455	455	130	0	0	0	0	0	0	0	455	455	130	0	152.24	0	0	0	0	0
19	455	455	0	0	0	80	0	0	0	0	455	455	0	0	162	80	0	0	0	0
20	455	455	0	0	0	80	0	0	0	0	455	455	0	0	162	80	0	0	0	0
21	455	455	0	0	0	80	0	0	0	0	455	455	0	0	162	80	0	0	0	0
22	455	455	0	130	162	0	0	0	0	0	455	455	0	130	162	0	0	0	0	0
23	455	455	0	130	147.72571	0	0	0	0	0	455	0	0	130	147.72571	0	0	0	0	0
24	455	455	0	130	155.93167	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0

Table-6.88d: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 61-80) with PEVs and solar during winter

Hour	**PGU61**	**PGU62**	**PGU63**	**PGU64**	**PGU65**	**PGU66**	**PGU67**	**PGU68**	**PGU69**	**PGU70**	**PGU71**	**PGU72**	**PGU73**	**PGU74**	**PGU75**	**PGU76**	**PGU77**	**PGU78**	**PGU79**	**PGU80**
1	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
4	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
5	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
6	455	0	130	130	144.89143	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
7	455	0	130	130	141.22	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
8	455	0	130	130	158.38143	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
9	455	455	0	130	151.0953	0	0	0	0	0	455	455	0	130	0	0	0	0	0	0
10	455	455	0	130	162	80	78.245	55	0	0	455	455	0	130	162	0	78.245	55	0	0
11	455	455	0	130	162	80	78.907778	0	0	0	455	455	0	130	162	80	78.907778	0	0	0
12	455	455	0	130	0	80	81.723	0	0	0	455	455	0	130	162	80	81.723	0	0	0
13	455	455	0	130	0	0	0	0	0	0	455	455	0	130	162	80	79.213333	0	0	0
14	455	455	130	130	0	0	0	0	0	0	455	455	130	130	162	0	0	0	0	0
15	455	455	130	130	0	0	0	0	0	0	455	455	130	0	157.81667	0	0	0	0	0
16	455	452.821	130	130	0	0	0	0	0	0	455	452.821	130	0	0	0	0	0	0	0
17	455	442.171	130	0	0	0	0	0	0	0	455	442.171	130	0	0	0	0	0	0	0
18	455	455	130	0	0	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
19	455	0	130	0	162	0	0	0	0	0	455	455	130	0	0	80	0	0	0	0
20	455	0	0	0	162	80	0	0	0	0	455	455	130	0	0	80	0	0	0	0
21	455	0	0	0	162	80	0	0	0	0	455	455	0	0	0	80	0	0	0	0
22	455	0	0	130	162	28.56	0	0	0	0	455	455	0	0	0	0	0	0	0	0
23	455	0	0	130	147.72571	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
24	455	0	0	130	155.93167	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0

The Table-6.88a is given as the power scheduling of 100-unit test system using hCSMA-SCA optimizer considering effect of PEVs and solar PV in winter for PGU1 to PGU20 with PEVs. The PGU10 and PGU20 is off for 24 hours. The PGU1, PGU11 and PGU12 is always remain on throughout the whole day. PGU8 and PGU18 gives 55 MW power only for 10^{th} and 12^{th} hour respectively.

In Table-6.88b represents the power scheduling of 21 to 40 unit for 100-unit system using hCSMA-SCA optimizer considering the effect of PEVs and solar PV in winter. The PGU21 and PGU22 is continuous on for 24 hours. The PGU29 to PGU30, and PGU40 remain off throughout the whole day. The PGU28 is on for 12^{th} and PGU39 is on for 10^{th} hour and 55 MW generated power can be measured.

In Table-6.88c represents the power scheduling of 41 to 60 unit for 100-unit system using hCSMA-SCA optimizer with PEVs and solar PV in winter. The PGU41, PGU42 and PGU51 is continuous on for 24 hours and 455 MW power can be obtained. PGU52 is on from 1^{st} hour to 22^{nd} hour. The PGU48 to PGU50 and PGU59 to PGU60 remain off for 24 hours.

Table-6.88d represents the power scheduling of 61 to 80 unit for 100-unit system using hCSMA-SCA optimizer considering the effect of PEVs and solar PV in winter. The PGU61 and PGU71 is always on and the output power is 455 MW for 24 hours. The PGU68 and PGU78 are on only for 10^{th} hour and 55 MW output power can be measured, PGU69 to PGU70 and PGU79 to PGU80 are remain off for 24 hours.

Table-6.88e represents the power scheduling of 81 to 100 unit for 100-unit system using hCSMA-SCA optimizer considering the effect of PEVs and solar PV in winter. The PGU81 is always on and the output power is 455 MW for 24 hours. The PGU88 to PGU90 and PGU99 to PGU100 is off for 24 hours.

Table-6.88e: Generation scheduling for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 81-100) with PEVs and solar during winter

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
2	455	0	0	0	0	0	0	0	0	0	455	0	0	0	0	0	0	0	0	0
3	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
4	455	0	0	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
5	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
6	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
7	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
8	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
9	455	455	130	130	0	0	0	0	0	0	455	455	130	130	0	0	0	0	0	0
10	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	78.245	55	0	0
11	455	455	130	130	162	80	0	0	0	0	455	455	130	130	162	80	78.907778	0	0	0
12	455	455	130	130	162	80	81.723	0	0	0	455	455	130	130	162	80	81.723	0	0	0
13	455	455	130	130	162	80	79.213333	0	0	0	455	455	0	130	162	80	0	0	0	0
14	455	455	130	130	162	80	57.01	0	0	0	455	455	0	130	162	80	0	0	0	0
15	455	455	0	130	157.81667	0	0	0	0	0	455	455	0	130	157.81667	0	0	0	0	0
16	455	452.821	0	0	0	0	0	0	0	0	455	452.821	0	0	0	0	0	0	0	0
17	455	442.171	0	0	0	0	0	0	0	0	455	442.171	0	0	0	0	0	0	0	0
18	455	455	0	0	0	0	0	0	0	0	455	455	130	0	0	0	0	0	0	0
19	455	455	0	0	0	80	0	0	0	0	455	455	130	0	0	80	0	0	0	0
20	455	0	130	0	0	80	0	0	0	0	455	455	130	0	0	80	0	0	0	0
21	455	0	130	0	0	80	0	0	0	0	455	455	130	130	0	80	0	0	0	0
22	455	0	130	130	0	0	0	0	0	0	455	0	130	130	0	0	0	0	0	0
23	455	0	130	130	0	0	0	0	0	0	455	0	0	130	0	0	0	0	0	0
24	455	0	130	130	0	0	0	0	0	0	0	0	0	130	0	0	0	0	0	0

Table-6.89a: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 1-20) with PEVs and solar during winter

Hour	PGU1	PGU2	PGU3	PGU4	PGU5	PGU6	PGU7	PGU8	PGU9	PGU10	PGU11	PGU12	PGU13	PGU14	PGU15	PGU16	PGU17	PGU18	PGU19	PGU20
1	10078.25	9164.1933	0	0	0	0	0	0	0	0	10078.25	9164.1933	0	0	0	0	0	0	0	0
2	10010	9942.1667	0	2860	0	0	0	0	0	0	10010	9942.1667	0	2860	0	0	0	0	0	0
3	10510.5	9938.7288	3003	3003	0	0	0	0	0	0	10510.5	9938.7288	3003	3003	0	0	0	0	0	0
4	10305.75	10203.146	2944.5	2944.5	0	0	0	0	0	0	10305.75	10203.146	2944.5	2944.5	0	0	0	0	0	0
5	10578.75	10578.75	3022.5	3022.5	3475.8169	0	0	0	0	0	10578.75	10578.75	3022.5	3022.5	3475.8169	0	0	0	0	0
6	10442.25	10442.25	2983.5	2983.5	3325.2583	0	0	0	0	0	10442.25	10442.25	2983.5	2983.5	3325.2583	0	0	0	0	0
7	10237.5	10237.5	2925	2925	3177.45	0	0	0	0	0	10237.5	10237.5	2925	2925	3177.45	0	0	0	0	0
8	10078.25	10078.25	2879.5	2879.5	3508.1486	0	0	0	0	0	10078.25	10078.25	2879.5	2879.5	3508.1486	0	0	0	0	0
9	10374	10374	2964	2964	3444.9728	0	0	0	0	0	10374	10374	2964	2964	3444.9728	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	2296.4908	1614.25	1614.25	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	0	1614.25	1614.25	0
11	13718.25	13718.25	0	3919.5	4884.3	2412	2379.0695	1658.25	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	2379.0695	1658.25	0	0
12	14400.75	14400.75	0	4114.5	5127.3	2532	2586.5329	1740.75	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2586.5329	1740.75	0	0
13	11193	11193	0	3198	3985.2	0	1948.648	0	0	0	11193	11193	3198	3198	3985.2	1968	1948.648	0	0	0
14	11147.5	11147.5	0	3185	3969	0	0	0	0	0	11147.5	11147.5	3185	3185	3969	1960	0	0	0	0
15	10237.5	10237.5	0	2925	3550.875	0	0	0	0	0	10237.5	10237.5	2925	2925	3550.875	0	0	0	0	0
16	10146.5	10097.908	0	2899	0	0	0	0	0	0	10146.5	10097.908	0	2899	0	0	0	0	0	0
17	10123.75	9838.3048	0	2892.5	0	0	0	0	0	0	10123.75	9838.3048	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	2866.5	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	2866.5	0	0	0	0	0	0
19	10101	10101	2886	0	0	1776	1045.953	0	0	0	10101	10101	0	2886	0	1776	0	0	0	0
20	10305.75	10305.75	2944.5	0	0	1812	1712.793	0	0	0	10305.75	10305.75	0	0	0	1812	1712.793	0	0	0
21	10510.5	10510.5	3003	0	0	1848	981.134	0	0	0	10510.5	10510.5	3003	0	0	1848	981.134	0	0	0
22	10442.25	10442.25	2983.5	0	3717.9	0	0	0	0	0	10442.25	10442.25	2983.5	0	3717.9	0	573.75	0	0	0
23	10351.25	0	2957.5	0	3360.76	0	0	0	0	0	10351.25	10351.25	2957.5	0	3360.76	0	0	0	0	0
24	10260.25	0	0	2931.5	3516.2591	0	0	0	0	0	10260.25	10260.25	2931.5	0	3516.2591	0	0	0	0	0

Table-6.89b: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 21-40) with PEVs and solar during winter

Hour	PGU21	PGU22	PGU23	PGU24	PGU25	PGU26	PGU27	PGU28	PGU29	PGU30	PGU31	PGU32	PGU33	PGU34	PGU35	PGU36	PGU37	PGU38	PGU39	PGU40
1	10078.25	9164.1933	0	0	0	0	0	0	0	0	10078.25	9164.1933	0	0	0	0	0	0	0	0
2	10010	9942.1667	0	0	0	0	0	0	0	0	10010	9942.1667	0	0	0	0	0	0	0	0
3	10510.5	0	3003	3003	0	0	0	0	0	0	10510.5	9938.7288	3003	3003	0	0	0	0	0	0
4	10305.75	0	2944.5	2944.5	0	0	0	0	0	0	10305.75	10203.146	2944.5	2944.5	0	0	0	0	0	0
5	10578.75	0	3022.5	3022.5	3475.8169	0	0	0	0	0	10578.75	10578.75	3022.5	3022.5	3475.8169	0	0	0	0	0
6	10442.25	0	2983.5	2983.5	3325.2583	0	0	0	0	0	10442.25	10442.25	2983.5	2983.5	3325.2583	0	0	0	0	0
7	10237.5	0	2925	2925	3177.45	0	0	0	0	0	10237.5	10237.5	2925	2925	3177.45	0	0	0	0	0
8	10078.25	0	2879.5	0	3508.1486	0	0	0	0	0	10078.25	10078.25	2879.5	2879.5	3508.1486	0	0	0	0	0
9	10374	0	2964	0	3444.9728	0	0	0	0	0	10374	10374	2964	2964	3444.9728	0	0	0	0	0
10	13354.25	0	3815.5	0	4754.7	2348	2296.4908	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	0	2296.4908	1614.25	1614.25	0
11	13718.25	13718.25	3919.5	0	4884.3	2412	2379.0695	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	0	2379.0695	0	0	0
12	14400.75	14400.75	4114.5	0	5127.3	2532	2586.5329	1740.75	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2586.5329	1740.75	0	0
13	11193	11193	3198	3198	3985.2	1968	1948.648	0	0	0	11193	11193	3198	3198	3985.2	1968	0	0	0	0
14	11147.5	11147.5	0	3185	3969	1960	0	0	0	0	11147.5	11147.5	3185	3185	0	1960	0	0	0	0
15	10237.5	10237.5	0	2925	3550.875	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
16	10146.5	10097.908	0	2899	0	0	0	0	0	0	10146.5	10097.908	0	2899	0	0	0	0	0	0
17	10123.75	9838.3048	0	2892.5	0	0	0	0	0	0	10123.75	9838.3048	0	2892.5	0	0	0	0	0	0
18	10032.75	10032.75	0	2866.5	0	0	0	0	0	0	10032.75	10032.75	0	0	0	0	0	0	0	0
19	10101	10101	0	0	0	1776	1045.953	0	0	0	10101	10101	0	0	0	1776	0	0	0	0
20	10305.75	10305.75	2944.5	0	0	1812	1712.793	0	0	0	10305.75	10305.75	0	0	3669.3	1812	0	0	0	0
21	10510.5	10510.5	3003	0	0	1848	981.134	0	0	0	10510.5	10510.5	0	0	3742.2	1848	0	0	0	0
22	10442.25	10442.25	2983.5	0	3717.9	0	0	0	0	0	10442.25	10442.25	2983.5	0	3717.9	0	0	0	0	0
23	10351.25	10351.25	2957.5	0	3360.76	0	0	0	0	0	10351.25	10351.25	2957.5	2957.5	3360.76	0	0	0	0	0
24	10260.25	10260.25	2931.5	0	3516.2591	0	0	0	0	0	10260.25	0	2931.5	2931.5	3516.2591	0	0	0	0	0

Table-6.89c: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 41-60) with PEVs and solar during winter

Hour	PGU41	PGU42	PGU43	PGU 44	PGU45	PGU46	PGU 47	PGU4 8	PGU 49	PGU 50	PGU51	PGU52	PGU 53	PGU 54	PGU55	PG U56	PGU57	PGU 58	PGU 59	PGU 60
1	10078.25	9164.1933	0	0	0	0	0	0	0	0	10078.25	9164.1933	0	0	0	0	0	0	0	0
2	10010	9942.1667	0	0	0	0	0	0	0	0	10010	9942.1667	0	0	0	0	0	0	0	0
3	10510.5	9938.7288	0	3003	0	0	0	0	0	0	10510.5	9938.7288	0	3003	0	0	0	0	0	0
4	10305.75	10203.146	2944.5	2944.5	0	0	0	0	0	0	10305.75	10203.146	2944.5	2944.5	0	0	0	0	0	0
5	10578.75	10578.75	3022.5	3022.5	0	0	0	0	0	0	10578.75	10578.75	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	10442.25	2983.5	2983.5	3325.2583	0	0	0	0	0	10442.25	10442.25	2983.5	2983.5	3325.2583	0	0	0	0	0
7	10237.5	10237.5	2925	2925	3177.45	0	0	0	0	0	10237.5	10237.5	2925	2925	3177.45	0	0	0	0	0
8	10078.25	10078.25	2879.5	2879.5	3508.1486	0	0	0	0	0	10078.25	10078.25	2879.5	2879.5	3508.1486	0	0	0	0	0
9	10374	10374	0	2964	3444.9728	0	0	0	0	0	10374	10374	0	2964	3444.9728	0	0	0	0	0
10	13354.25	13354.25	0	3815.5	4754.7	2348	2296.4908	0	0	0	13354.25	13354.25	0	3815.5	4754.7	2348	2296.4908	1614.25	0	0
11	13718.25	13718.25	0	3919.5	4884.3	2412	2379.0695	0	0	0	13718.25	13718.25	0	3919.5	4884.3	2412	2379.0695	0	0	0
12	14400.75	14400.75	0	4114.5	5127.3	2532	2586.5329	0	0	0	14400.75	14400.75	0	4114.5	0	2532	2586.5329	0	0	0
13	11193	11193	0	3198	3985.2	1968	1948.648	0	0	0	11193	11193	0	3198	0	0	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	1960	0	0	0	0	11147.5	11147.5	3185	3185	0	0	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	2925	0	0	0	0	0	0
16	10146.5	10097.908	2899	2899	0	0	0	0	0	0	10146.5	10097.908	2899	0	0	0	0	0	0	0
17	10123.75	9838.3048	2892.5	0	0	0	0	0	0	0	10123.75	9838.3048	2892.5	0	0	0	0	0	0	0
18	10032.75	10032.75	2866.5	0	0	0	0	0	0	0	10032.75	10032.75	2866.5	0	3356.892	0	0	0	0	0
19	10101	10101	0	0	0	1776	0	0	0	0	10101	10101	0	0	3596.4	1776	0	0	0	0
20	10305.75	10305.75	0	0	0	1812	0	0	0	0	10305.75	10305.75	0	0	3669.3	1812	0	0	0	0
21	10510.5	10510.5	0	0	0	1848	0	0	0	0	10510.5	10510.5	0	0	3742.2	1848	0	0	0	0
22	10442.25	10442.25	0	2983.5	3717.9	0	0	0	0	0	10442.25	10442.25	0	2983.5	3717.9	0	0	0	0	0
23	10351.25	10351.25	0	2957.5	3360.76	0	0	0	0	0	10351.25	0	0	2957.5	3360.76	0	0	0	0	0
24	10260.25	10260.25	0	2931.5	3516.2591	0	0	0	0	0	10260.25	0	0	2931.5	0	0	0	0	0	0

The Table-6.89a is presented the hourly profit for 100-generating unit system using proposed hCSMA-SCA optimization algorithm with PEVs and solar PV in winter. From 100 numbers of power generating units, this table shows the hourly profit of PGU1 to PGU20 for 24 hours. The PGU1, PGU11 and PGU12 are on for every hours, while PGU3 and PGU4 have been off for some hours. The PGU9 is on only for 10^{th} hour and 1614.25 $ profit can be obtained.

The Table-6.89b is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm for units 21 to unit 40 considering effect of solar PV in winter. In this table, the PGU21, PGU22 and PGU31 are on for 24 hours and maximum profit are obtained. The PGU29, PGU30 and PGU40 are off throughout the whole day. Others PGU are remained on for some hours and off for few hours. From those units, the profit can be measured for that particular hour when it was on.

The Table-6.89c is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm considering effect of solar PV in winter for PGU41 to PGU60. The PGU41, PGU42 and PGU51 remain on for 24 hours. The PGU48 to PGU50 and PGU59 to PGU60 remain close throughout the whole day. Other units are remained on sometime and off for few times.

The Table-6.89d is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm considering effect of solar PV in winter for units 61 to unit 80. The PGU61 and PGU71 are continuously on for 24 hours. Further PGU69, PGU70, PGU79 and PGU80 is off for 24 hours.

The Table-6.89e is presented the hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm considering effect of solar PV in winter for units 81 to unit 100. The PGU81 has been on for 24 hours. PGU88 to PGU90 and PGU99 to PGU100 have been off for 24 hours.

Table-6.89d: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 61-80) with PEVs and solar during winter

Hour	PGU61	PGU62	PGU63	PGU64	PGU65	PGU66	PGU67	PGU68	PGU69	PGU70	PGU71	PGU72	PGU73	PGU74	PGU75	PGU76	PGU77	PGU78	PGU79	PGU80
1	10078.25	0	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	0	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	0	0	3003	0	0	0	0	0	0	10510.5	0	0	3003	0	0	0	0	0	0
4	10305.75	0	2944.5	2944.5	0	0	0	0	0	0	10305.75	0	2944.5	2944.5	0	0	0	0	0	0
5	10578.75	0	3022.5	3022.5	0	0	0	0	0	0	10578.75	0	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	0	2983.5	2983.5	3325.2583	0	0	0	0	0	10442.25	0	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	0	2925	2925	3177.45	0	0	0	0	0	10237.5	0	2925	2925	0	0	0	0	0	0
8	10078.25	0	2879.5	2879.5	3508.1486	0	0	0	0	0	10078.25	0	2879.5	2879.5	0	0	0	0	0	0
9	10374	10374	0	2964	3444.9728	0	0	0	0	0	10374	10374	0	2964	0	0	0	0	0	0
10	13354.25	13354.25	0	3815.5	4754.7	2348	2296.4908	1614.25	0	0	13354.25	13354.25	0	3815.5	4754.7	0	2296.4908	1614.25	0	0
11	13718.25	13718.25	0	3919.5	4884.3	2412	2379.0695	0	0	0	13718.25	13718.25	0	3919.5	4884.3	2412	2379.0695	0	0	0
12	14400.75	14400.75	0	4114.5	0	2532	2586.5329	0	0	0	14400.75	14400.75	0	4114.5	5127.3	2532	2586.5329	0	0	0
13	11193	11193	0	3198	0	0	0	0	0	0	11193	11193	0	3198	3985.2	1968	1948.648	0	0	0
14	11147.5	11147.5	3185	3185	0	0	0	0	0	0	11147.5	11147.5	3185	3185	3969	0	0	0	0	0
15	10237.5	10237.5	2925	2925	0	0	0	0	0	0	10237.5	10237.5	2925	0	3550.875	0	0	0	0	0
16	10146.5	10097.908	2899	2899	0	0	0	0	0	0	10146.5	10097.908	2899	0	0	0	0	0	0	0
17	10123.75	9838.3048	2892.5	0	0	0	0	0	0	0	10123.75	9838.3048	2892.5	0	0	0	0	0	0	0
18	10032.75	10032.75	2866.5	0	0	0	0	0	0	0	10032.75	10032.75	2866.5	0	0	0	0	0	0	0
19	10101	0	2886	0	3596.4	0	0	0	0	0	10101	10101	2886	0	0	1776	0	0	0	0
20	10305.75	0	0	0	3669.3	1812	0	0	0	0	10305.75	10305.75	2944.5	0	0	1812	0	0	0	0
21	10510.5	0	0	0	3742.2	1848	0	0	0	0	10510.5	10510.5	0	0	0	1848	0	0	0	0
22	10442.25	0	0	2983.5	3717.9	655.452	0	0	0	0	10442.25	10442.25	0	0	0	0	0	0	0	0
23	10351.25	0	0	2957.5	3360.76	0	0	0	0	0	10351.25	0	0	2957.5	0	0	0	0	0	0
24	10260.25	0	0	2931.5	3516.2591	0	0	0	0	0	10260.25	0	0	2931.5	0	0	0	0	0	0

Table-6.89e: Hourly profit for 100-generating unit system using hCSMA-SCA optimization algorithm (Units 81-100) with PEVs and solar during winter

Hour	PGU81	PGU82	PGU83	PGU84	PGU85	PGU86	PGU87	PGU88	PGU89	PGU90	PGU91	PGU92	PGU93	PGU94	PGU95	PGU96	PGU97	PGU98	PGU99	PGU100
1	10078.25	0	0	0	0	0	0	0	0	0	10078.25	0	0	0	0	0	0	0	0	0
2	10010	0	0	0	0	0	0	0	0	0	10010	0	0	0	0	0	0	0	0	0
3	10510.5	0	0	3003	0	0	0	0	0	0	10510.5	0	0	3003	0	0	0	0	0	0
4	10305.75	0	0	2944.5	0	0	0	0	0	0	10305.75	0	0	2944.5	0	0	0	0	0	0
5	10578.75	0	3022.5	3022.5	0	0	0	0	0	0	10578.75	0	3022.5	3022.5	0	0	0	0	0	0
6	10442.25	0	2983.5	2983.5	0	0	0	0	0	0	10442.25	0	2983.5	2983.5	0	0	0	0	0	0
7	10237.5	0	2925	2925	0	0	0	0	0	0	10237.5	0	2925	2925	0	0	0	0	0	0
8	10078.25	0	2879.5	2879.5	0	0	0	0	0	0	10078.25	0	2879.5	2879.5	0	0	0	0	0	0
9	10374	10374	2964	2964	0	0	0	0	0	0	10374	10374	2964	2964	0	0	0	0	0	0
10	13354.25	13354.25	3815.5	3815.5	4754.7	2348	0	0	0	0	13354.25	13354.25	3815.5	3815.5	4754.7	2348	2296.4908	1614.25	0	0
11	13718.25	13718.25	3919.5	3919.5	4884.3	2412	0	0	0	0	13718.25	13718.25	3919.5	3919.5	4884.3	2412	2379.0695	0	0	0
12	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2586.5329	0	0	0	14400.75	14400.75	4114.5	4114.5	5127.3	2532	2586.5329	0	0	0
13	11193	11193	3198	3198	3985.2	1968	1948.648	0	0	0	11193	11193	0	3198	3985.2	1968	0	0	0	0
14	11147.5	11147.5	3185	3185	3969	1960	1396.745	0	0	0	11147.5	11147.5	0	3185	3969	1960	0	0	0	0
15	10237.5	10237.5	0	2925	3550.875	0	0	0	0	0	10237.5	10237.5	0	2925	3550.875	0	0	0	0	0
16	10146.5	10097.908	0	0	0	0	0	0	0	0	10146.5	10097.908	0	0	0	0	0	0	0	0
17	10123.75	9838.3048	0	0	0	0	0	0	0	0	10123.75	9838.3048	0	0	0	0	0	0	0	0
18	10032.75	10032.75	0	0	0	0	0	0	0	0	10032.75	10032.75	2866.5	0	0	0	0	0	0	0
19	10101	10101	0	0	0	1776	0	0	0	0	10101	10101	2886	0	0	1776	0	0	0	0
20	10305.75	0	2944.5	0	0	1812	0	0	0	0	10305.75	10305.75	2944.5	0	0	1812	0	0	0	0
21	10510.5	0	3003	0	0	1848	0	0	0	0	10510.5	10510.5	3003	3003	0	1848	0	0	0	0
22	10442.25	0	2983.5	2983.5	0	0	0	0	0	0	10442.25	0	2983.5	2983.5	0	0	0	0	0	0
23	10351.25	0	2957.5	2957.5	0	0	0	0	0	0	10351.25	0	0	2957.5	0	0	0	0	0	0
24	10260.25	0	2931.5	2931.5	0	0	0	0	0	0	0	0	0	2931.5	0	0	0	0	0	0

Table-6.90: Statistical analysis of results for hCHHO-SCA & hCSMA-SCA optimization algorithms with PEVs and solar during winter for PBUCP

Test Systems	10 Unit System		40 Unit System		100 Unit System	
Methods	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**
Best Profit	**102510.7591**	**102510.7591**	**403998.558**	390728.498	**995710.65**	907174.855
Average Profit	101724.262	101724.262	381258.719	358395.982	893879.819	841509.685
Worst Profit	100736.0964	100736.0964	360727.007	346904.371	841111.854	808937.707
Std.	478.2782537	478.2782537	11603.2916	10229.2334	38335.1192	23930.2026
Median	101737.1191	101737.1191	383517.969	355652.726	879359.544	837368.862

Table-6.91: Hypothetical testing of hCHHO-SCA & hCSMA-SCA optimization algorithms with PEVs and solar during winter for PBUCP

Test Systems		10 Unit System		40 Unit System		100 Unit System	
Methods		**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**
Wilcoxon-rank sum test [p-value]		1.72569E-06	1.72569E-06	1.7344E-06	1.7344E-06	1.7344E-06	1.7344E-06
t-test	**p-value**	2.81065E-69	2.81065E-69	9.2371E-46	1.4376E-46	1.905E-41	1.2926E-46
	h-value	1	1	1	1	1	1

Table-6.92: Comparison of computational time for hCHHO-SCA & hCSMA-SCA optimization algorithms with PEVs and solar during winter for PBUCP

Test Systems	10 Unit System		40 Unit System		100 Unit System	
Methods	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**
Best time (sec.)	0.109375	0.0118745	0.21875	0.015625	0.359375	0.015625
Average time (sec.)	0.460416667	0.014583333	1.7421875	0.01666667	2.03020833	0.03489583
Worst time (sec.)	0.953125	0.015625	3.296875	0.046875	4	0.0625

6.7 COMPARISIONS OF RESULTS

Enriched solutions of profit based unit commitment problem by various proposed optimizer show that the integration of hCHHO-SCA and hCSMA-SCA have severely improvement of performances of classical Harris hawks and sine cosine optimizers. The performances of singer chaotic map of only Harris hawks optimizer and singer chaotic map of only sine cosine algorithms are compared for three cases with those proposed hybrid optimizer which are shown in tabular form and discussed below. The comparisons of the results are in term of best profit, average profit, worst profit, reserve capacity, best computational time, average and worst computational time with standard deviation and median for 10-, 40- and 100-generating unit system power generating systems with all of the two proposed hybrid techniques with other proposed techniques for all cases have been shown below. It is observed from comparison table that the performances of the proposed hybrid chaotic HHO with sine cosine function is preforming better than other optimizers.

In the previous chapter, section 5.7 shows the comparison with several existing optimizer with proposed hybrid metaheuristics optimizers. Comparison of the performances of results for 10-, 40- and 100-generating unit system are shown with other proposed hybrid optimizers and the suggested method **hCHHO-SCA** is performing better than other methods. The Table-6.93 shows the comparison of best profit obtained for various generating units including impact of PEVs and solar PV. In this table it has been presented that without considering the charging and discharging effect of PEVs and the, the profit for the selected unit is maximum. But considering the effect of only PEVs, then the profit decreased compared with all cases. The consideration of solar PV in winter and summer without the impact of PEVs is also performing better than other cases. The analysis from the comparison shows the best profit value for CHHO, CSCA, hCHHO-SCA and hCSMA-SCA are compared without considering the impact of PEVs and RES, the effect of only PEVs, only solar PV in summer and winter days and considering both the effect of PEVs and solar PV in summer and winter days.

Table-6.93: Comparison of Best Profit obtained for various generating units with PEVs and solar PV during summer and winter

Power Generation Units	**Proposed Optimizer**	**Best Profit without PEVs & RES**	**Best Profit with PEVs**	**Best Profit with RES during Summer**	**Best Profit with RES during Winter**	**Best Profit with PEVs and RES during Summer**	**Best Profit with PEVs and RES during Winter**
10-Generating Unit Systems	CHHO	107702.576639973	91543.1834966869	92242.4605970785	92970.1337767649	100615.695106595	102052.808022287
	CSCA	107702.576639973	92263.9140570312	92273.6015970786	93109.5837775404	101247.997950726	102510.759143009
	hCHHO-SCA	**107702.5766**	**102518.9807**	**105592.9791**	**106917.3426**	**101298.9838**	**102510.7591**
	hCSMA-SCA	107702.5766	91985.7291	92273.6016	93109.58378	100949.603293642	102510.7591
40-Generating Unit Systems	CHHO	411514.212937851	371259.568800103	404790.7961	391481.4382	379491.075345579	381378.7078
	CSCA	418677.346916291	383700.2599	405132.7889	433846.755	391141.0151	399397.1553
	hCHHO-SCA	**422919.4939**	**419370.74**	**449961.773**	**440563.577**	**407653.112**	**403998.558**
	hCSMA-SMA	401052.096	358805.925	399358.8298	414311.9571	400084.9156	390728.4984
100-Generating Unit Systems	CHHO	983872.509457148	905765.937777842	898381.794	905274.4886	878682.9331	875396.1206
	CSCA	991693.601785342	961064.3936	948926.744	947281.9985	946753.906	935169.9867
	hCHHO-SCA	**1068177.9**	**987027.953**	**978929.409**	**966825.849**	**993567.629**	**995710.65**
	hCSMA-SCA	923722.874	923596.4603	883387.9286	924140.0658	896905.0412	907174.8547

The Table- 6.94 shows the best, average and worst profit with standard deviation and median of testing units using CHHO and CSCA optimizer for PBUCP without PEVs & solar PV. It shows that the profit value for 10-Generating unit is **107702.58 $** using CHHO and CSCA optimization algorithm. In case of 40-Generating unit system, the profit value using CSCA optimization algorithm is **418677.347 $** which is better or higher that the profit value using CHHO optimization algorithm, i.e. 411514.213 $. Furthermore, for 100-Generating units, the profit value using CSCA optimization algorithm is **991693.602 $** which is greater than the profit from CHHO optimization algorithm, i.e. 983872.509 $. So, it is verified after test that the CSCA optimizer s performing better than CHHO optimization algorithm. The worst and average profit value are also considered with standard deviation and median value for each generating units, i.e. 10-,40- and 100-Generating unit using CHHO and CSCA optimization algorithm.

Table-6.94: Statistical analysis of results for CHHO and CSCA optimizer for PBUCP without PEVs & solar PV

Test Systems	10-Generating Unit System		40-Generating Unit System		100-Generating Unit System	
Methods	**CHHO**	**CSCA**	**CHHO**	**CSCA**	**CHHO**	**CSCA**
Best Profit	**107702.58**	**107702.577**	411514.213	**418677.347**	983872.509	**991693.602**
Average Profit	107702.58	107702.577	388307.124	407065.733	890685.051	959223.582
Worst Profit	107702.58	107702.577	373045.131	395616.366	850747.645	939255.958
Std.	0	0	11325.5912	5593.64589	23942.0165	12942.0029
Median	107702.58	107702.577	384733.521	405985.167	888228.468	958422.972

The convergence curves shows the analysis of finite numbers of elements which defines the relation between grid intervals with accuracy of analysis for the test systems. The convergence curve for 10-Generating unit system using CHHO and CSCA are shown in the **Fig.6.24** as the best profit value is **107702.58 $,** where x-axis is denoted as number of iterations which is taken as 100 and the y-axis denoted as the total profit in $. In case of 40-Generating unit system, the profit value using CSCA optimization algorithm is **418677.347 $** which is better or higher that the profit value using CHHO optimization algorithm, i.e. **411514.213 $** shown in the convergence graph. Furthermore, for 100-Generating units, the profit value using CSCA optimization algorithm is **991693.602 $** which is greater than the profit from CHHO optimization algorithm, i.e. **983872.509 $** are shown in the convergence curve for 100-Generating unit test system for 100 iterations. **Fig.6.24** shows the Graphical analysis of profit for

10-, 40- and 100-generating unit system using CHHO and CSCA optimizers without PEVs and solar PV.

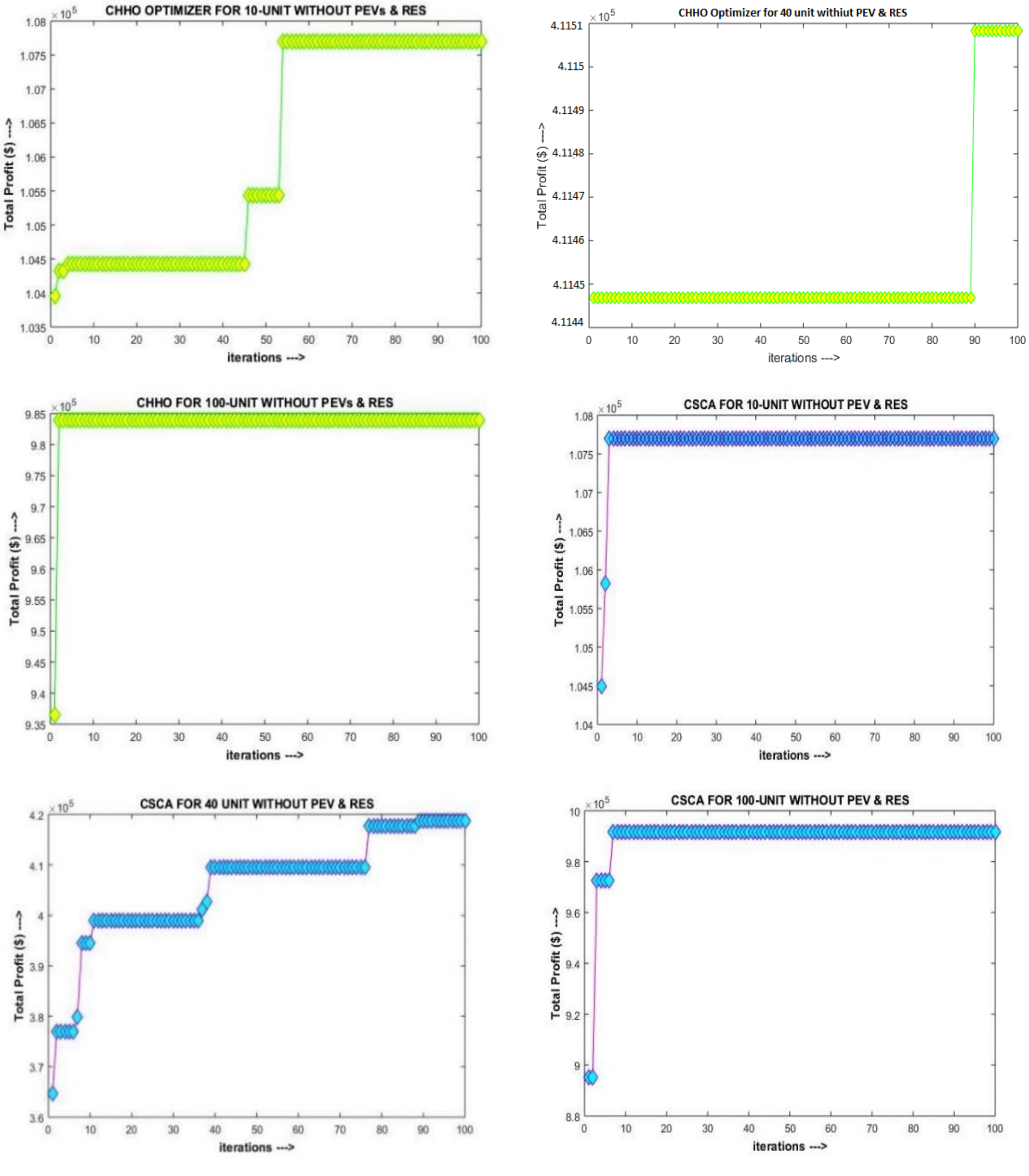


Fig.6.24: Convergence curve for 10-, 40- and 100-generating unit system using CHHO and CSCA optimization algorithm without PEVs and solar PV

The Table-6.95 shows the Best, average and worst profit with standard deviation and median of testing units using hCHHO-SCA and hCSMA-SCA optimizer for PBUCP without PEVs & solar PV. It shows that the profit value for 10-Generating unit is **107702.58 $** using hCHHO-SCA and hCSMA-SCA optimization algorithm. In case of

40-Generating unit system, the profit value using hCHHO-SCA optimization algorithm is **422919.494 $** which is better or higher that the profit value using hCSMA-SCA optimization algorithm, i.e. 401052.096 $. Furthermore, for 100-Generating units, the profit value using hCHHO-SCA optimization algorithm is **1068177.9 $** which is greater than the profit from hCSMA-SCA optimization algorithm, i.e. 923722.874 $. So, it is verified after test that the hCHHO-SCA optimizer s performing better than hCSMA-SCA optimization algorithm. The worst and average profit value are also considered with standard deviation and median value for each generating units, i.e. 10-,40- and 100-Generating unit using hCHHO-SCA and hCSMA-SCA optimization algorithm.

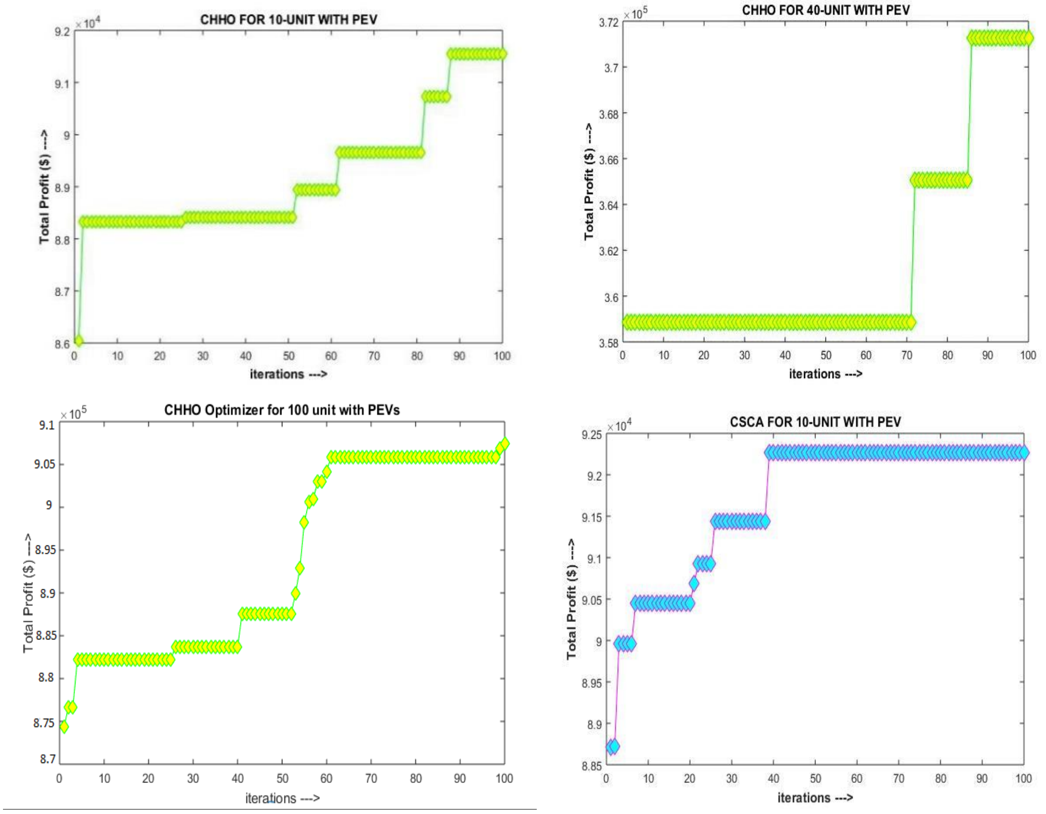
Table-6.95: Statistical analysis of results for hCHHO-SCA and hCSMA-SCA optimizer for PBUCP without PEVs & solar PV

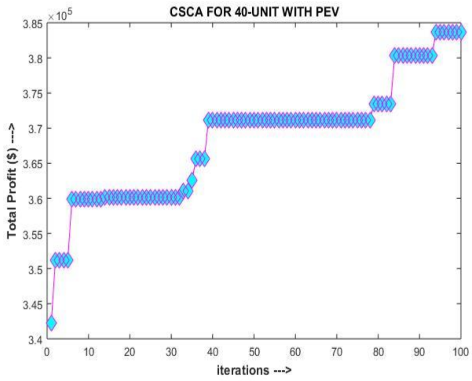
Test Systems	**10-Generating Unit System**		**40-Generating Unit System**		**100-Generating Unit System**	
Methods	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**	**hCHHO-SCA**	**hCSMA-SCA**
Best Profit	**107702.58**	107702.58	**422919.494**	401052.096	**1068177.9**	923722.874
Average Profit	107698.09	107687.39	402695.13	369142.576	972655.001	870330.085
Worst Profit	107568.01	107516.11	372765.214	349306.39	896549.374	830309.263
Std.	24.567913	47.001202	11450.1242	12338.6338	40959.2319	24741.3492
Median	107702.58	107702.58	402861.3	366483.932	976296.738	869898.996

The Table-6.96 shows the best, average and worst profit with standard deviation and median of testing units using CHHO and CSCA optimizer for PBUCP with considering the charging as well as discharging nature of PEVs. It shows that the profit value for 10-Generating unit is **92263.9141 $** using CHHO and CSCA optimization algorithm. In case of 40-Generating unit system, the profit value using CSCA optimization algorithm is **383700.26 $** which is better or higher that the profit value using CHHO optimization algorithm, i.e. 371259.569 $. Furthermore, for 100-Generating units, the profit value using CSCA optimization algorithm is **961064.394 $** which is greater than the profit from CHHO optimization algorithm, i.e. 905765.938 $. So, it is verified after test that the CSCA optimizer s performing better than CHHO optimization algorithm. The worst and average profit value are also considered with standard deviation and median value for each generating units, i.e. 10-,40- and 100-Generating unit using CHHO and CSCA optimization algorithm. **Fig.6.25** shows the Graphical analysis of profit for 10-, 40- and 100-generating unit system using CHHO and CSCA optimizers with PEVs.

Table-6.96: Statistical analysis of results for CHHO and CSCA optimizer for PBUCP with PEVs

Test Systems	10-Generating Unit System		40-Generating Unit System		100-Generating Unit System	
Methods	**CHHO**	**CSCA**	**CHHO**	**CSCA**	**CHHO**	**CSCA**
Best Profit	91543.1835	**92263.9141**	371259.569	**383700.26**	905765.938	**961064.394**
Average Profit	90212.4262	91553.7458	358576.105	380413.476	875124.025	933701.974
Worst Profit	89143.7849	90744.815	348045.392	373283.59	849733.442	916170.541
Std.	582.993297	375.862215	5415.17496	2159.72258	15828.3127	12658.6264
Median	90198.4837	91553.7594	359733.172	380744.85	877943.248	931208.75





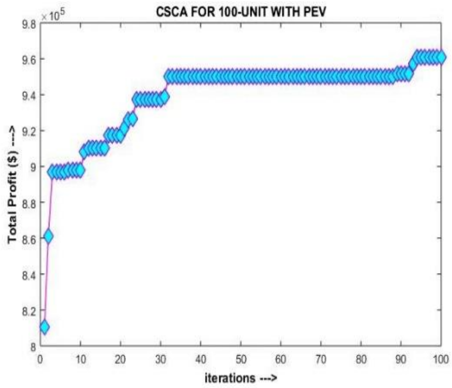


Fig.6.25. Convergence curve for 10-, 40- and 100-generating unit system using CHHO and CSCA optimization algorithm with PEVs

The Table-6.97 shows the best, average and worst profit with standard deviation and median of testing units using hCHHO-SCA and hCSMA-SCA optimizer for PBUCP with PEVs. Table-6.98 shows the Best, average and worst profit with standard deviation and median of testing units using CHHO and CSCA optimizer for Best Profit with RES during summer. **Fig.6.26** shows the Graphical analysis of profit for 10-, 40- and 100-generating unit system using CHHO with RES in summer and winter days. **Fig.6.27** shows the Graphical analysis of profit for 10-, 40- and 100-generating unit system using CSCA with solar PV in summer and winter days. The convergence curves shows the analysis of finite numbers of elements which defines the relation between grid intervals with accuracy of analysis for the test systems. The convergence curve for 10-Generating unit system using hCHHO-SCA are shown in the figure as the best profit value is **102518.9807 $,** where x-axis is denoted as number of iterations which is taken as 100 and the y-axis denoted as the total profit in $. In case of 40-Generating unit system, the profit value using hCHHO-SCA optimization algorithm is **419370.7404 $** which is better or higher that the profit value using hCSMA-SCA optimization algorithm, i.e. **358805.925 $** shown in the convergence graph. Furthermore, for 100-Generating units, the profit value using hCHHO-SCA optimization algorithm is **987027.953$** which is greater than the profit from hCSMA-SCA optimization algorithm, i.e. **923596.46 $** are shown in the convergence curve for 100-Generating unit test system for 100 iterations.

Table-6.97: Statistical analysis of results for hCHHO-SCA and hCSMA-SCA optimizer for PBUCP with PEVs

Test Systems	10-Generating Unit System		40-Generating Unit System		100-Generating Unit System	
Methods	hCHHO-SCA	hCSMA-SCA	hCHHO-SCA	hCSMA-SCA	hCHHO-SCA	hCSMA-SCA
Best Profit	**102518.9807**	91985.7291	**419370.7404**	358805.925	**987027.953**	923596.46
Average Profit	101968.3564	90687.8946	380659.928	343015.657	886399.289	852121.951
Worst Profit	100804.8464	89911.6396	361291.044	334138.484	823542.602	823065.991
Std.	395.7227137	528.856755	14324.1285	5794.92401	47650.4667	21449.5106
Median	102022.8654	90619.6752	377990.552	342285.38	871287.676	850886.365

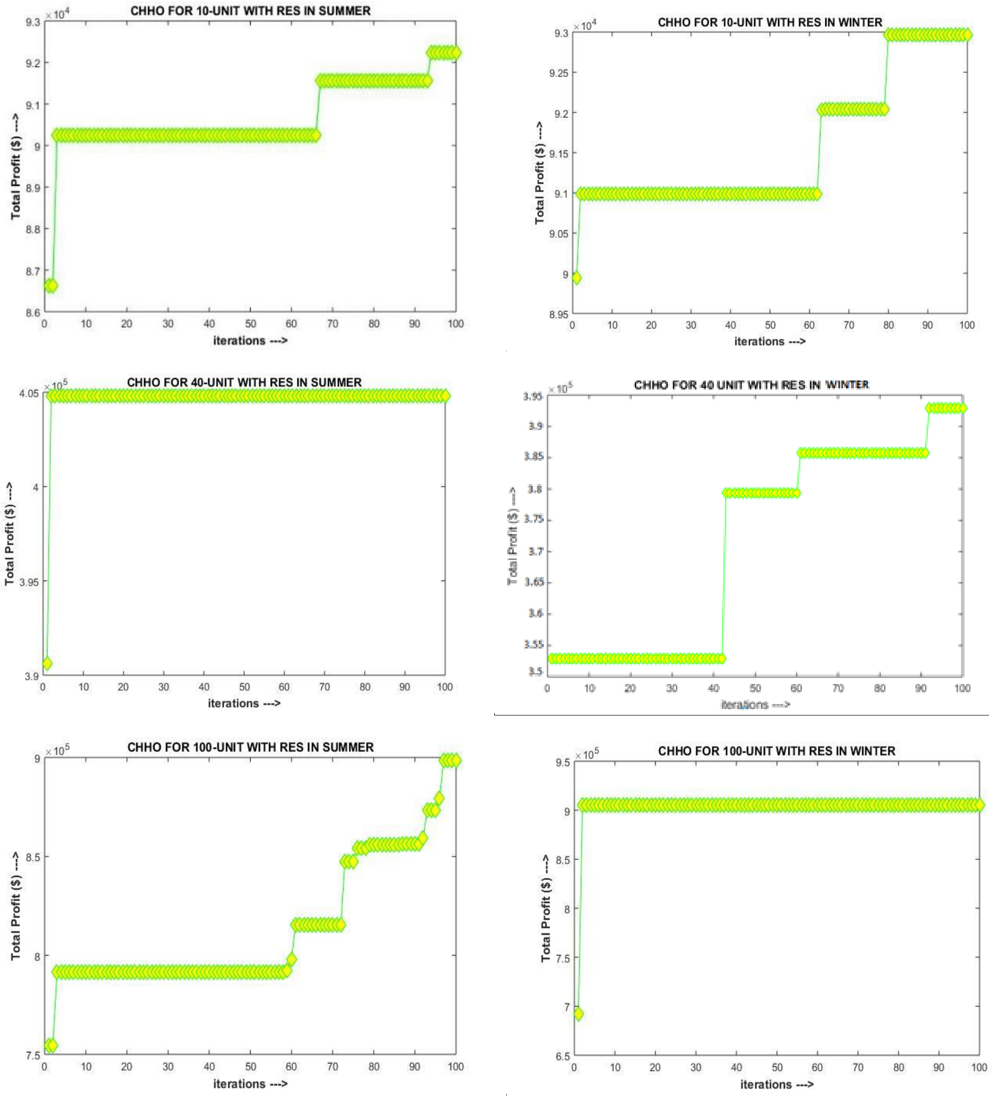
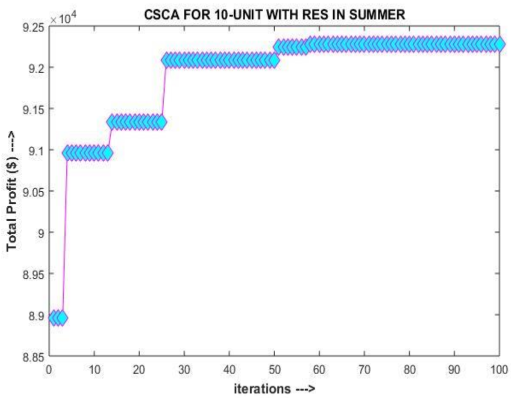
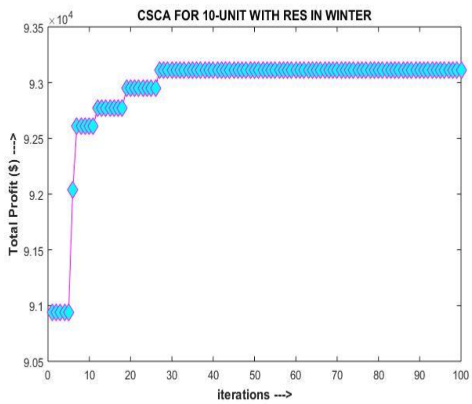


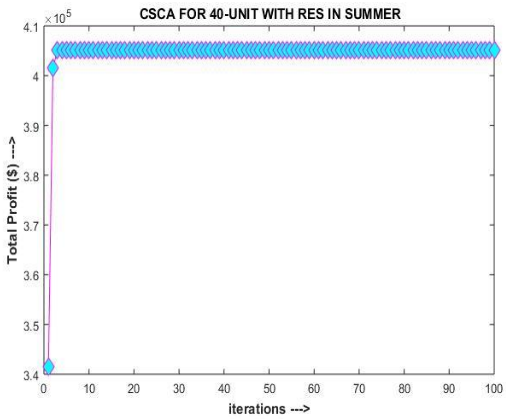
Fig.6.26. Convergence curve for 10-, 40- and 100-generating unit system using CHHO optimization algorithm with solar PV during summer and winter

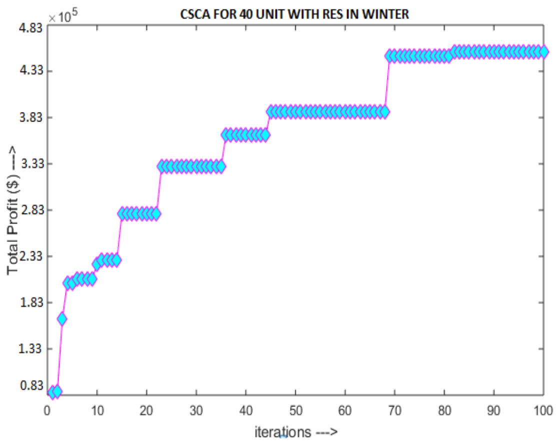
Table-6.98: Statistical analysis of results for CHHO and CSCA optimizer for PBUCP with solar PV during summer

Test Systems	10-Generating Unit System		40-Generating Unit System		100-Generating Unit System	
Methods	**CHHO**	**CSCA**	**CHHO**	**CSCA**	**CHHO**	**CSCA**
Best Profit	92242.4606	**92273.6016**	404790.796	**405132.789**	898381.794	**948926.744**
Average Profit	90812.508	92265.7767	374930.763	396379.986	842015.99	916844.052
Worst Profit	88950.1895	92139.0376	357576.044	388109.671	781775.324	895302.594
Std.	900.37778	26.0282227	12445.8488	4731.4135	23905.7001	11225.451
Median	90783.1206	92273.6016	371812	396870.594	841465.263	916185.193









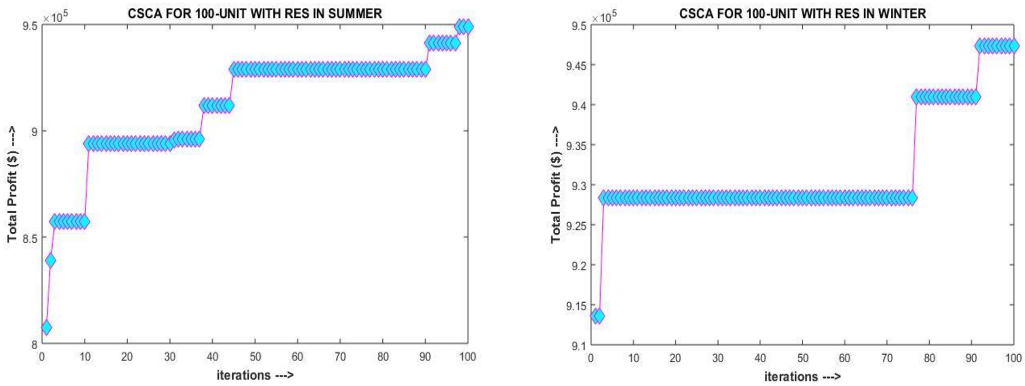


Fig.6.27. Convergence curve for 10-, 40- and 100-generating unit system using CSCA optimization algorithm with solar PV during summer and winter

The Table-6.99 shows the best, average and worst profit with standard deviation and median of testing units using CHHO and CSCA optimizer for best profit with RES during winter days.

Table-6.99: Statistical analysis of results for CHHO and CSCA optimizer for PBUCP with solar PV during winter

Test Systems	**10-Generating Unit System**		**40-Generating Unit System**		**100-Generating Unit System**	
Methods	**CHHO**	**CSCA**	**CHHO**	**CSCA**	**CHHO**	**CSCA**
Best Profit	92970.1338	**93109.58378**	391481.438	**433846.755**	905274.489	**947281.998**
Average Profit	92192.9929	93109.58378	374718.615	399612.404	848786.417	917337.863
Worst Profit	90698.2625	93109.58378	355566.424	391917.681	784778.978	899021.829
Std.	583.535521	4.44021E-11	9202.99155	7974.75274	22106.661	12096.2717
Median	92103.0356	93109.58378	374359.991	398038.262	846496.773	914083.625

The Table-6.100 shows the best, average and worst profit with standard deviation and median of testing units using CHHO and CSCA optimizer for PBUCP with PEVs and solar PV in summer. Table-6.101 shows the Best, average and worst profit with standard deviation and median of testing units using CHHO and CSCA optimizer for Best Profit with PEVs and solar PV during winter. **Fig.6.28** and **Fig.6.29** shows the Graphical analysis of profit for 10-, 40- and 100-generating unit system using CHHO and CSCA with PEVs and solar PV in summer and winter days. The convergence curves show the analysis of finite numbers of elements which defines the relation between grid intervals with accuracy of analysis for the test systems. The convergence curve for 10-Generating unit system using CSCA are shown in the figure as the best profit value is **101247.998 $,** where x-axis is denoted as number of iterations which is taken as 100 and the y-axis denoted as the total profit in $. In case of 40-Generating unit system, the profit value using CSCA optimization algorithm is **391141.015 $** which is better or higher that the profit value using CHHO optimization algorithm, i.e., **379491.075 $** shown in the convergence graph. Furthermore, for 100-Generating units, the profit value using CSCA optimization algorithm is **946753.906 $** which is greater than the profit from CHHO optimization algorithm, i.e., **878682.933 $** are shown in the convergence curve for 100-Generating unit test system for 100 iterations in summer days considering the effect of PEVs.

Table-6.100: Statistical analysis of results for CHHO and CSCA optimizer for PBUCP with PEVs and solar PV during summer

Test Systems	**10-Generating Unit System**		**40-Generating Unit System**		**100-Generating Unit System**	
Methods	**CHHO**	**CSCA**	**CHHO**	**CSCA**	**CHHO**	**CSCA**
Best Profit	100615.695	**101247.998**	379491.075	**391141.015**	878682.933	**946753.906**
Average Profit	99617.8466	100562.827	358881.259	385233.489	843485.885	917113.827
Worst Profit	98179.6648	100226.105	340558.554	380002.266	803314.027	899087.794
Std.	704.313046	290.501349	8778.60842	2695.73282	17111.9514	11575.2617
Median	99733.7385	100603.123	358639.728	385246.611	844255.116	918871.331

Fig.6.28 shows the Graphical analysis of profit for 10-, 40- and 100-generating unit system using CHHO with solar PV in summer and winter days with PEVs.

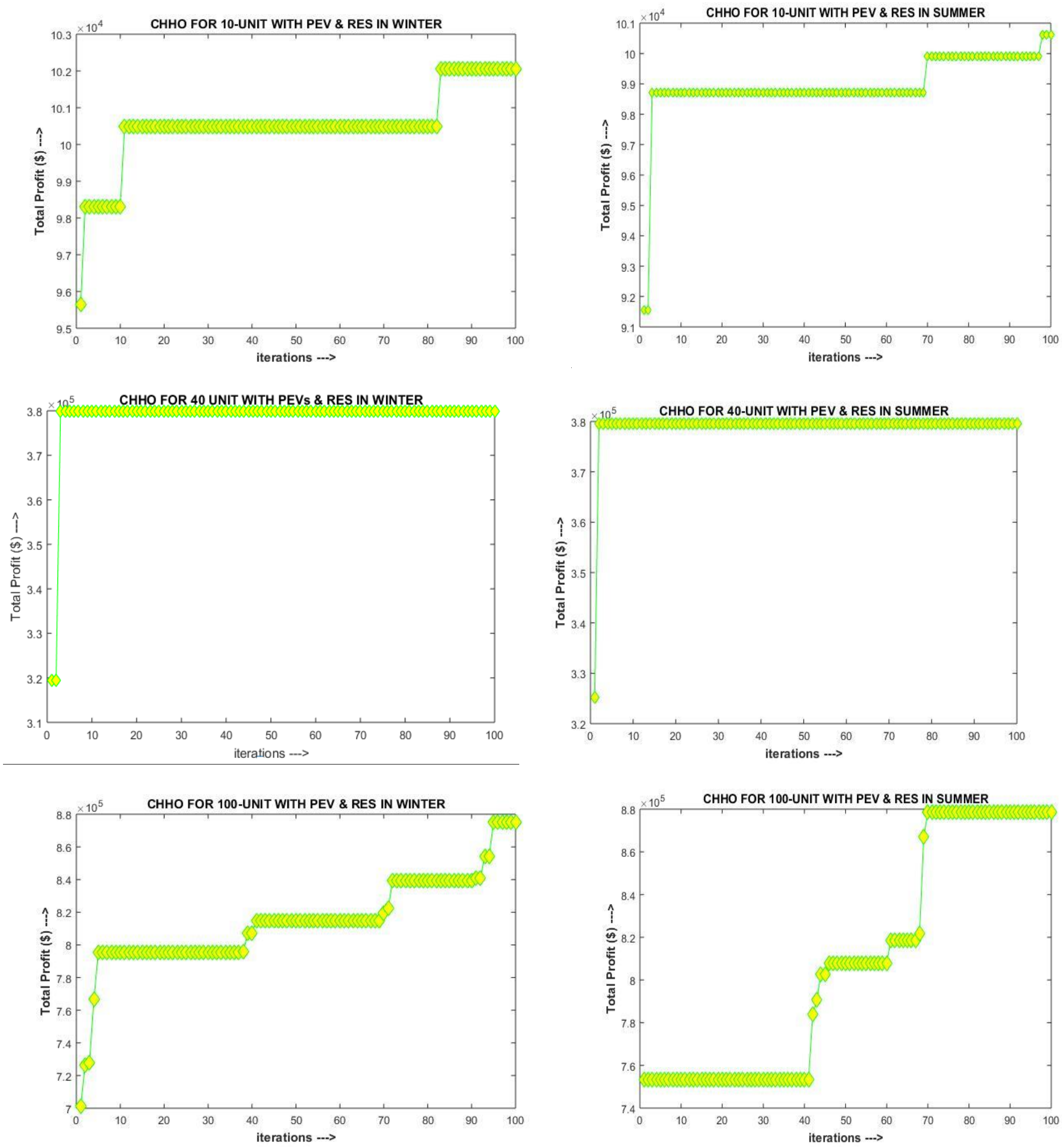


Fig.6.28. Convergence curve for 10-, 40- and 100-generating unit system using CHHO optimization algorithm with PEVs and solar PV during summer and winter

The Table-6.105 shows the best, average and worst profit with standard deviation and median of testing units using CHHO and CSCA optimizer for best profit with PEVs and solar PV during winter days. **Fig.6.29** shows the Graphical analysis of profit for 10-, 40- and 100-generating unit system using CSCA with solar PV in summer and winter days with PEVs and solar PV.

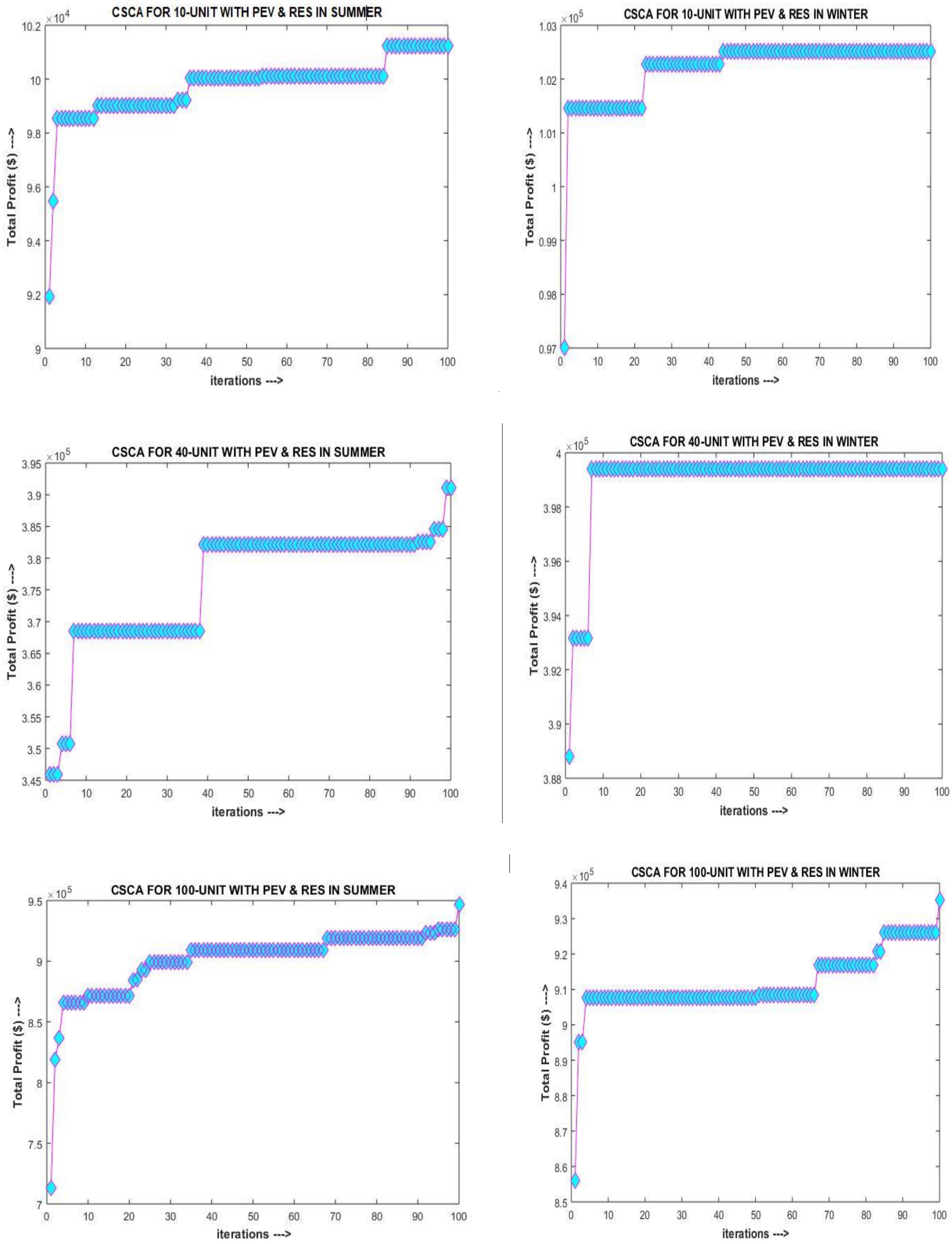


Fig.6.29. Convergence curve for 10-, 40- and 100-generating unit system using CSCA optimization algorithm with PEVs and solar PV during summer and winter

Table-6.101: Statistical analysis of results for CHHO and CSCA optimizer for PBUCP with PEVs and solar PV during winter

Test Systems	10-Generating Unit System		40-Generating Unit System		100-Generating Unit System	
Methods	**CHHO**	**CSCA**	**CHHO**	**CSCA**	**CHHO**	**CSCA**
Best Profit	102052.808	**102510.759**	381378.708	**399397.155**	875396.121	**935169.987**
Average Profit	100551.501	102199.28	363027.771	385982.288	843861.842	918983.193
Worst Profit	98864.113	101837.276	345314.734	378885.337	810592.558	900122.649
Std.	844.122088	194.286444	9494.82163	4919.16043	15292.936	9599.52144
Median	100753.062	102212.775	362994.084	385524.48	844101.553	918645.72

The Table-6.102 shows the hypothesis test including p-value, t-value and h-value with the best, average and worst time for unit systems using CHHO & CSCA optimizer PBUCP without PEVs & solar PV. Table-6.103 shows the hypothesis test best, average and worst time for unit systems using CHHO and CSCA optimizer for PBUCP with considering the effect of PEVs. Hypothetical testing is also important to check and verify the null hypothesis of the optimization algorithm for each test systems. In this research work some non-parametric statistical test, i.e., P-Value, t-Test and h-Value are taken into consideration by using CHHO and CSCA optimization algorithm. The assumption from null hypothesis of any system which have the difference in-between true value of mean and comparison values are same as zero. The highest value of t-Test indicates about the huge difference between the two test samples sets. That means the groups are different in case of higher value output from t-Test. The Table-6.108 shows the effectiveness of CHHO and CSCA optimization algorithm by shown that the values are indicated as justifications for null hypothesis. The P-Value for 10-Generating unit system using CHHO and CSCA optimization algorithm are **4.3205E-08** which is justified the null hypothesis as the value is almost near about zero. In case for 40- and 100-Generating units the P-Value using CHHO and CSCA are **1.7344E-06**. In case of t-Test for 10-Generating unit system is 0 by using CHHO as well as CSCA optimizer. The t-Test for 40-Generating units using CHHO optimization algorithm is **2.6927E-46** and using CSCA optimization algorithm is **9.0215E-56** which is almost near about the value zero which validate the null hypothesis. The t-Test for 100-Generating unit system using CHHO optimization algorithm is **2.5288E-47** and using CSCA optimization algorithm is **5.3065E-56** that is near about the value zero and which validates the null hypothesis. The best, worst and the average time for 10-, 40- and 100-Generating unit systems using CHHO and CSCA optimization algorithm are given in this Table-6.102.

Table-6.102: Hypothetical testing of CHHO and CSCA optimization algorithms without PEVs and solar PV for PBUCP

Test Systems	10-Generating Unit System		40-Generating Unit System		100-Generating Unit System	
Methods	**CHHO**	**CSCA**	**CHHO**	**CSCA**	**CHHO**	**CSCA**
P-Value	4.3205E-08	4.3205E-08	1.7344E-06	1.7344E-06	1.7344E-06	1.7344E-06
t-Test	0	0	2.6927E-46	9.0215E-56	2.5288E-47	5.3065E-56
h-Value	1	1	1	1	1	1
Best time (sec.)	0.09375	0.140625	0.1875	0.1875	0.3125	0.28125
Average time (sec.)	0.2859375	0.38697917	1.14166667	0.521875	1.13958333	0.70677083
Worst time (sec.)	0.609375	0.90625	3.078125	0.765625	2.015625	1.453125

Table-6.103: Hypothetical testing of CHHO and CSCA optimization algorithms with PEVs for PBUCP

Test Systems	10-Generating Unit System		40-Generating Unit System		100-Generating Unit System	
Methods	**CHHO**	**CSCA**	**CHHO**	**CSCA**	**CHHO**	**CSCA**
P-Value	1.7344E-06	1.7344E-06	1.7344E-06	1.7344E-06	1.7344E-06	1.7344E-06
t-Test	2.8496E-65	5.5035E-71	1.3934E-54	6.6595E-67	2.6012E-52	6.1038E-56
h-Value	1	1	1	1	1	1
Best time (sec.)	0.109375	0.25	0.203125	0.140625	0.328125	0.28125
Average time (sec.)	0.34114583	1.04791667	0.87291667	0.71197917	1.36927083	0.8875
Worst time (sec.)	0.6875	1.875	1.703125	1.078125	2.71875	1.453125

Table-6.104 shows the same for CHHO and CSCA optimizer for best time with solar PV during summer days.

Table-6.104: Hypothetical testing of CHHO and CSCA optimization algorithms with solar PV for PBUCP during summer

Test Systems	**10-Generating Unit System**		**40-Generating Unit System**		**100-Generating Unit System**	
Methods	**CHHO**	**CSCA**	**CHHO**	**CSCA**	**CHHO**	**CSCA**
P-Value	1.7333E-06	1.9773E-07	1.7344E-06	1.7344E-06	1.7344E-06	1.7344E-06
t-Test	6.9988E-60	1.036E-104	1.1433E-44	1.5211E-57	1.2332E-46	3.1766E-57
h-Value	1	1	1	1	1	1
Best time (sec.)	0.15625	0.15625	0.15625	0.140625	0.28125	0.28125
Average time (sec.)	0.45052083	0.46927083	0.48385417	0.43177083	0.63385417	0.56979167
Worst time (sec.)	0.890625	0.796875	0.828125	0.84375	1.078125	0.96875

Table-6.105 shows the same parameters of those systems using CHHO and CSCA optimizer for hypothesis test considering solar PV during winter days.

Table.6.105: Hypothetical testing of CHHO & CSCA optimization algorithms with solar PV for PBUCP during winter

Test Systems	**10-Generating Unit System**		**40-Generating Unit System**		**100-Generating Unit System**	
Methods	**CHHO**	**CSCA**	**CHHO**	**CSCA**	**CHHO**	**CSCA**
P-Value	1.7344E-06	4.32046E-08	1.7344E-06	1.7344E-06	1.7344E-06	1.7344E-06
t-Test	1.5595E-65	0	1.8469E-48	4.5023E-51	1.0128E-47	2.7292E-56
h-Value	1	1	1	1	1	1
Best time (sec.)	0.171875	0.15625	0.125	0.15625	0.28125	0.3125
Average time (sec.)	0.45989583	0.4546875	0.43385417	0.44166667	0.6796875	1.2578125
Worst time (sec.)	0.859375	0.765625	0.765625	0.859375	1.09375	2.28125

Table-6.106 represents the hypothesis test, best, average and worst time for unit systems using CHHO and CSCA optimizer for Best Profit with PEVs and solar PV during summer days.

Table.6.106: Hypothetical testing of CHHO and CSCA optimization algorithms with PEVs and solar PV for PBUCP during summer

Test Systems	10-Generating Unit System		40-Generating Unit System		100-Generating Unit System	
Methods	**CHHO**	**CSCA**	**CHHO**	**CSCA**	**CHHO**	**CSCA**
P-Value	1.6966E-06	1.6044E-06	1.7344E-06	1.7344E-06	17111.9514	1.7344E-06
t-Test	3.8605E-64	2.061E-75	1.6435E-48	2.8632E-64	844255.116	7.6682E-57
h-Value	1	1	1	1	1.7344E-06	1
Best time (sec.)	0.140625	0.171875	0.234375	0.203125	7.253E-51	0.25
Average time (sec.)	0.5265625	0.32447917	1.15885417	1.1140625	1	0.60416667
Worst time (sec.)	0.921875	0.5	2.4375	2.53125	0.28125	0.984375

The Table-6.107 represents the Hypothesis test, Best, Average and Worst time for unit systems using CHHO and CSCA optimizer for Best Profit with PEVs and solar PV during winter days.

Table-6.107: Hypothetical testing of CHHO and CSCA optimization algorithms with PEVs and solar PV for PBUCP during winter

Test Systems	10-Generating Unit System		40-Generating Unit System		100-Generating Unit System	
Methods	**CHHO**	**CSCA**	**CHHO**	**CSCA**	**CHHO**	**CSCA**
P-Value	1.7344E-06	1.6322E-06	1.7344E-06	1.7344E-06	1.7344E-06	1.7344E-06
t-Test	5.618E-62	1.1075E-80	1.1438E-47	1.0161E-56	2.7539E-52	3.1782E-59
h-Value	1	1	1	1	1	1
Best time (sec.)	0.15625	0.171875	0.234375	0.296875	0.25	0.3125
Average time (sec.)	0.48854167	0.42447917	1.06197917	1.06822917	0.6421875	1.38229167
Worst time (sec.)	1.015625	0.84375	2.25	1.78125	1.109375	2.28125

The comparison of proposed methods for 10-, 40- and 100-generating unit systems with PEVs and solar PV in summer and winter are shown in **Fig.6.30**, **Fig.6.31** and **Fig.6.32** respectively. From the graphical analysis, it shows that the suggested hHHO-SCA optimizer is performing better than other optimizer in all cases. The best profit value is much more for this particular proposed hHHO-SCA optimization algorithm than the other proposed CHHO, CSCA, hCSMA-SCA optimization algorithms.

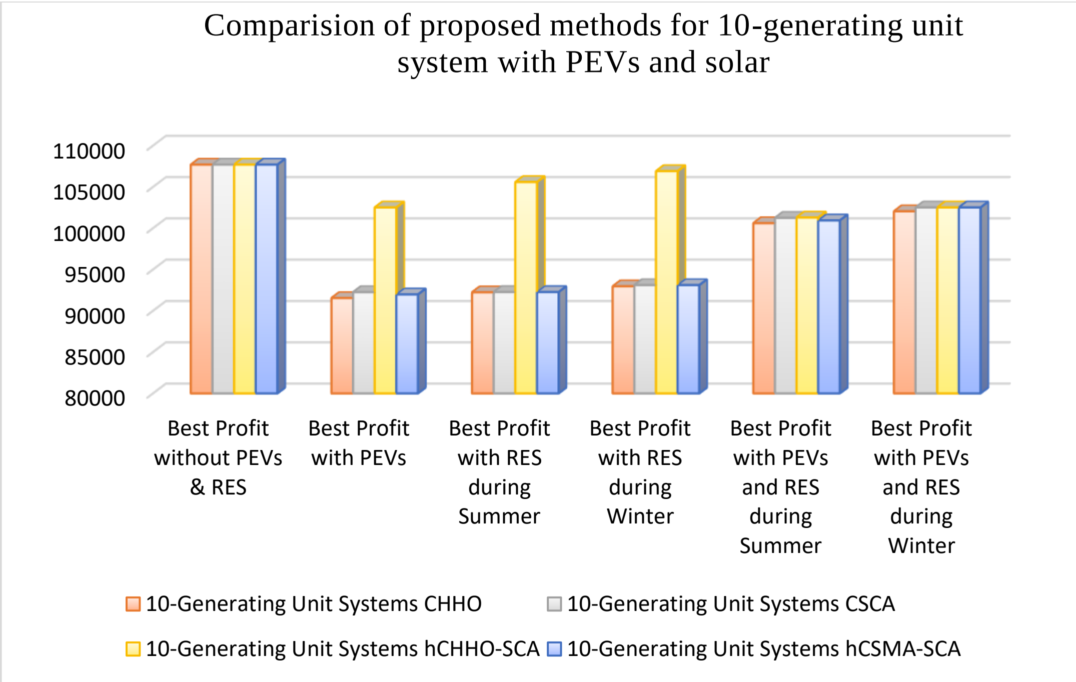


Fig.6.30. Comparison of proposed methods for 10-generating unit system with PEVs and solar

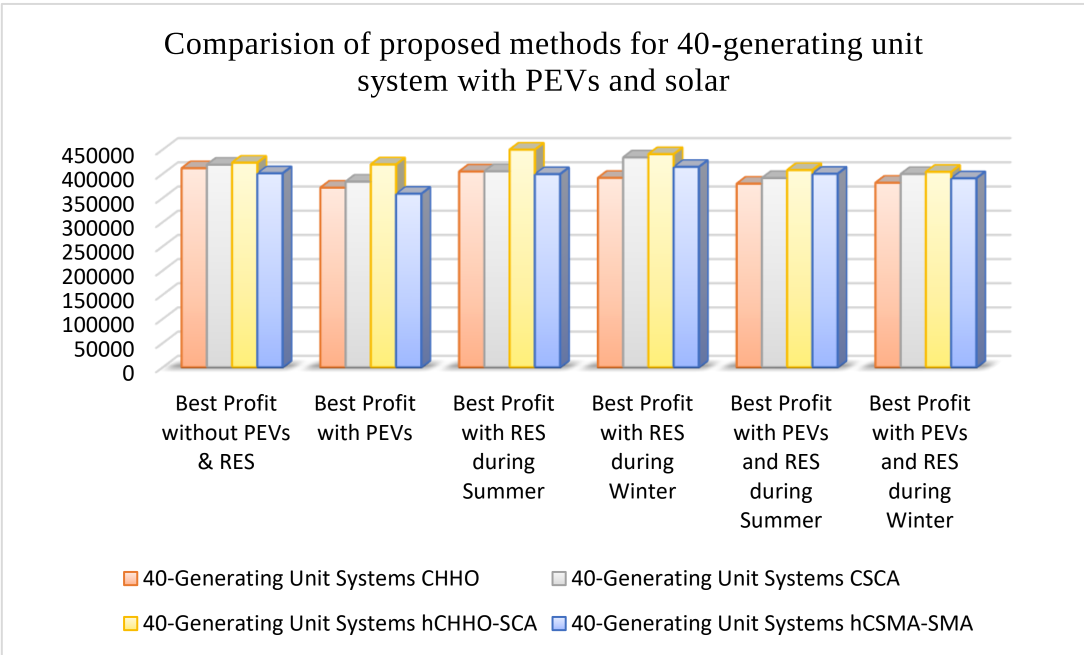


Fig.6.31. Comparison of proposed methods for 40-generating unit system with PEVs and solar

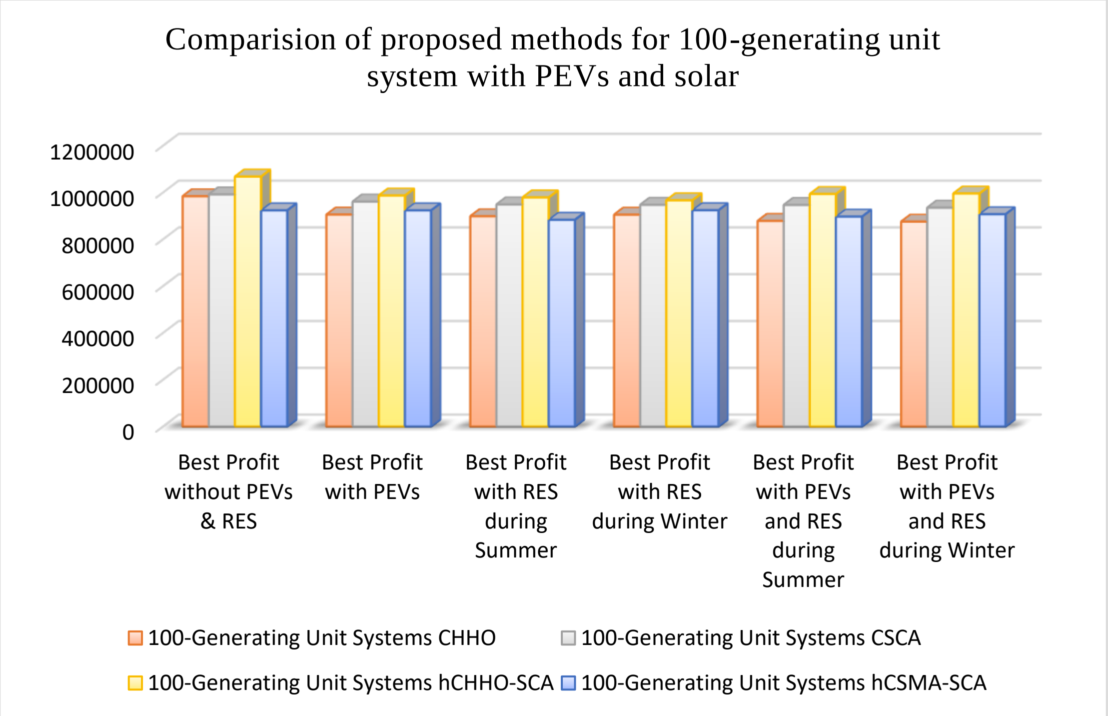


Fig.6.32. Comparison of proposed methods for 40-generating unit system with PEVs and solar

In case of 10-generating unit system, comparing within proposed CHHO, CSCA, hCHHO-SCA and hCSMA-SCA, with PEV penetration 10.7% profit are increased by using hCHHO-SCA optimizer, considering RES in summer days 12.64% profit have been increased, considering RES in winter days 13.04% profit increased, with PEV penetration and RES in summer days 0.67% profit and in winter days 0.45% profit have increased by using proposed hCHHO-SCA optimizer.

Further, 40-generating unit system, comparing within proposed CHHO, CSCA, hCHHO-SCA and hCSMA-SCA, including PEV penetration 14.44% profit are increased, considering solar PV in summer days 11.2% profit have been increased, considering RES in winter days 11.14% profit increased, with PEV penetration and RES in summer days 6.91% profit and in winter days 5.59% profit have increased by using proposed hCHHO-SCA optimizer.

Moreover, for 100-generating unit system, comparing within proposed CHHO, CSCA, hCHHO-SCA and hCSMA-SCA, including PEV penetration 8.23% profit are increased, considering solar PV in summer days 9.76% profit have been increased, considering RES in winter days 6.28% profit increased, with PEV penetration and solar PV in summer days 11.56% profit and in winter days 12.08% profit have increased by using proposed hCHHO-SCA optimizer.

6.8 CONCLUSION

In the suggested research work, the authors have successfully presented mathematical formulation of PBUCP considering battery electric vehicles, plug-in electric vehicles and renewable energy sources (solar power), which is one of the challenging problems in power system operation control and planning. PBUCP of electric power system is considered.

The proposed numerical construction of PBUCP will be helpful for researchers, who are working in this kind of problems with PEVs, i.e., battery electric vehicles, solar PV unit. In this chapter, profit based unit commitment problem has been resolved using hCHHO-SCA and hCSMA-SCA. The test units are consisting of 10, 40 and 100-generating unit systems have been scheduled successfully and gain maximum profits using suggested hybrid optimizers. From the simulated results for profit of hCHHO-SCA optimizer, it is analyzed that the performances are better than the others existing as well as recently established heuristics, meta-heuristics and evolutionary search optimizer. From the simulation outcomes, it is seen that the suggested optimizer determines the satisfactory profit value with commitment scheduling within a reasonable time of computation.

Such a powerful optimizer can be applied to get solution of profit based unit commitment for modern power sectors. Analysis of the variation in profit value, i.e., best, average and worst value with its standers deviation and median value are taken into considerations. Some of the hypothesis testing including Wilcoxon rank sum method and t-test are taken into consideration through which p-value and h-value can be determined. The computational times are also analyzed as best, average and worst time of simulations. It has been successfully presented the efficiency and validity of hCHHO-SCA and hCSMA-SCA optimization technique to solve PBUCP with impact of PEVs and solar PV in summer and winter days and evaluated performance of the suggested hybrid optimized method for standard test system, which consists of thermal generating units for small, medium and large-scale power sectors. The efficacy of the suggested algorithm was tested for 10-generating unit system, 40-generating unit system and 100-generating unit system. After successful experiment, it was observed that the suggested optimizer is more effective to solve continuous, discrete and non- linear optimization problems compared with another existing optimizer. The comparison of profit for novel hCHHO-SCA and hCSMA-SCA optimizer is better from other existing methods which are shown in this chapter.

CHAPTER-7

CONCLUSION AND FUTURE SCOPE

7.1 INTRODUCTION

This chapter represents the significant and salient contributions of the research work undertaken and presented in the thesis with a brief report concerning a few recommendations for further research. The significant contributions are listed and discussed in this section. The research work has been made to improve a profit-based analysis to solve profit-based unit commitment problems including a plug-in electric vehicle with considering uncertain renewable energy sources. The suggested work is also tested on various types of IEEE test systems which are consists of small, medium, and large systems. To verify the optimum solutions for-profit-based unit commitment problem, the three different types of chaotic optimization and two-hybrid optimization strategies have been employed. Those implemented optimization strategies have been tested on standard benchmark functions and engineering design problems. The feasibility of the suggested work has been explored by testing different IEEE test systems consisting of small, medium, and large systems.

7.2 SIGNIFICANT CONTRIBUTION

This research work explained information about various recent optimization methodologies to solve complex design problems. The purpose of this suggested research is to establish a new optimization strategy to increase the profit with considering some system constraints. In this research, solar power is taken as a renewable energy source. In PBUCP, there is one of the important tasks is to maintain the generator scheduling to meet the power demand by increasing the profit of the generation company. Further, due to the huge operational cost, conventional fossil fuels are required to generate power. Moreover, due to the thermal power plants and vehicle transportation, the emissions are more which is harmful to the environment. So, alternative energy sources are needed to find an existing source of energies is nom-replicable. Thus, renewable energy sources, i.e., solar energy are taken into consideration. Solar energy can be divided into solar photovoltaics or solar thermal as a source of energy. In this research solar photovoltaics have been taken into consideration as renewable energy sources. By using solar photovoltaics, it cannot give a constant power output as it depends upon the environmental condition. Further, due to the development of control engineering and power storage devices, the solar photovoltaic system can be stored for further use. Nowadays research and development team supports to development of new projects at low manufacturing prices which increases the efficiency as well as the better performance of photovoltaics technologies. Electricity can produce directly from photovoltaics which is reliable for photovoltaic technologies. The Levelized Cost of the photovoltaic energy has reduced roughly by 90% since 2011. Thus, the photovoltaic research and development team has been focused on the opportunities of huge price reduction to meet the Levelized cost of energy of $0.03/kWh. This thing allows maintaining the price competitiveness up to several cents/kWh to improve the performance of the power grid and electricity dispatch ability. The utilization of electric vehicles is to take the electricity from the grid and it has various types of power storage systems. Furthermore, the stored energy from the electric vehicle can be fed back to the grid. So, sufficient charging and discharging facilities are there for the plug-in electric vehicle. A substantial amount can be fed back to the power grid during peak load conditions and save energy.

In this research work, the chaotic maps are used to improve the exploitation capability of the optimizer in local search space. The metaheuristics hybrid search methods are designed to solve the PBUCP related problems including the impact of PEVs and solar PV in summer and winter. Three different chaotic algorithms and two-hybrid algorithms are developed using recent algorithms, i.e., Harris hawk's optimizer, sine cosine algorithm, and slime mould algorithm.

The Harris Hawks Optimizer, Sine Cosine Algorithm, and Slime Mould Algorithms are applied to improve the exploration capability of the optimizer in global search regions. The Harris Hawks bird has a unique nature, i.e., chasing style and cooperative behavior. Due to this, the hawks can free to move in different directions. Further, in the case of slime mould, other unique behaviors have for approaching and wrapping the food. Those unique nature were mathematically mimicked and created metaheuristics optimizer. The searching capabilities in the global search region of that optimizer are better than the other existing methods. As SCA is a population-based algorithm, it has the upgradation capability for explorations in different regions of the search space. Moreover, there are several methods are already tested, but from those existing methods, the suggested optimization algorithms were performing better than the others methods. Thus HHO, SCA, and SMA have been selected to solve the problem in the global search region.

Three different hybrid algorithms are developed using recent modern search algorithms such as HHO, SCA, and SMA. In the suggested research work, two-hybrid algorithms and three chaotic algorithms are developed as follows.

i. Hybrid chaotic Harris hawks Optimization is combined with a basic sine cosine algorithm. This new hybrid algorithm is abbreviated as hCHHO-SCA.
ii. A hybrid chaotic slime mould algorithm is combined with a basic sine cosine algorithm. This new hybrid algorithm is abbreviated as hCSMA-SCA.
iii. Chaotic Harris hawks optimization algorithm by including Sigmoid and Tent chaotic function. The abbreviation of this algorithm is CHHO.
iv. Chaotic slime mould algorithm by including Sigmoid and Tent chaotic function. The abbreviation of this algorithm is CSMA.
v. Chaotic sine cosine algorithm by including Sigmoid and Tent chaotic function. The abbreviation of this algorithm is CSCA.

Firstly to check the efficiency of the suggested research, 23 standard benchmark functions have been verified by proposed hybrid methodologies. After that, to check the feasibility of the suggested research work, 10 multidisciplinary engineering design problems such as truss design problem, pressure vessel design, welded beam design, rolling element problem, etc. were verified successfully. Further, the test results are validated by comparing the output with other existing stochastic, heuristics, and meta-heuristic algorithms. After recognizing the effectiveness of proposed methods for profit-based unit commitment problem has been determined for different test systems consisting of 10, 40, and 100 units. The significant contributions of the outcomes are discussed below in this section.

- Firstly to check the effectiveness of the proposed hybrid metaheuristics algorithms, CHHO, CSCA, CSMA, hCHHO-SCA, and hCSMA-SCA have been tested over 23 standard benchmark functions. The unimodal functions are taken from F1 to F7, the multi-modal functions are taken from F8 to F13 and the fixed dimension functions are taken from F14 to F23.

  It has been shown that the phase of exploitation of the existing HHO optimizer has been upgraded successfully using the chaotic singer function and updated the phase of explorations by HHO and SCA techniques also. The SMA optimizer has been upgraded with a singer chaotic map for exploitation and updated by the SCA optimizer, for exploration the proposed optimizers are successfully tested for unimodal, multimodal, and fixed dimension standard benchmark problems.
- Further, to validate the efficiency of the proposed research, 11 types of multidisciplinary engineering design problems are taken into consideration, such as pressure vessel problem, truss design problem, welded beam design problem, rolling element problem, and I-beam design problem, etc.
- A profit-based unit commitment problem has been implemented to maximize profit value and minimize the overall operating prices subjected to technological and physical constraints with satisfying the hourly variation of power demand. It is a large, non-linear, mixed-integer, and non-convex optimization problem and has been solved by hybrid metaheuristics methods CHHO, CSCA, hCHHO-SCA, and hCSMA-SCA. The chaotic maps, HHO, SCA, and SMA are combined to develop hCHHO-SCA and hCSMA-SCA optimizers. The metaheuristic process has been adopted to tackle different kinds of operational and system as well as unit constraints of PBUCP. These techniques are implemented successfully upon various types of test systems comprising 10-,40- and 100- power generating units.
- The proposed algorithms are successfully used to solve PBUCP and its performances have been tested for a standard test system, which consists of thermal generating units for small, medium, and large scale power sectors. The efficacy of the suggested algorithm was tested for 10 generating systems, 40 generating systems, and 100 generating systems. After a successful experiment,

it was observed that the suggested optimizer, hCHHO-SCA is more effective to solve continuous, discrete, and non-linear optimization problems compared with other existing optimizers. The obtained profit by hCHHO-SCA and hCSMA-SCA optimizer is better than other existing methods.

- PBUCP has been resolved using hCHHO-SCA and hCSMA-SCA by considering the impact of PEVs and solar PV along summer and winter days and the test system, which consists of thermal generating units for small, medium, and large scale power sectors have been taken into consideration. The efficacy of the suggested algorithm was tested for 10 generating systems, 40 generating systems, and 100 generating systems. From the simulated results of the hCHHO-SCA optimizer, it is analyzed that the performances are better than the other existing as well as recently established heuristics, meta-heuristics, and evolutionary search optimizers.

  Further, it is seen that the suggested optimizer determines the satisfactory profit value with commitment scheduling within a reasonable time of computation. Hence, such a powerful optimizer can be applied to get a solution of profit-based unit commitment for modern power sectors. For statistical analysis, the best value, average value, worst value, standard deviation, and median value are taken into consideration. Also, the hypothesis testing was done using the Wilcoxon rank-sum method and t-test, where the p-value and h-value are recorded. The computational times are also analyzed as the best time, average time, and worst time of simulations.

  The findings in comparison to the relevant literature statistically have been taken into consideration. It has been tested that the hCHHO-SCA optimizer is performing better than other existing and suggested optimization algorithms. So, the percentage analysis of incremental profit has been calculated concerning the profit of the hCHHO-SCA optimizer. For the 10-generating unit system, the profit increased by 6.143% using the hCHHO-SCA method in comparison with TS-RP [299] method. 4.124% and 4.091% profit values are increased by using the hCHHO-SCA method in comparison with the profit of TS-IRP [299] and MM [9] optimizer respectively. Further, 3.539%, 3.107%, and 3.085% profit have been increased by using this proposed method in comparison with ACO

[109], PSO [13], and BSCA 2 [35] optimization algorithms. Using proposed hCHHO-SCA optimizer, the profit was increased by 2.921%, 2.357% and 2.054% than PPSO [294], IPDM [47] and ICA-DBD [295] optimization techniques. 1.999% profit increased by hCHHO-SCA than NACO [109] method. 1.69% profit increased by hCHHO-SCA method in comparisons with VTS-PEPSO [294], TS-EPSO [296], PABC [12], ABC [12] and PNACO [13]. Using the suggested optimizer hCHHO-SCA, the profit value is increased 1.563% than GSA [293] optimizer, 1.357% than MOPSO [296], 1.265% than ICA [295] and 0.857% than BSCA-4 [35] optimizer.

Further, for the 40-generating unit system, 2.97% profit and 2.958% profit have been increased by using the proposed hCHHO-SCA optimizer in comparison with ICA [295] and BSA-CSO [47] optimizers. 2.513% and 2.452% profit are increased by the hCHHO-SCA method than BDE and MBDE [47] optimization algorithm respectively. 1.003% and 2.696% profit have been increased by using this suggested hCHHO-SCA method in comparison with our proposed method CSCA and CHHO.

The statistical comparisons of profit value for the 100-generating unit system are discussed here. The profit value of 4.737% and 2.957% are increased by using the proposed hCHHO-SCA optimizer than TS-RP and TS-IRP [299] methods. 2.699% profit is increased by the hCHHO-SCA method in comparison with MM [9] optimization method. Using the proposed hCHHO-SCA optimizer is further performing better than the other suggested methods, i.e., CHHO and CSCA. 7.892% and 7.160% profit have been increased by using the suggested CHHO and CSCA methods respectively.1.89% profit value has been increased using this hybrid optimizer than PSO and PPSO [13]. 1.421% profit increased by using the suggested hCHHO-SCA method than ACO [109] optimizer. Further, 1.083%, 0.996%, 0.926% and 0.73% profit have been increased by using proposed hCHHO-SCA optimizer in comparisons with PABC [12], ICA [295], IPPD [9] and PNACO [13] optimization methods respectively.

- The outcomes are summarized as
    - For the 10 generating unit system, the profit increased up to 6.146% by using the proposed CHHO, CSCA, hCHHO-SCA, and hCSMA-SCA optimizer.

- ❖ For 40 unit test system, the maximum profit increased up to 5.17% by using the proposed hCHHO-SCA optimizer.
- ❖ For 100 unit test system, the maximum profit increased up to 0.5% by using the proposed hCHHO-SCA optimizer.
- ❖ For 10 unit system, comparing within proposed CHHO, CSCA, hCHHO-SCA, and hCSMA-SCA, with PEV penetration 10.7% profit is increased by using hCHHO-SCA optimizer, considering RES in summer days 12.64% profit has been increased, considering RES in winter days 13.04% profit increased, with PEV penetration and RES in summer days 0.67% profit and winter days 0.45% profit has increased by using proposed hCHHO-SCA optimizer.
- ❖ For 40 unit system, comparing within proposed CHHO, CSCA, hCHHO-SCA, and hCSMA-SCA, including PEV penetration 14.44% profit are increased, considering RES in summer days 11.2% profit has been increased, considering RES in winter days 11.14% profit increased, with PEV penetration and RES in summer days 6.91% profit and winter days 5.59% profit has increased by using proposed hCHHO-SCA optimizer.
- ❖ For 100 unit system, comparing within proposed CHHO, CSCA, hCHHO-SCA, and hCSMA-SCA, including PEV penetration 8.23% profit are increased, considering RES in summer days 9.76% profit has been increased, considering RES in winter days 6.28% profit increased, with PEV penetration and RES in summer days 11.56% profit and winter days 12.08% profit has increased by using proposed hCHHO-SCA optimizer.

7.3 SUGGESTIONS FOR FUTURE WORK

The following futuristic research studies can be taken into consideration as the future scope of the proposed research work:

- ▪ The impact of deregulated market scenario can be taken as one of the aspects along with profit as future research study.

- The multi-Objective profit-based unit commitment problem can be taken into consideration using the proposed methodologies.
- Profit-based unit commitment problem for multi-area power systems may be taken as one of the future research studies.
- New variants of metaheuristics search algorithms can be explored to solve the futuristic profit-based unit commitment problem.

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ANNEXURE-I

SPINNING RESERVE CONSTRAINT FOR PBUCP WITH PEVS DURING CHARGING AND DISCHARGING ALGORITHM

In order to fulfil the requirement of reserve capacity of different types of power units, minimum up and down time of every power unit along with time durations for that i^{th} unit is in continuously OFF condition should considered and reserve constraints must repair as per the algorithm.

Step 1: Sort the generators in descending order of maximum generating capacity.

Step 2: *for* $i = 1$ *to* NG *if* $u_{i,h} = 0$, then $u_{i,h} = 1$, *else if* $T_{i,h}^{OFF} > MDT_i$ then $T_{i,h}^{ON} = T_{i,h-1}^{ON} + 1$ and $T_{i,h}^{OFF} = 0$.

Step 3: Verify new generating power of units.

Step 4: if $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} \geq PD_h + PD_h^{EVs/BEVs} + R_h$ for charging and $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} \geq PD_h - PD_h^{EVs/BEVs} + R_h$ for discharging then stop the algorithm, else go to step-2.

Step 5: if $T_{i,h}^{OFF} < MDT_i$ then do $l = h - T_{i,h}^{OFF} + 1$ and set $u_{i,h} = 1$.

Step 6: Calculate $T_i^l = T_{i,l-1}^{ON} + 1$ and $T_{i,h}^{OFF} = 0$.

Step 7: if $l > h$, Verify generator output power $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} \geq PD_h + PD_h^{EVs/BEVs} + R_h$ for charging and $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} \geq PD_h - PD_h^{EVs/BEVs} + R_h$ for discharging of PEVs and go to step-5.

ANNEXURE-II

ALGORITHM OF SPINNING RESERVE CONSTRAINT FOR PBUCP WITH SOLAR PV

In order to fulfil the requirement of reserve capacity of different types of power units, minimum up and down time of every power unit along with time durations for that ith unit is in continuously OFF condition should considered and reserve constraints must repair as per the algorithm. The solar energy has been considered as RES.

Step 1: Sort the generators in descending order of maximum generating capacity.

Step 2: *for* $i=1$ *to* NG *if* $u_{i,h}=0$, then $u_{i,h}=1$, *else if* $T_{i,h}^{OFF} > MDT_i$ then $T_{i,h}^{ON} = T_{i,h-1}^{ON}+1$ and $T_{i,h}^{OFF}=0$.

Step 3: Verify new generating power of units.

Step 4: if $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} + P_h^{\mathrm{Re}newable} \geq PD_h + R_h$ then stop the algorithm, else go to step-2.

Step 5: if $T_{i,h}^{OFF} < MDT_i$ then do $l = h - T_{i,h}^{OFF} + 1$ and set $u_{i,h}=1$.

Step 6: Calculate $T_i^l = T_{i,l-1}^{ON}+1$ and $T_{i,h}^{OFF}=0$.

Step 7: if $l>h$, Verify generator output power $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} + P_h^{\mathrm{Re}newable} \geq PD_h + R_h$ for charging and go to step-5.

ANNEXURE-III

SPINNING RESERVE CONSTRAINT FOR PBUCP WITH PEVS AND SOLAR PV DURING CHARGING AND DISCHARGING ALGORITHM

In order to fulfil the requirement of reserve capacity of different types of power units, minimum up and down time of every power unit along with time durations for that ith unit is in continuously OFF condition should considered and reserve constraints must be repaired as per the algorithm.

Step 1: Sort the generators in descending order of maximum generating capacity.

Step 2: *for* $i = 1 \quad to \quad NG$ *if* $u_{i,h} = 0$, then $u_{i,h} = 1$, *else if* $T_{i,h}^{OFF} > MDT_i$ then $T_{i,h}^{ON} = T_{i,h-1}^{ON} + 1$ and $T_{i,h}^{OFF} = 0$.

Step 3: Verify new generating power of units.

Step 4: if $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} + P_h^{\mathrm{Re}newable} \geq PD_h + PD_h^{EVs/BEVs} + R_h$ for charging and $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} + P_h^{\mathrm{Re}newable} \geq PD_h - PD_h^{EVs/BEVs} + R_h$ for discharging of PEVs then stop the algorithm, else go to step-2.

Step 5: if $T_{i,h}^{OFF} < MDT_i$ then do $l = h - T_{i,h}^{OFF} + 1$ and set $u_{i,h} = 1$.

Step 6: Calculate $T_i^l = T_{i,l-1}^{ON} + 1$ and $T_{i,h}^{OFF} = 0$.

Step 7: if $l > h$, Verify generator output power $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} + P_h^{\mathrm{Re}newable} \geq PD_h + PD_h^{EVs/BEVs} + R_h$ for charging and $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} + P_h^{\mathrm{Re}newable} \geq PD_h - PD_h^{EVs/BEVs} + R_h$ for discharging of PEVs and go to step-5.

ANNEXURE-IV

REPAIRING MINIMUM UP AND DOWN TIME CONSTRAINTS ALGORITHM

The Minimum up and down time requirements of thermal units can be repaired by using the algorithm which is given below.

Step 1: Sort the generator according to the minimum capacity of power generation.

Step 2: For $h=1\ to\ H$ and $i=1:NG$, then set $i=1$**.**

Step 3: If $U_{i,h}=1$ then set $U_{i,(h-1)}=0$**.**

Step 4: Verify $T_{i,h}^{ON}<MDT_i$ and set $U_{i,h}=0$, or else set $U_{i,h}=1$**.**

Step 5: if $U_{i,(h-1)}=1$, then set $U_{i,h}=0$.

Step 6: if $T_{i,(h-1)}^{ON}<MUT_i$**,** then set $U_{i,h}=1$ and end if.

Step 7: if $h+MDT_i-1\leq H$ and $T_{h+MDT_i-1}^{OFF}\leq MDT_i$**,** then set $U_{i,h}=1$ and end if.

Step 8: if $h+MDT_i-1>H$ and $\sum_{h=1}^{H}U_{i,h}>0$**,** then set $U_{i,h}=1$ and end if or else go to step 5.

Step 9: Update the time duration of the committed as well as decommitted generation unit for ith unit by the equations $T_{i,h}^{ON}\geq T_i^{UP}$ and $T_{i,h}^{OFF}\geq T_i^{DW}$.

ANNEXURE-V

DECOMMITMENT OF THE EXCESSIVE THERMAL UNITS WITH PEVS AND SOLAR PV DURING CHARGING AND DISCHARGING ALGORITHM

The decommitment of units are obtained for charging and discharging behaviour of PEVs and considering impact of RES which are discuss in given sub sections in details.

The excessive thermal units need to decommit and the load demand, reserve requirements of all thermal units must be fulfilled with maintain the minimum Down and Up time of every units along with the duration through which ith power unit is in continuously OFF condition and the constraint can be repaired as per algorithm. The steps for decommitment of the excessive units with charging and discharging behaviour of PEVs are discussed below.

Step 1: Sort the generator according to the minimum capacity of power generation.

Step 2: for h=1 to H and for i=1 to NG, then $i = h(NG+1-i)$ and calculate the generated power, i.e. $P1 = P_{i(\max)} \times (U_{i,h})'$.

Step 3: Verify the new generating power of the unit.

Step 4: if $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} \geq PD_h + PD_h^{EVs/BEVs} + R_h$ for charging and

$\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} \geq PD_h - PD_h^{EVs/BEVs} + R_h$ for discharging of PEVs and $T_{i,h}^{ON} > MUT_i$ then do

$U_{i,h} = 0$, else stop the algorithm, or else if $T_{i,h}^{ON} = 1$, do $u_{i,h} = 0$, else increase 1 by 1 and go to step 2.

Step 5: set $T_{i,h}^{ON} = 0$ and calculate $T_{i,h}^{OFF} = T_{i,h_0}^{OFF} + 1$.

Step 6: if $U_{i,h} = 1$, Verify the generated output power $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} \geq PD_h + PD_h^{EVs/BEVs} + R_h$

for charging and $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} \geq PD_h - PD_h^{EVs/BEVs} + R_h$ for discharging of PEVs, else OFF the unit and go to step 4.

ANNEXURE-VI

DECOMMITMENT OF THE EXCESSIVE THERMAL UNITS WITH SOLAR PV ALGORITHM

The excessive thermal units need to decommit and the load demand, reserve requirements of all thermal units must be fulfilled with maintain the minimum down and up time of every units along with the duration through which i^{th} power unit is in continuously OFF condition and the constraint can be repaired as per algorithm.

The steps for decommitment of the excessive units with RES are discussed below:

Step 1: Sort the generator according to the minimum capacity of power generation

Step 2: for h=1 to H and for i=1 to NG, then $i = h(NG + 1 - i)$ and calculate the generated power, i.e. $P1 = P_{i(\max)} \times (U_{i,h})^{'}$.

Step 3: Verify the new generating power of the unit.

Step 4: if $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} + P_h^{\mathrm{Re}newable} \geq PD_h + R_h$ and $T_{h,i}^{ON} > MUT_i$ then do $U_{i,h} = 0$, else stop the algorithm, or else if $T_{i,h}^{ON} = 1$, do $u_{i,h} = 0$, else increase 1 by 1 and go to step 2.

Step 5: set $T_{i,h}^{ON} = 0$ and calculate $T_{i,h}^{OFF} = T_{i,h_0}^{OFF} + 1$.

Step 6: if $U_{i,h} = 1$, Verify the generated output power $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} + P_h^{\mathrm{Re}newable} \geq PD_h + R_h$, else OFF the unit and go to step 4.

ANNEXURE-VII

DECOMMITMENT OF THE EXCESSIVE THERMAL UNITS WITH PEVS AND SOLAR PV DURING CHARGING AND DISCHARGING

The excessive thermal units need to decommit and the load demand, reserve requirements of all thermal units must be fulfilled with maintain the minimum down and up time of every units along with the duration through which i^{th} power unit is in continuously OFF condition and the constraint can be repaired as per algorithm.

The steps for decommitment of the excessive units with charging and discharging behaviour of PEVs and RES are discussed below:

Step 1: Sort the generator according to the minimum capacity of power generation.

Step 2: for h=1 to H and for i=1 to NG, then $i = h(NG+1-i)$ and calculate the generated power, i.e. $P1 = P_{i(\max)} \times (U_{i,h})'$.

Step 3: Verify the new generating power of the unit.

Step 4: if $\sum_{i=1}^{NG} P_{i(\max)}U_{i,h} + P_h^{\mathrm{Re}newable} \geq PD_h + PD_h^{EVs/BEVs} + R_h$ for charging and

$\sum_{i=1}^{NG} P_{i(\max)}U_{i,h} + P_h^{\mathrm{Re}newable} \geq PD_h - PD_h^{EVs/BEVs} + R_h$ for discharging of PEVs and $T_{i,h}^{ON} > MUT_i$ then

do $U_{i,h} = 0$, else stop the algorithm, or else if $T_{i,h}^{ON} = 1$, do $u_{hi} = 0$, else increase 1 by 1 and go to step 2.

Step 5: set $T_{i,h}^{ON} = 0$ and calculate $T_{i,h}^{OFF} = T_{i,h_0}^{OFF} + 1$.

Step 6: if $U_{i,h} = 1$, Verify the generated output power

$\sum_{i=1}^{NG} P_{i(\max)}U_{i,h} + P_h^{\mathrm{Re}newable} \geq PD_h + PD_h^{EVs/BEVs} + R_h$ for charging and

$\sum_{i=1}^{NG} P_{i(\max)}U_{i,h} + P_h^{\mathrm{Re}newable} \geq PD_h - PD_h^{EVs/BEVs} + R_h$ for discharging of PEVs, else OFF the unit and go to step 4.

ANNEXURE-VIII

ALGORITHM FOR PBUCP INCLUDING THE IMPACT OF CHARGING AND DISCHARGING NATURE OF PEVS AND IMPACT OF SOLAR PV IN SUMMER AND WINTER DAYS

A complete procedure to PBUCP including the impact of charging and discharging nature of PEVs and impact of RES in summer and winter days is given below.

Step 1: Enter PBUCP inputs including the impact of charging and discharging nature of PEVs and impact of RES in summer and winter days i.e. power through solar radiation, power through G2V and V2G operations, maximum power, minimum power, revenue, energy price, minimum up time, minimum time, initial status, hot start cost and cold start cost.

Step 2: Initialize of the inputs parameters for the proposed algorithm.

Step 3: Set iteration counter K=1.

Step 4: Initialize the random location of search agents.

Step 5: Calculate the power according to priority list for search agent including the impact of charging and discharging nature of PEVs and impact of RES in summer and winter days.

Step 6: Update the position of search agent to satisfy the spinning reserve constraint including the impact of charging and discharging nature of PEVs and impact of RES in summer and winter days.

Step 7: Repair each position of search agent to maintain minimum up & minimum down time violations.

Step 8: Decommitment the excessive generating units to decrease excessive spinning reserve including the impact of charging and discharging nature of PEVs and impact of RES in summer and winter days by $\sum_{i=1}^{NG} P_{i(\max)} U_{i,h} + P_h^{\mathrm{Re}newable} \geq PD_h \pm PD_h^{EVs/BEVs} + R_h$.

Step 9: Calculate fuel cost using start-up cost and overall profit.

Step 10: Evaluate the individual cost and profit for each generating unit.

Step 11: Compare total power generation cost of every population through best value of total fuel cost and upgrade the generators scheduling through proposed technique.

Step 12: Verify the value of K for maximum number of iterations or else Increase the count of iteration K through 1.

Step 13: Evaluate the actual power generation schedule and profit for the committed unit.

Step 14: Record the status of power generation scheduling and status of the commitment units and optimal profit including the impact of charging and discharging nature of PEVs and impact of RES in summer and winter days.