DESIGN AND DEVELOPMENT OF IOT BASED FRAMEWORK FOR SMART BILLING SYSTEM FOR ELECTRICITY POWER CONSUMPTION

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

In

Computer Applications

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Declaration

I, hereby declared that the presented work in the thesis entitled "Design and Development of IoT Based Framework for Smart Billing System for Electricity Power Consumption" in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision Dr. Arun Malik, working as Associate Professor, in the Department of Computer Science and Engineering of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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Certificate

This is to certify that the work reported in the Ph. D. thesis entitled "Design and Development of IoT Based Framework for Smart Billing System for Electricity Power Consumption" submitted in fulfillment of the requirement for the reward of degree of **Doctor of Philosophy (Ph.D.)** in the Computer Applications, is a research work carried out by Kuldeep Sharma, 41800416, is bonafide record of his/her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

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Abstract

In order to achieve the targets, set in electricity power consumption of this research work, it opens the wings for the usage of electrical as well as electronic devices for proper accounting and auditing of the electricity power consumption and power to ensure proper operation. It is fact that the electricity units generated at the power generation are never matches with the units invoiced at the end consumer premises. This thesis presents the general evaluation of Design & Development of the IoT-Based-Framework for Smart Billing System for Electricity Power Consumption. It also covers Optimizations in electricity generation, transmission, and distribution system through emerging technologies via smart grid system by considering the supply, load along with keeping the various production-type security procedures as key parameters. Additionally, it also implemented the IoT based designed smart meter converters for the legacy traditional electricity meters to communicate with the latest modern infrastructure.

The objective of this doctoral thesis is to study & analyze the technologies behind smart grids and IoT applications and investigate the potential of existing techniques used in different applications of electricity power consumption targeted to improve energy efficiency along with Revenue Management System (RMS) consisting of the Core activities i.e. Electricity Meter Reading, Bill Generation and Collection of Revenue for the electric power consumption. In power sector of developing countries, electricity distribution utilities, AT & C (Aggregate Technical & Commercial) Loss is a burning concept. Maximum of power distribution companies are running with a huge AT & C Loss. The research work scope is covering the analysis and development of the frameworks useful in the reduction of the AT & C Loss and supply of the electricity with quality. The proposed prototypes for collection of the electricity meter readings via IoT techniques and frameworks for decision support systems for Meter Data Acquisition System are supporting the distribution companies for seamless acquisition of the meter readings. For micro

analysis of the electricity power consumption, the system can be studied with two broad aspects. The information technology aspect and the other one is operational technology aspect. In the information technology, the revenue management system i.e. meter reading, invoice generation and the revenue collection along with energy accounting and auditing is focused with Geographical information system, assets management, inventory management etc. where as in the operational technology aspect the smart grid, smart meters, meter data acquisitions, head end systems etc. are studied and analyzed.

Recently, all the power distribution companies across the globe are focused on re-strengthening their infrastructure for their information technology and operational technology aspects. In the developing countries like India, the power distribution companies are running with a huge aggregate technical and commercial losses. These companies are trying to work around to solve the issue. In last decade, India achieved a good position in the field of the electricity power consumption. But still there are distribution companies which are keep on strengthening their capabilities to provide a good electricity supply with minimum AT & C Losses.

More particularly, many novel methods for gathering data on energy use, ways for generating and collecting money, identification of AT & C Loss patterns, and suggestions for electricity use strategies are all covered. For energy evaluators and other stakeholders, the provided approaches show themselves to be potent instruments that can generate useful, actionable insights.

The current research work is stated with the aforesaid main targets of a power utility. The research work carried out a review of the literature of technology behind the smart grid, electricity power consumption, revenue management system, operational technology, information technology, energy tariffs, electricity meter modes i.e. post-paid as well as pre-paid. Methods of the electricity measuring, generation of electricity bills/ invoices of electricity consumed for a particular time-duration & collection of the revenue against such electricity power consumption from the end users. Most of the utilities are running with multiple processes of such revenue related activities due to different schemes launched by central authorities at different time for different set of parameters like RAPDRP.

First, a thorough and in-depth overview of several cutting-edge approaches is given in order to estimate electricity use for energy efficiency savings and to foresee the effects. Strengths and disadvantages of the evaluated methodologies are discussed, and advice is given to determine the best performing methodology based on the analysis's scenario and the data at hand.

These advanced schemes are adding the technology in their working culture along with adaptive approach of the consumers for the same. Smart meters and that in the pre-paid mode is being implemented in some of the sates with a positive response. The compute infrastructure and the network communication is again the challenge in the existing scenario.

This research is approaching to the use of the IoT devices to bridge the gap between the traditional infrastructure and the advanced emerging technologies. In the current research, the existing infrastructure in the power utilities is given a backup support for using the traditional devices for real-time power consumption monitoring. The proposed work has developed a device as the converter for the existing traditional electricity meters embedded with RS232/RS485 ports. Accordingly, an innovative model is developed to provide quality of the service in the IoT devices attached with the traditional electricity meters. The VEnvMQTT model is developed in this research, it is virtually built environment oriented HTTPServerModel also known as VEnvMQTT and is used for efficient processing of the data in the data acquisition center over IoT environment's edge computing architecture. Actuators, smart metering devices and IoT server at other end, data make up the proposed VEnvMQTT concept. The suggested VEnvMQTT model analyses the sensor data, electricity power consumption parameters at an efficient rate of processing time using edge computing technology. According to an examination of the simulation's results, the suggested VEnvMQTT model provides a reduced-latency with 24.566 ms, i.e. 20% less than the MQTTModel as it currently stands. This model helps the power consumption metering very fast. It can be used for the pre-paid as well as post-paid electricity smart meters.

The electricity power consumption can be controlled at the homes of the end users also by developing some advanced framework. In this series, the current research work proposed a Framework for Energy Efficiency in Smart Homes Based on Artificial Intelligence (AI) techniques. An Effective AI-Based-Framework to enhance energy-efficiency in the smart electricity devices of the smart homes is developed and designed for optimal electricity utilization with shifting a load across the day along with its priority for benefiting from both the consumer's financial as well as electricity's aspect to control the demand at the peak-loads. A thorough analysis of a smart home's instantaneous maximum load is presented. In order to avoid paying a tariff penalty for exceeding the sanctioned load, suggested framework prioritises smart electricity appliances according to needs and re-schedules accordingly as per load time of the day in mind. IoT device integrated into the electricity appliances and manages the load using improved smart home architecture. The framework's HDFS architecture uses bigdata to quickly and accurately control the demand for electricity. The framework incorporates artificial intelligence and machine learning (AI and ML) techniques to automatically manage patterns of electricity usage. This strategy aids power distribution utilities in meeting customer demand for high-quality electricity while simultaneously saving consumers money. For assessing the patterns of power use and optimizing the schedules of the home appliances in accordance, several techniques for sampling, ML-algorithms and frameworks for the big-data-approximation are discussed. This framework uses cutting-edge automation and self-contained controller technologies.

After a systematic study in the literature of the electricity power consumption along with the interviews with the representatives of electricity power distributions, it was revealed that theft of the electricity is also a serious issue to the power distribution utilities. For such issues, a framework is proposed in the recent research. This framework is made for electric-utilities / organizations to identify any illegal electricity-theft in their lines of power supply. The IoT methodologies are foundation in this framework. This framework must examine the data for all consumers who have been assigned tags for a particular geographic area. The framework in the first section examines historical power consumption data for a certain area. This region may be at the level of the distribution transformer or the feeder, or it could be any place where there is a suspicion of power theft. With these IoT devices, metering units placed for measuring the power consumption of the electricity are intelligently monitoring the flow the electricity. The amount of the electricity sent to the area will be tallied from this source in real time. IoT devices will be installed to various electricity supply line segments. depending on the situation, on the basis of real-time data analysis of gathered data accumulated with the help of incorporating IoT devices in the framework by use of GSMtechnology on compute infrastructure side i.e. server situated at data center/Cloud-Storage etc. The framework will identify the precise region that is impacted by electricity theft. Another IoT surveillance gadget is utilized to take pictures of the scenes for monitoring the exposed wire in order to prevent electricity theft. The power distribution company officials are receiving alerts from these devices' Real-Time reporting to take the appropriate action to decrease losses brought on by energy theft. Nowadays, advanced infrastructure is a little bit more vulnerable to the electricity-theft. The Advanced Metering Infrastructure, which is completely M2M (machine-to-machine) functional, makes it possible for theft to occur if the system is compromised. Over the past two decades, numerous researchers have proposed their expert algorithms to reduce electricity theft. The current research suggests improvements to the literature on detecting and preventing electricity theft.

In the series of the survey of the literature and the electricity issues to end-users, i.e. Electricity consumers , it was also notices that the consumers of the power utilities are facing the no power issues, unscheduled power outages and non-receipt of the bills. For this issue, the recent research introduced a strategy for missed-call-messaging-system to its valued electricity end-consumers. There are some customers nowadays who are getting the difficulties in the receiving the hard printed electricity invoices/ bills at a regular time interval in the form of a tangible papers, particularly those who live in rural locations or far away from electricity bill disbursing office of the power distribution companies/utility offices. The tendency of the customers living apart from the utility offices for depositing their electricity consumption dues is positive. They can deposit their outstanding due against their electricity consumption on time every month, but as soon as the backlog grows, they become defaulters since there isn't enough money to cover the backlog plus a substantial penalty for late payments against electricity invoices. They are therefore prepared to make monthly payments but are unable to do so since they are unaware of the amount of their dues. Therefore, a system for missed call services is suggested for electricity consumers, particularly for rural area consumers, most of them are not familiar with modern emerging technologies like website, smart phones, internet services etc., in order to mitigate this issue. Consumers do not need to worry for remembering big string with number of digits as their consumer id; an alternate arrangement is incorporated for displaying the dues details along with consumer profile to the smart or basic mobile hand set via SMS to the RMN(Registered-Mobile-Number) registered at the time of application of the electricity service connection. On placing a missed call by the consumer on a specified number allocated for this services, to get the message for outstanding payment due details, they will receive messages regarding their pending dues amount and due-date against their electricity service connection.

It was noticed from the distribution companies' point of view that millions of the consumers in a power utility getting the electricity supply. the power outage and the other invoice related complaints are normal in nature in the utilities in the developing countries where the power distribution companies are starting their infrastructure to modernization. Hence the bridge between the new technology and the legacy technology will generate such numerous common public issues. To mitigate this huge issue, A virtual assistant for the customers of the electricity utilities is also proposed in the current research. There are a lot of consumers facing different types of issues in day-to-day life, starting from the no power complaints to bills payments of the energy invoices. In a power distribution company, millions of the users are consuming the electricity. The complete life cycle of the consumer service connection, starting from application for new electricity connection to the termination / disconnection of the electricity connection, the users are eager to now all the information on the tips. They are physically visiting the power utility office for gathering such information like what the various documents are required for establishing an electricity service connection, what may be the fee or charges for various milestones, what is the rate of the electricity power consumption per unit etc. this such general information can be served through an artificial intelligence based virtual assistant. By inventing such framework, the people can avail such facilities from their home itself on the internet via accessing the virtual assistant proposed in this research work on the open-source-technology.

Subsequently, a novel data-driven methodology is suggested for measuring and verifying calculations, with a particular emphasis on electricity meter reading, invoice production, and revenue collecting activities in the energy efficiency sector. The method is founded on a cutting-edge technique and the extraction of frequent power consumption profile patterns.

The results in this thesis show the potential in the electricity power consumption but highlights how energy efficiency can be affected by amalgamation of advanced technologies like AI/ML, IoT, NB-IoT, Big Data Analytics etc. The results achieved using the suggested methodology are contrasted with those offered by VEnvMQTT , a cutting-edge model, demonstrating improved accuracy and better robustness to real data server processing..

Preface/Acknowledgement

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Last but not least, to our friends, family, colleagues, seniors and loved ones for being there for us during this more then five years of the time duration, without your support, it could not be possible to achieve this task.

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CHAPTER 1

Introduction

1.1 IoT based Smart Billing System in Electricity Power Consumption

SMART billing system in the electricity power consumption is the emerging research issues in the power distribution utilities as well as in the academics. The power distribution losses specially the commercial losses can be reduced with smart billing systems with proper trading of the electricity supply with an efficient energy accounting. The cognitive capabilities of the IoT Based smart billing system essential to tackle this challenge of real-time, accurate and instant delivery of the invoices generated against the electricity supply.

This chapter covers the background of the research work with a brief introduction to the electricity consumption and the background of the aggregate technical and commercial losses occurring in the supply of the electricity. Further the related work and the recent state-of-the-art in the electricity consumption is presented as well as methods, implementations and the discussion and result of the work.

1.2 Background and Motivations

In this age of industrialization, electricity can be put to the list of essential demands. Along with providing wholesome and secure daytime illumination, it also cools down homes on hot summer days in many countries and warms them up in others throughout the winter. When the use of electricity is necessary to maintain their proper operation, it allows the use of electrical and electronic gadgets everywhere. Any energy use that involves the use of electrical power energy is considered to be electric energy consumption. Generally speaking, the term electricity-energy-consumption refers to the real energy demands placed on the available electrical supply for transportation, commercial, residential, industrial, and other unnamed applications.

In the power domain. The electricity is generated at the power generation plants. The electricity cannot be stored for a long time. It is very costly for the storing of the electricity. Hence it is consumed as and when generated. The transmission lines are transmitting the electricity from the electricity generation companies to the power distribution companies. Finally, the electricity is supplied to the end consumers through the various chain of the grids sub stations, power substations, distribution transformers etc. all such lines are controlled by the smart line controllers , smart grids. Flow of both the electricity and information in both side is main task of the electricity smart grid.

The emerging technologies are entering in all the domains. The electricity consumption is not skipped from this modernisation. There are smart electronic devices, Internet of Things, smart meters etc. used in daily operations of the electricity supply. This thesis work is mainly concerned with gap between the electricity units generated and the invoiced at the consumers premises to control the aggregate technical and commercial losses in the power distribution companies across the globe.

IoT for power sector is Convergence of OT and IT. IT (Information Technology) and the OT (Operation Technology) both, first and foremost, we are depending on the IoT. In recent decades, the IoTs are playing a vital role in these technologies. Starting from the data center, the Building Management System is fully equipped with the IoT for reporting various parameters like temperature, humidity, very early smoke detection or fire detection etc. through IoT Based Devices. The electricity consumption meters are also based on the IoT as well as NB-IoT techniques for real time recording of electricity consumption via electric meter readings. The power generation, transmission, and distribution sectors are also having their operations technologies embedded with the functionality of the IoT.

1.2.1 Internet of Things

A network of physical objects, or things, that are connected to and exchange data with other Internet-connected systems and devices is referred to as the Internet of Things. These things may include software, sensors, and other technologies. At Carnegie Mellon University, this idea of the Internet of Things was first addressed in 1982 using a modified Coca-Cola vending machine. It was the first piece of connected technology and was too intelligent to keep its inventory and beverage temperatures a secret. In 1999, it was believed that radio-frequency identification (RFID) was a crucial component of the Internet of Things, allowing computers to communicate with particular objects and control them. To more simply explain Internet-of-Things, think of it as a network of linked devices which can communicate with one another and with humans or machines equipped with sensors to detect changes in the physical or environmental surroundings. The Internet of Things is the fusion of operational and information technology. Additionally, OT plus IT equals IoT. It consists of individually recognisable items (things) with sensing and actuation that are always accessible. In this context, anyplace does not mean everywhere, and anytime does not mean everywhere; rather, it signifies the location of the requirement and time of requirement.

IoT refers to a network with inter-connected objects with possible programmability and actuation. In essence, an IoT-embedded device or system can link numerous items or objects via networks in order to collect data from various systems or devices, which can then be managed, controlled, or monitored in scenarios that are close to real-time.

The IoT can also be defined as, a system of inter-related devices/smart devices/computerized devices, mechanical machines, IoT may be considered as main part in the fourth industrial revolution. Real-time monitoring, communication, and interpretation are all features of smart devices. As a result, system optimization and relevant data collection are made possible through this emerging technology in the communication field in the current era.

In composition of such devices i.e. this IoT, the assets are to be digitized. The data has to be collected about the assets via any medium like internet IPV4 or IPV6. After collection of data the computational algorithms are to be designed to manage and control the system formed by the web of the assets interconnected. The IoT has the sensors like temperature, humidity, movement etc., and same can trigger code over the events. IoT-embedded devices are necessary for utilities' decision support systems to decide which investment types, timing, and locations in a grid are beneficial versus when to motivate others to make investment plans. Profitability decisions are driven all the way down to the circuit level by locational system performance analysis. This investment planning strategy makes sense for the utility since it balances costs, benefits, and risks more effectively than a system-level strategy would. Additionally, it develops the connectivity required for operating and managing these resources.

In this thesis, we have developed IoT devise for collection of the electricity consumption data at a central storage device which further processed with big data analytics for prompt decision-making in each domain of the electricity consumption.

1.2.2 The Information Value Loop

Information-Value-Loop refers to the set of technologies that allowed the Internet of Things to essentially transform every device into a source of information, assisting organisations in generating value from user information and a series of actions for harvesting this information as a value-chain. A foundation for our direction is provided by the Information Value Loop (IVL). It aids in identifying information bottlenecks and figuring out which technologies could solve them to generate value. In summary, the IVL can help utilities develop a plan to realise their goals for an intelligent grid. The IVL provides a guide for identifying business value and taking action to capture it. Understanding that information must finish the loop is essential if any inherent value is to be realised through prudent action. Even if one or more of the stages are minimised, each stage of the IVL must be completed before value may be recovered. This issue merits investigation because it is crucial. The IVL is a technique for assessing IoT investment alternatives by identifying the areas and methods for value creation.

1.2.3 Value drivers for IoT

Magnitude: It covers the Scope, frequency and the scale. Value is formed by collecting specific data to determine profitability. Utility business performance can be monitored by defining, collecting and aggregating the data values. This value is unlocked in direct proportion to the accuracy and speed of the data accessible to aggregators and operators to build the real-time view of grid state and capacity.

Risk:- Risk is associated in context of Security of the information. Accuracy of the information and the reliability risk of the information. The financial performance of a utility effectively drives the confidence management. The vast amount of data gathered from various IoT Assets distributed around the grid needs to be accessed in a reliable, safe, and accurate manner for an intelligent grid to function.

Time: - Latency and timeliness are the key time value factors. Data must be timely and readily available in order to add value to the utility. To maintain system stability and safety, DER management requires precise data to be received during the decision cycle, which is frequently measured in milliseconds.

Stages:- The various states of the information are Act(Action). Create of the information. Then communication of the information from various sources to a central place. At aggregators, the information is aggregated and finally analyzed to result in the important decision.

Technologies:- The various technologies includes Sensors. The medium of the communication i.e. Network then Standards and Augmented Intelligence and Augmented Behaviors.

1.2.4 IoT in Electricity Power Consumption

Smart metres and smart thermostats are two consumer-focused IoT technologies that have benefitted the power sector. At starting phases the IoT Based electric meters were used for communicating the electricity consumption readings to the power utility billing engine via internet / GSM media.

In the earlier phase, the mechanical meters were used to calculate the electricity consumption in which a solid metallic disk was mechanically rotating, and the count of the rotations were moving the disks of number to show the consumption the consumption was recorded physically by a human-being working as meter-reader or meter-reading-agent through a company or individual. After that, in the sequence of advancement in the technologies in the field of the electricity meter reading with the information technology and operational technology in the electricity consumption, AMR/RMR/AMI an automation in the meter-reading techniques and remote meter reading came into the existence and after that the AMI advanced meter reading infrastructure which turned the electric meter to the smart in the prepaid as well as postpaid mode.

The AMI introduced the energy accounting/ energy management/ meter data management/MDAS/ SCADA/ RTDAS/ for outage management system and voltage distribution to reduce the losses. Improvement of reliability of grid with control of dropping SAIFI(System average interruption Frequency Index) and SAIDI(System average interruption Duration index).

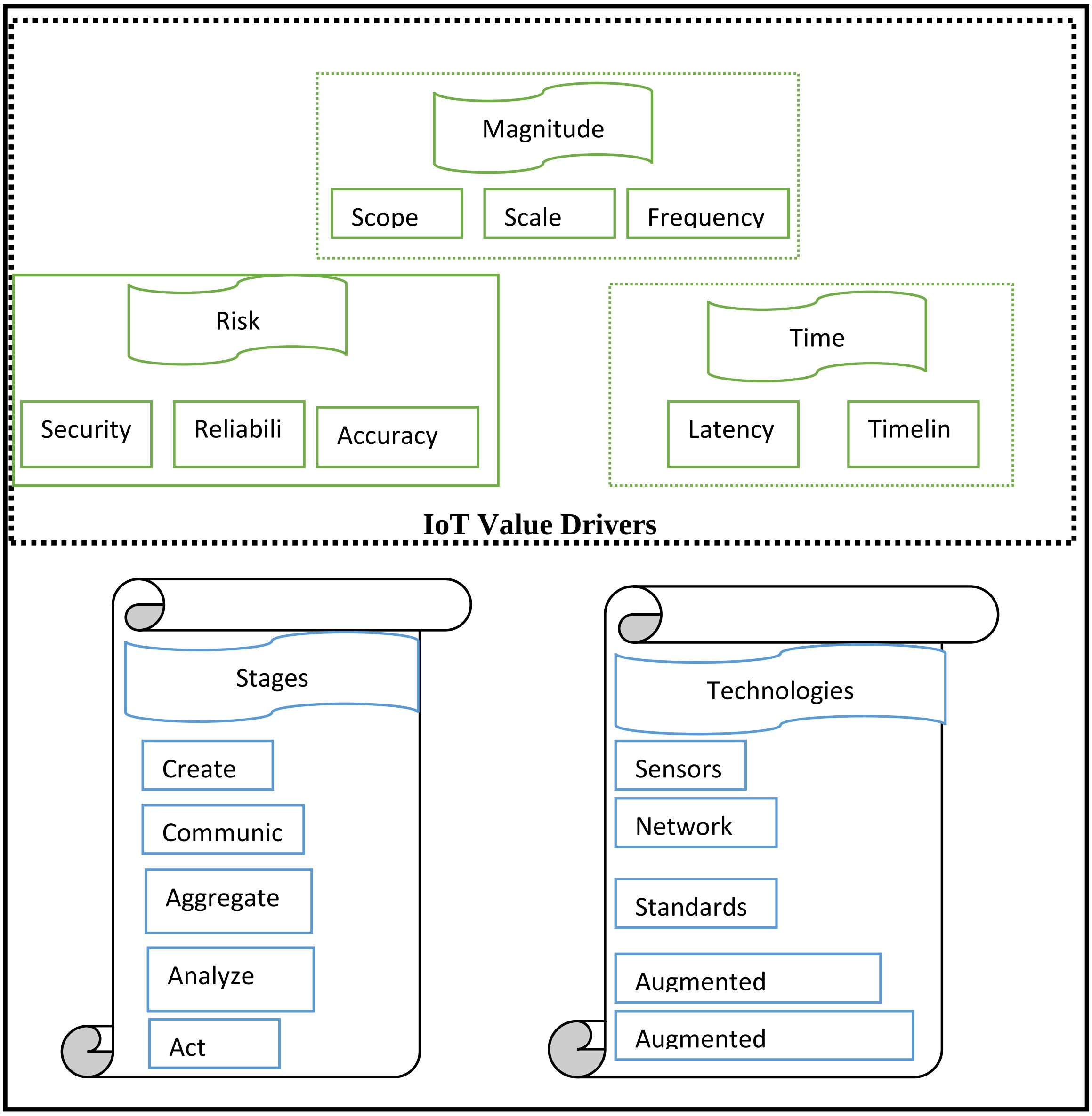


Figure 1.1 IoT Value Drivers

Smart thermostats are interconnected deices to record temperature and humidity. Numerous deep learning methods are integrated in a select few machine learning applications to strike a compromise between energy conservation and user-customized comfort. Applications of the IoT in the electricity sectors can be used to achieve condition monitoring and predictive maintenance. IoT hence changes the traditional periodic maintenance to the proactive strategy. IoT can enhance the real time data acquisition system, the electricity generations / supply to the specific area can also be predicted via the use of IoT devices over the specific area, the smart meters, now a days, are transmitting the data to the cloud/utility data centers at the periodical interval may be 30 minutes to 15 minutes as per requirements. The consumptions pattern may be incorporated in the machine learning/ artificial intelligence algorithms over to the various applications to predict the future requirements/ demands of the electricity over the specific regions which is monitored via the IoT devices. The electric power business could undergo a substantial transformation because to IoT. It's all about personalising technology and connecting assets, data, and information. With the help of devices and sensors, the digital world is connecting more and more. By fusing post-time and real-time data with analytics, IoT may boost asset dependability, reduce operational costs, reduce unforeseen downtime, and boost productivity for electric power companies. IoT is essential for the generation of renewable energy sources like wind energy since it reduces wake losses in wind farms and allows for appropriate adjustments to individual turbine settings. The demand and supply graphs are also controlled by the IoT and may prove a good balancer of demand and supply of electricity.

Emergence of IoT:- Efficiency is the key to sustainable operations due to an increasingly unstable electrical supply picture, regulatory requirements, and market factors, together with India's rising electricity consumption. This realisation has led DISCOMs in developing nations to increasingly adopt cutting-edge technologies like big data, cloud computing, the Internet of Things (IoT), cyber security/ Block Chain Technology and AI/ML. IoT systems collect real-time data on network operations and assets using sensors and internet-based technology with RS232/RS485 etc communication. They then send the data from these devices registers to a remote control centre for time-series analysis, monitoring, and visualisation.

The Electricity Power-Systems are divided in three broad components based upon the nature of work i.e. generation , transmission and distribution of the electricity.

IoT applications in Power Generation

IoT is important in the context of power generation because all of these components can improve the electric power grid's performance and efficiency on three different levels, depending on the context, as data collections from various sensors increase the grid's resilience. As a result, top management at power firms can make wise decisions by managing resources more effectively based on data gathered from diverse assets. IoT hence, in the long run, is useful for improving the efficiency, reduction of the unscheduled downtime and minimizes the costs and lowering the risks related to the assets.

The plants which convert the conventional energy to the electricity energy. Eg. Hydro/thermal/wind plants.

- Remote Asset Management
- Process Optimization
- Decentralized Energy Generation

Remote Asset Management:- One of the most intriguing applications in the context of power generation is IoT-powered asset tracking and management. IoT technology is essential for improving the capabilities of Remote Asset Management (RAM). RAM entails keeping an eye on, managing, and preserving resources that are situated in inhospitable or remote areas. Remote assets can have IoT sensors and devices installed to collect and communicate real-time data about their performance, status, and conditions. Because of this, businesses can keep an eye on their assets from a single location and learn more about their utilisation, health, and operational effectiveness. IoT provides predictive maintenance practises by gathering data on asset performance and conditions. In order to find patterns and anomalies, machine learning algorithms may analyse both historical and current data. This allows them to anticipate probable breakdowns and maintenance needs. This strategy aids businesses in avoiding unscheduled downtime, lowering maintenance costs, and improving asset performance. The automation and remote control of asset operations can be made possible by IoT devices. Operators can remotely monitor and control asset functioning, change settings, or initiate activities using a centralised management system. The requirement for physical presence at remote sites is removed thanks to this feature, which lowers expenses and boosts productivity. The inventory levels of remote assets, such as raw materials, spare parts, or finished goods, can be tracked and monitored using IoT sensors. Inventory management systems can transmit this data in real-time, allowing businesses to improve supply chain operations, cut down on stockouts, and guarantee prompt replenishment. Remote assets can be monitored and secured using IoT-based security solutions. Unauthorised access, tampering, or suspicious activity can all be found using sensors, cameras, and access control systems. Additionally, GPS or RFID-enabled asset monitoring systems can provide real-time location data, allowing businesses to track and retrieve lost or stolen property. Energy use in distant assets can be optimised with the use of IoT devices. The use of smart metres, sensors, and actuators can be used to track energy use, spot inefficiencies, and automatically change settings to maximise energy use. This makes it possible for businesses to save energy expenses, increase sustainability, and adhere to regulations. Remote asset management that is IoT-enabled enables remote equipment or machinery diagnostics and troubleshooting. IoT devices can provide diagnostic data to professionals who are positioned away, who can then analyse the data and offer direction or support for upkeep or repair tasks. By reducing pointless on-site trips, this method conserves time and resources. These Internet of Things (IoT) solutions unite the participants, resources, and assets from each supply chain link to a single network. Additionally, the general condition of assets like turbines and transmission lines can be evaluated using embedded connected sensors that track temperature, vibration, wear, and tear. Real-time alarms, predictive analytics, automatic reporting, and real-time visibility are just a few benefits of implementing IoT in power generation.

Process Optimization:- With the use of intelligent analytics driven by the IoT, utility companies may significantly improve operating procedures, enhancing performance and output. By providing real-time data on a power plant's overall condition, IoT devices assist in automating plants. Power generation may accomplish affordability, sustainability, and availability while lowering maintenance costs by analysing enormous amounts of data in real-time.

Decentralized Energy Generation:- The majority of industrialised nations now receive their electricity from widely dispersed centralised power facilities. However, the energy losses experienced during transmission and the absence of a reliability guarantee have shown that this centralised approach is ineffective. Decentralised electricity generation, in comparison, seems to be a more dependable and economical strategy. In this context, decentralisation refers to obtaining power from several, localised energy networks.

1.2.5 IoT applications in Power Transmission

The following section presents the use of IoT application in a power transmission domain. The smart grids, real time data acquisition of various grid sub stations for effective monitoring and digitally controlling the same.

A smart grid:- Today, In electric power networks, a smart grid envisages implementation of technologies specially digital, efficient monitoring intelligent systems, primarily digital control appliances. Numerous potential economic and environmental advantages of an intelligent grid include: -

- ✓ Reliability:- An Improved reliability of power quality & transmission,
- ✓ Efficiency:- An improved efficiency of power distribution,
- ✓ Cost:- lower utility expenses for electricity,
- ✓ Gas Emission:- Lower-gas-emissions.

Modern advanced grids are essentially moving away from a unidirectional system, in which power transmits from a centralised generating unit to electricity consumers, and towards a system, which can identify and manage the decentralised electricity consumption and production assets by improving the flow of information and power in multiple directions.

The main task of transmission is a mediator from generation to distribution.

- o Asset Maintenance Management
- o Grid balancing
- o Optimization of grid contribution

Asset Maintenance Management:- Transmission lines, generators, transformers, and other devices used in power transmission and distribution are common examples. To avoid issues like overloading and vandalism, all of this equipment needs to be constantly monitored. Physical assets and their data can be monitored and tracked with IoT-embedded asset management solutions. IoT technology can be used to improve asset availability and reliability by allowing asset maintenance systems to identify failure and fault sources before they become critical.

Grid Balancing: IoT's capacity to deliver real-time data can significantly contribute to balancing the supply and demand of energy while also reducing congestion on transmission and distribution (T&D) lines. The practise of managing the supply and demand of power on the electrical grid in order to preserve stability and dependability is known as grid balancing. It entails balancing the varying electrical demand patterns with the fluctuating power generation from various sources, including renewable energy. Demand response programmes, energy storage systems, flexible generation resources, and smart grid technologies are some of the methods used to balance the grid. Grid operators maintain and balance the grid by modifying electricity generation, allocating reserves, and controlling grid frequency and voltage using real-time monitoring and control systems. In order to maintain system stability, maximise the use of renewable energy, and reduce the need for backup fossil fuel-based power, effective grid balancing is essential.

Optimization of Grid Contribution: Utilising renewable energy to generate power is gaining popularity. According to BP, the percentage of renewable energy used to generate electricity climbed to 8.4% in 2017 and accounted for almost 50% of the rise in worldwide power generation. IoT was appropriate in this situation as well. The term grid-contribution-optimisation refers to the employment of a variety of methods and tools to maximise the effective and efficient integration of distributed energy resources such as renewable energy sources, energy storage systems, and other energy sources into the electrical grid. Grid operators can encourage consumers to reduce or change their electricity usage at times of high demand or low renewable energy generation by implementing demand response programmes. Demand response helps the grid balance supply and demand by altering energy usage patterns, which also lessens the need for new fossil fuel-based generation. The ability to store extra renewable energy produced during times of low demand is made possible by the use of energy storage equipment, such as batteries or pumped hydro storage. The grid can then be stabilised and less reliance on fossil fuel-based power can be achieved by discharging the stored energy during times of high demand or low renewable generation. Real-time monitoring and control of energy generation and consumption are made possible by the grid's AMI, smart metres, and sensors. Smart grid technologies let grid operators use renewable energy resources as efficiently as possible based on the grid's present state.Accurate forecasting of the generation of renewable energy sources is necessary for their successful grid integration. Predictive analytics, machine learning, and weather forecasting can all be used to identify patterns in the production of renewable energy, allowing grid operators to plan and optimise their grid operations. Advanced grid management approaches increase grid flexibility, enabling the seamless integration of renewable energy sources. In order to keep the grid stable, this also entails active power control, voltage regulation, and frequency response capabilities. The stability and effectiveness of the grid are also improved by offering ancillary services like spinning reserves and reactive power support from renewable sources. To allow for further penetration of renewable energy sources, the grid infrastructure, including the transmission and distribution networks, must be upgraded and modernised. This entails boosting interconnections across various locations, expanding grid capacity, and deploying grid automation technology for effective power flow management. Blockchain technology is used by peer-to-peer energy trading platforms to enable direct transactions between energy producers and customers. As a result, grid congestion and transmission losses are decreased and localised energy transactions are made possible, encouraging local communities to use renewable energy sources. Feed-in tariffs, net metering, and grid codes are examples of supportive policies and laws that can encourage the production of renewable energy and make it easier to incorporate dispersed energy resources into the grid. The grid contribution optimisation procedure is made more efficient by clear connectivity standards, market processes, and grid connection guidelines. Rooftop solar panels or wind turbine surplus energy can be distributed and sold to the grid by installing an IoT-powered system for grid contribution.

1.2.6 IoT applications in Power Consumption

DMS software can be connected with IoT-based systems, cloud computing, big data, and AI/ML for improved network visibility, predictive analytics, and outage avoidance. To prevent losses and improve asset performance for real-time energy and condition data monitoring, the following smart grid applications in Indian DISCOMs use IoT, Cloud, Big Data, and AI/ML:

ADMS:- IoT embedded solutions called Advanced Distribution Management solutions are used to reach this level of situational awareness. A unified controlling and monitoring system is created by an integrated programme or piece of software that makes use of both new and old applications. The managed control system is the most effective at preserving reliability, utilising various embedded devices and dispersed resources, and protecting people and property from the inherent variability of a contemporary grid. The potential that exists across all three value loop drivers makes it evident that ADMS is essential to bringing the intelligent grid to life. For utility operations, an ADMS's total value is important.

Outage Management System (OMS):- On transformers and feeders at substations, IoT-based fault sensors take real-time readings of electrical parameters and send them to the OMS for processing. Algorithms based on AI/ML are used to forecast issues that could cause future outages. These cutting-edge methods are employed to create improved maintenance plans and enhance network performance.

PLM:- A crucial smart grid application for balancing load demand and supply availability is peak load management (PLM). Long-term demand spikes might put the distribution systems under too much strain. With the use of intelligent IoT sensors and cloud computing techniques, the rate of change in instantaneous voltage, current, and power is identified. In addition to SCADA/ HMI and historian data, time- and season-sensitive energy and load profile data are evaluated. These inputs support system balance, safeguard susceptible assets, and enable the best switching of overloaded feeder sections.

Advanced Asset Analytics:- The advantages of Advanced Asset Analytics, which are integrated with DISCOM's smart metering, asset, and outage management, include increased regulatory compliance, outage reduction, improved network performance, and asset life extension.

The Internet of Things uses cutting-edge technology to manage and optimise a variety of assets including improving safety, managing the grid, and maintaining power. The SCADA (supervisory control and data acquisition), Real Time Data Acquisition System, and AMI (advanced metering infrastructure) are the key IoT applications in energy power consumption.

SCADA:- The actuators and sensors that make up SCADA are used to communicate with, manage, and operate a centralised unit (Master Unit), as well as to provide an interactive user interface via a visual human-machine interface. For better decision-making, analysis of the data gathered by the system in connection to the occurrence of events with time-stamped data is conducted.

AMI:- Smart equipment on both the utility and customer sides (electric metres) can communicate with one another using the two-way, two-side AMI system. The AMI, which includes smart metres, home area networks, in-home displays, communication networks, energy management systems, and utility data management systems, is an essential component of the smart grid. By acting on early warning signals and enabling preventive measures, this can assist increase network reliability and performance when combined with IoT-based fault management system. Recent advancements in IoT computers, databases, and analytical tools now enable the speedy application of predictive and prescriptive analytics to enormous volumes of

SCADA, AMI, and data from different commercial and consumer IoT devices. This study also aids upper management in making better decisions. Following are some locations where IoT is used:-

- Smart grids
- Smart buildings
- Wind power plant
- Solar power plant
- Electric vehicles
- Smart homes
- Combined heat and power
- Electricity grid.
- Operation of connected mini grids.
- Aggregation and control of distributed energy resources
- Optimised market operation.

1.3 Energy Efficiency in Electricity Consumption

In today's dynamic and ever-evolving landscape of electricity consumption, the integration of advanced technologies is pivotal in ensuring a comprehensive and efficient management system. Two key components, the Standardized Advanced Metering Infrastructure (AMI) and Supervisory Control and Data Acquisition (SCADA) systems, stand as cornerstones in orchestrating a holistic scenario for monitoring, controlling, and optimizing electricity consumption. AMI, with its real-time data collection capabilities, provides granular insights into individual consumer usage patterns, fostering a more interactive and informed approach to energy management. Concurrently, SCADA systems offer a robust framework for real-time monitoring and control of the broader electricity grid, contributing to enhanced reliability, fault detection, and load balancing. Together, the standardized implementation of AMI and the precision of SCADA create a symbiotic relationship, forming an indispensable duo that paints a holistic and intelligent portrait of the modern electricity consumption landscape.

Around the world, there is currently a lot of interest in the AMI-related issues. Numerous theoretical and experimental papers have been written about this topic. Very intriguing works in the topic literature should be mentioned. Numerous recent studies address problems pertaining to the integration of SM with PV systems in buildings under varying environmental and climatic circumstances or to remote network operation monitoring. The literature gives considerable weight to studies on the AMI's collaboration with microgrids , as well as how they function in sizable rural and urban areas .

This argument makes the case that Advanced Metering Infrastructure, which let energy meters to communicate in both directions, is essential to the LV grid's dependable operation. It is made up of several parts, including recorders, energy meters, communication systems, modules, and concetrators that allow for two-way communication between the meters and the central system. Meter Data Management (MDM) software is another feature of AMI that is used to manage measurement data. In addition to meeting the needs of DSOs and customers today, AMI's solutions may also be appropriate for addressing more recent power industry challenges, such as the growing number of RES, the need for electric car charging stations, or the growing interest of providers and customers in Demand Response programs. It is important to remember that AMI can improve network dependability by reducing the amount of disruptions, accelerating maintenance, and fostering improved communication by disseminating information on malfunctions and breakdowns.

Many manufacturers offer AMI meters that combine SG with a Smart Home. Consumer-owned smart meters come with communication ports that act as interfaces between different devices. They can be used to manage domestic appliances, read data from other meters, and link a variety of external devices, including communication modems. The DSO will have a major influence on how the Smart Home is used. From a wider angle, smart meters can also be considered a component of the Industrial Internet of Things (IIoT), which offers several features and techniques for processing and analyzing data, including Deep Learning. While some of them can run on the conventional meter system, others need newer models of meters. Their benefit to DSO is that they manage resources rationally, resulting in actual savings.

Smart meters are more than just tools for monitoring energy use from a distance. Contemporary meters come with event-recording features. It is crucial to document occurrences like Primary Power Down, Primary Power Up, and Voltage Sag in the dependability analysis. Furthermore, the last-gasp functionality can only be very helpful. It entails notifying the DSO of the supply interruption by sending a brief message to the grid. All of the communication devices that connect the meter and the operator must be operational for this feature to be used. For the operator to react quickly in such circumstances, accurate information regarding the incidence of an interruption is essential. Recording the precise moment when the disruption started and the moment the electricity supply was restored is also helpful. On occasion, though, if there is a very long breakdown, the device may send out too much information, or if the disruption is brief, it may send out false information.

It is impossible to have online power network diagnostics without a functional teletechnical communication network. The range area of AMI communication can be used to categorize it into three different networks: the local network, which concentrators and other devices use to read meters directly; the Home Area Network (HAN), which uses smart meters to send control signals and other information to the home network; and the crucial wide-area network, which is used to exchange data between specific servers meant for information collection and concentrators. The user can now remotely control gadgets in their home or workplace via permitted Internet access, all thanks to the smart meter's link to HAN. Within HAN networks, common technology solutions are used to facilitate communication. Advanced Distribution Management Systems (ADMSs) are being implemented by utilities to manage and oversee the intricate grid. Applications such as the fault location, isolation, and self-restoration (FLIR) and outage management system (OMS) assist utilities in making complex decisions when there is a high demand for electricity. The communication networks supporting their smart meters (AMI) need to be examined by utilities who are either planning or currently deploying Advanced Distribution Management Systems (ADMS). In certain situations, smart meters can function as edge-of-grid sensors that report voltage and power quality data in addition to power loss alerts, which is something that utilities need to consider. The integration of growing Distributed Energy Resources (DER), such as microgrids, electric cars, grid-linked photovoltaic systems, and demand management.

1.4 Problem Formulation

One of the major problems undertaken in this research work is reduction of the aggregate technical and commercial losses in the power distribution companies. This thesis mainly focuses on the challenges in the power utilities with basic core functions of the revenue management system i.e., Meter reading, Bills generation with instant delivery of the invoices against the electricity consumption and revenue collection against invoices generated with proper accounting and auditing. The research work mainly involves IoT devices for accurate and real-time consumption of the electricity with fast processing of data acquired at a data lake for efficient deep analysis through various emerging technologies like AI/ML/Big Data Analytics/Block Chain Technologies etc . The IoT Based smart meter converter device helps to enhance the meter reading accuracy with real-time monitoring of the electricity consumption. The device also supports to convert the existing legacy electronic meter embedded with RS232 port to smart pre-paid meter system. The AI and Big data analytics-based framework helps in taking the prompt decisions in real-time with such an efficient framework by providing an interactive visual dashboard.

1.5 Purpose

A sustainable energy plan is stated to be built on the two pillars of energy efficiency and renewable sources. Energy efficiency improves the environment, the community, and human health in addition to lowering costs and increasing the resiliency and reliability of the electric grid. Every utility in the world must reduce aggregate technical and commercial losses (AT&C), as they impede both the development of the business and of society as a whole. The goal of the current research is to examine the technologies that are already available in this field, analyse real-time energy use, and offer alternatives and solutions to any existing process or infrastructural bottlenecks or defects in legacy systems.

This work carried out the extensive survey of the technologies behind the smart grids and the IoT applications for the smart devices. New prototypes are designed and simulated the scenarios to study the problem at micro level. Work from this project presented and discussed in many international conferences and implemented the knowledge gained through such conferences.

1.6 Research questions

It is fact that the electricity units produced at the electricity generation plan are never matching with the electricity units invoiced at the consumers premises. There exists a gap between these two units. And this gap is termed as the technical and distribution losses. In some places, it is also termed as aggregate technical and commercial losses. The following questions are generated from the above discussion.

RQ.1 What are the difficulties and challenges in the electricity consumption specially in the intelligent electronic devices, smart grids and IoT and its Applications?

– Review of Literature (Chapter 2).

RQ.2 How to enhance the parameters used to collect data on energy consumption, machine performance, and energy production, enhance utility metre data gathering to decrease billing errors?

-- Methodology for Measurement oT Device Converter (Chapter 3.3.4).

RQ.3 How to conduct a data audit to look for energy theft, energy waste, and chances to improve off-peak energy production?

-- IoT Based Theft Detecting Framework (See Section 3.3.5).

RQ.5 How to provide the quality of electricity supply to end consumers with minimum power outages with available resources?

-- AI Based Energy Efficiency Framework (See section 3.3.7).

A thorough review of the literature in the field of power consumption is necessary to provide answers to the concerns raised above. A plan can be developed to address the problems raised above after examination of the numerous factors affecting, directly or indirectly, the total technical and commercial losses in the power trading..

1.7 Research Objective and Contributions

The goal of the research work is to examine and evaluate the current methods for calculating power consumption along with the Revenue Management System (RMS), which consists of the three core tasks of reading energy metres, creating bills, and collecting revenue related to electricity consumption. Particularly in developing countries like India, aggregate technical and commercial (AT & C) loss is a hot topic in the power distribution industry. The majority of electricity distribution businesses experience considerable AT & C losses.. The research work scope is covering the analysis and development of the frameworks useful in the reduction of the AT & C Loss and supply of the electricity with quality. The proposed prototypes for collection of the electricity meter readings via IoT techniques and frameworks for decision support systems for Meter Data Acquisition System are supporting the distribution companies for seamless acquisition of the meter readings.

1.8 Organization of the Thesis

Following the chapter on introduction, this thesis is structured as follows: A brief review of power metre reading, invoice creation, revenue collection, and the technologies underlying smart grids and IoT applications are provided in Chapter 2. It also covers the Research Gap, Research questions and problem formulation parts. Chapter 3 presents the model design and implementation including the methodology for collection of the real-time electricity consumption parameters for instant decision making, placing a missed-call for receiving a message for the electricity end-users for power-outage and consumer-grievances related issue for no invoice delivery or requesting the duplicate invoice through missed call, framework for electricity theft detection on real-time on the sport and enhancing the energy efficiency part of the power distribution companies, AI based virtual assistant chat bot utility-tool for electricity distribution customer care center to cut-down the expenses for human agents through this an efficient virtual assistant. experimental work, model for real time data at servers i.e. the VEnvMQTT model and the AI based energy efficiency framework for the smart homes. An efficient framework to optimize the maximum load at the home premises by scheduling the various electric appliances. Chapter 4 presents result and discussion on the technologies behind the various technologies in the electricity consumption and last but not least, Chapter 5 presents the summary and conclusions also discusses the limitations of the study and suggests directions of future research.

CHAPTER 2

Review of Literature

2.1 Introduction

ELECTRICITY consumption literature contains the methods, processes, techniques related to electricity trading with a assent of the emerging technologies like Artificial Intelligence, Block Chain technologies, Cyber Security, Big data Analytics, Internet of Things etc. In developing countries like India, the power Distribution Company of every state faced a lot of challenges and has to customize their standards of assessing energy accounting on the daily basis. The reduction of Aggregate Technical & Loss, previously called as Transmission & Distribution losses, which was result of technical as well as commercial loss due to technical loss in transmission sector and theft or commercial loss at distribution level. The power distribution companies are targeting mainly the 24X7 electricity supply with quality and with minimum transmission and distribution losses.

This chapter presents the state of art in the electricity consumption for the aspect of measurement and verification processes with existing review studies along with prediction and recommendations of the review. Followed by the research gap, problem formulation and objectives of the thesis work.

The materials for the study of the existing literature of the power consumption collected from the various open source journals along with reputed SCI, SCIE and Scopus indexed journals. The papers are from SCI and Scopus-indexed journals published from 2011 onwards. A systematic survey of the literature on smart grid technologies. A list of 590 research papers with different aspects of smart grid techniques is filtered. Finally, 79% of papers from recent last six years are on emerging technologies of smart grids related to IoT are 20%, NB-IoT at 24%, smart intelligent systems at 16% and 21% from the networking area.

2.2 Criteria for paper selection

Recent publications from the recent literature, directly aligns with the goals and objectives and addresses/explored the similar research question. The methods used in the research work are suitable for research context and appropriateness of the research methodology employed in this research work. The criteria of the paper selection is as follows:-

1. Relevance to Research Objectives.
2. Methodology and Research Design, Assess the quality and appropriateness of the research methodology employed in the paper.
3. Evaluate the validity and reliability of the data and findings presented in the paper
4. Quality of Analysis and Interpretation.
5. Considered the reputation and credibility of the authors.
Evaluated the reputation of the journal or conference where the paper is published.

6. Recentness of Publication Ensure that the paper adheres to ethical standards in research.

7. Considered whether the research design and conduct align with ethical guidelines in electricity consumption.

2.3 Paper Filtering

Research is interdisciplinary, assessed the papers draw from and contributes to multiple disciplines. Based on the various parameters, the papers from the recent literature of the electricity consumption taken from the advanced metering infrastructure, supervisory control and data acquisition system, distribution management system, outage management system, peak load , demand and supply analysis etc. Evaluated the paper acknowledges its limitations and potential areas for future research.

- Categorization Aspects
    - Bi-directional communication in smart devices and utility.
    - Controlling and managing devices remotely.
    - Automatic and bi-directional metering and billing customers accordingly.
    - Outage management system by detecting and diagnosing the system faults.
    - Real-time data acquisition system formulations.
    - Storing and managing the metering information at central place.

    - Discovery of other complicated applications, e.g., detection of electricity theft, enhancement of system security, DSM, and load balancing.
- Deployment Aspects
    - Traditional meters
    - Smart meters
    - Post paid tariffs
    - Pre-paid tariffs
- Operational/ Functional Aspects
    - *Regular and Precise Metering*
    - *Data Recording and Alarming*
    - *Two-way Communication*
    - *Appliance Control*
    - *Demand-Side Management*
    - *Time-of-Use (TOU)*
    - *Incremental Pricing (IP)*
    - *Critical Peak Pricing (CPP)*
    - *Critical Peak Rebate (CPR)*
    - *Detection of Electricity Theft and Enhancing System Security*

- Core of Revenue Management Aspects
    - *Electricity Meter Readings Techniques*
    - *Metering Functions*
        - Data Recording
        - Total Consumption
        - Time-of-Use Metering
        - Max(peak) Demand Metering
        - Load Survey (Profile or Tie-Series Data)
        - Recording of Power Outage
    - *Monitoring and Control*
        - Reporting of Real-Time Power outage
        - Detection of Leak
        - Detection of Tamper
        - Disconnection/Reconnection (remotely in prepaid or postpaid mode)
        - Control of Load
        - Scheduling of Load
    - *Customer Interface*

    - Security
    - Customer Billing Functions
    - Energy Management Systems
  - *Communications Metering Techniques*
    - Electromechanical Meter
    - AMR/RMR
    - AMI
    - Smart Metering

2.4 Measurement With IoT

In the current situation, readings from electricity metres are taken in a variety of ways, with problems noted in the electronic readings by human metre readers on notepads and keying them into utility interfaces at one central location, which increases the likelihood of human errors in reading/keying in the readings. The door-to-door approach, premises locks, non-visibility of metre readings, skipping a few metre readings, etc. may be the chances of failing to achieve the goal of 100% accurate metre readings as well as for physically disconnecting and reconnecting the supply of electricity to the premises of the consumers by a human representative of the utility.

It was determined that some old vintage electronic metres still exist but are not in communication with the utility's billing engine, MDAS, or MDM. Numerous researchers have created various Internet of Things (IoT)-based devices that count reading units and other metrics using various sensors and interact with the central billing system, but they have not been able to deliver the user-required bill payment.

An IoT Based Device to Convert Legacy Electronic Meter Functionality to Smart Electronic Meters (Postpaid/Prepaid). The comparison report with the relevant patent references and relevant non-Patent references to clearly picture the state of art in the electricity meter reading techniques is appended as in the table below:

Table2.1 : comparison report with the relevant patent references and relevant non-Patent references

Relevant Patent References

sl no	Sources	Specifications/Key Features	Comparison with Proposed system.
1	Automatic Metering System For Power Remote Meter Reading	RMR system for Power, acquisition system and GIS Module,	This system is only data acquisition system with GSM and GIS modules. This system can not be used for the prepaid mode. This system has only RMR options. Case 2 and case 3 in the proposed system are the alternate of failure of this first case.
2	Wireless Meter-Reading System(Smart Electricity Meter) for Smart Home Based	Wifi System for electric meters, wifi module and a wireless interrupter module, wireless AP module and a microprocessor, the system is for smart home environment. All the modules are interconnected wire lessly via wifi connectivity. Signal encryption module.	The system is based on smart home wifi concept. The proposed system has high availability with three case scenarios for hundred percentage metering and billing efficiency of the DISCOMs. The system is using only wifi connectivity with the microcontroller interconnected wirelessly with AP Module and interrupter module.
3	RMR Data Collecting-System-Based-On-Wireless-Fidelity(Wi-Fi)	Data collection system on wifi remotely. A power module and image sensor is used to capture the readings, RS232/485 adaptive interface. A central communicating server. Wi-Fi signal amplifier.	The reading is sensed by image sensor. The changes of image processing erors. The system is only a case-I option of the proposed system.
4	Wireless Fidelity (WIFI) Wireless Intelligent Electric Energy Meter	It is Wi-Fi based electric energy meter. Master control module comprises of central processing and storage. Best for full operation of an intelligent grid.	The system is wi-fi based. The meter reading and the operational signals are passed to the gird operations. Prepaid and postpaid mode of the billing are not connected with the billing engine for the auto disconnect / reconnect

			of the sytem.
5	WIFI-Based-Based RMR, MDAS	Remote Data acquisition system. Cpu power module, storage, and RS232/485 adaptive interface and image sensor.	The system is a meter reading accumulation system. The RMR is the main function of the system. Image sensors are used for capturing of the readings, may be prone to errors. The system has case -1 operational capability of the proposed system.
6	Intelligent MDAS On Wi-Fi Communication Technology	Meter reading with wifi technology. radio frequency module, one lcd screen, wifi rf module are connected to functional pin. Wifi meter reading terminal is carried out by rf module.	RMR with wifi and radio frequency technology. The system is capable of the functions of the case-I of the proposed system. The system is also not capable of functioning the prepaid as well as postpaid mode as in the proposed system.
7	Automatic Meter Reading Terminal Based On WIFI Network	AMR Based on wifi technology. This terminal comprises an instrument terminal, sensor connected with processor and processor is connected with signal generator, MCU Provides gerentocratic identification. The feed circuit of the described wifi transceiver are provided with energy saving switch controlled by MCU .	In this referenced work, the authors proposes a model based on the wi-fi technology for AMR. It uses sensors and processing the same with the MCU. The system is not using any load control and the system is not fit for the prepaid or postpaid automatic connection/disconnection mode as done in the proposed system.

Table 2.2: Relevant Non-Patent References

Relevant Non-Patent References			
sl no	Sources	Specifications/ Key Features	Comparison with Proposed system.
1	IOT-Based-Energy	Analysis of the system for	The system is for meter billing and

	(MBC) System -A Case Study	meter billing and monitoring, it is IoT Based. Relay switch. LCD-Display and interfacing with the Controller. It has RF ID, Sensor, Smart tech and nano tech with IoT infrastructure.	monitoring system. It is IoT based. It is composed of relay switch sensors and interfaces with LCD Display. The current system is lacking the postpaid system as done in the proposed system.
2	IOT-Based-Energy Metering Reading-System (Automatic Billing)	IoT based energy meter reading with fault detection. Unit usage periodical of one fortnight, with automatic and manual option, SMS alert to user, LED for fault detection, EEPROM is used for data memory, software is Arduino IDE.ATMEGA328P, WiFi Module, LCD Display, V/I Controller, EEPROM, RTC. LDR sensor for counting the blinking LED pulse. IoT Server on cloud.	The system is IoT based meter reading system. It is a fault detection system. EEPROM is used for data memory. Wifi module and i/v controllers are used. The system has operational capability of case-I of the proposed system. The system lacks the high availability of the metering and billing functionality.
3	GSM-Based-AMR(Instant Billing)	It is need of Efficient AMR. GSM Energy meter with web interface, .Net and C# for web interface. PC with GSM connectivity for data collection and providing to the database a billing engine. The system is for postpaid method. AMR on wireless and wired system. PLC and optical cable and GPRS, Bluetooth, GSM Technology. Data stored in EEPROM, MAX 232, RS232/485 Converter. CMOS Battery. TTL Compatible converter.	The system is efficient AMR GSM based. The system has the functionality of the case-I proposed. The current system is not able to work smartly in the prepaid or postpaid mode. The auto connect/disconnect is not introduced in the system. The system may work on the PLC/ GPRS, Bluetooth and GSM technology. The system has the CMOS battery for the power backup. Current system is lacking the high availability as in the case iii of the proposed system.
4	IOT-based Electricity	IoT based system for fault	The system is good for the prepaid

	Prepaid Metering &Billing with Payment System	identification. In case of fault, one notification is sent. The webpage is used for showing the contents of the captured information. Wifi module, RTC , EEPROM , v/I controller is used with microcontroller. It uses wifi module. It is an AMR system. Relay circuit is also used for load controlling. Email notifications are also generate, the fault analysis is also shown on the graph by web interface. Power usage chart is also shown on the dashboard.	system for best monitoring the power usage. The power consumption is shown on the dashboard in the form of graphical presentation. The fault identification is also a positive outcome of the system. The current system is AMR system. The case-I is met with postpaid mode. Smart functionality of the auto connect/disconnect is missing the system.
5	IoT-Based Power Security and Prepaid Electricity System	Arduino based system reading pulses of the meter, it uses the relay switch for load control too. LCD Display for the various message display. GSM SIM900 for gsm connectivity. It is analogues to relay. ULN2003 is used for stepper motor operation.	The system is good for the prepaid electricity system as it composed of the load control system for stepper motor operations also. The system is using GSM module. The system may not work fit for the postpaid mode. The system is not able to connect nearby systems for collections of the readings in case of failure of the network connectivity. The self-assessment as done in the case iii in the proposed systems is also limited in the current system.

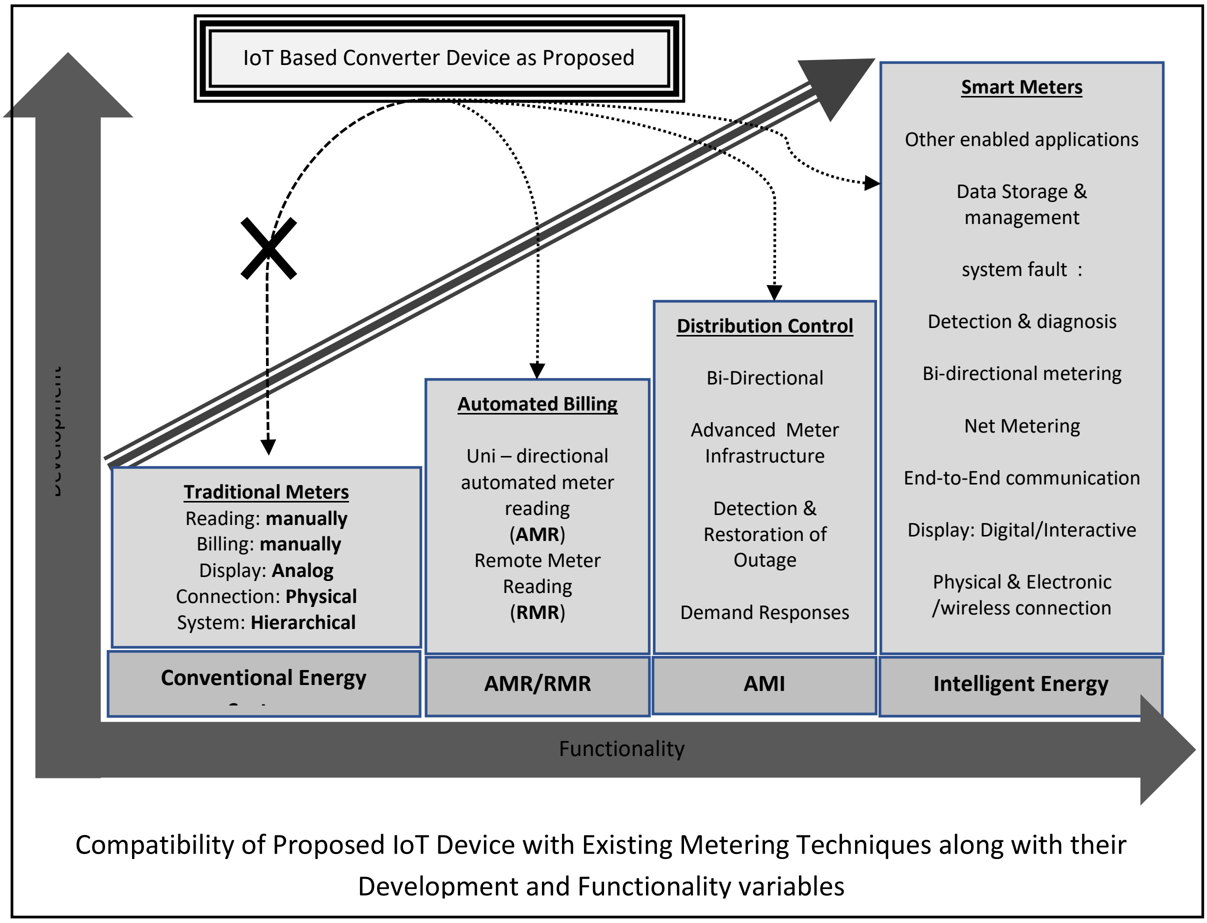
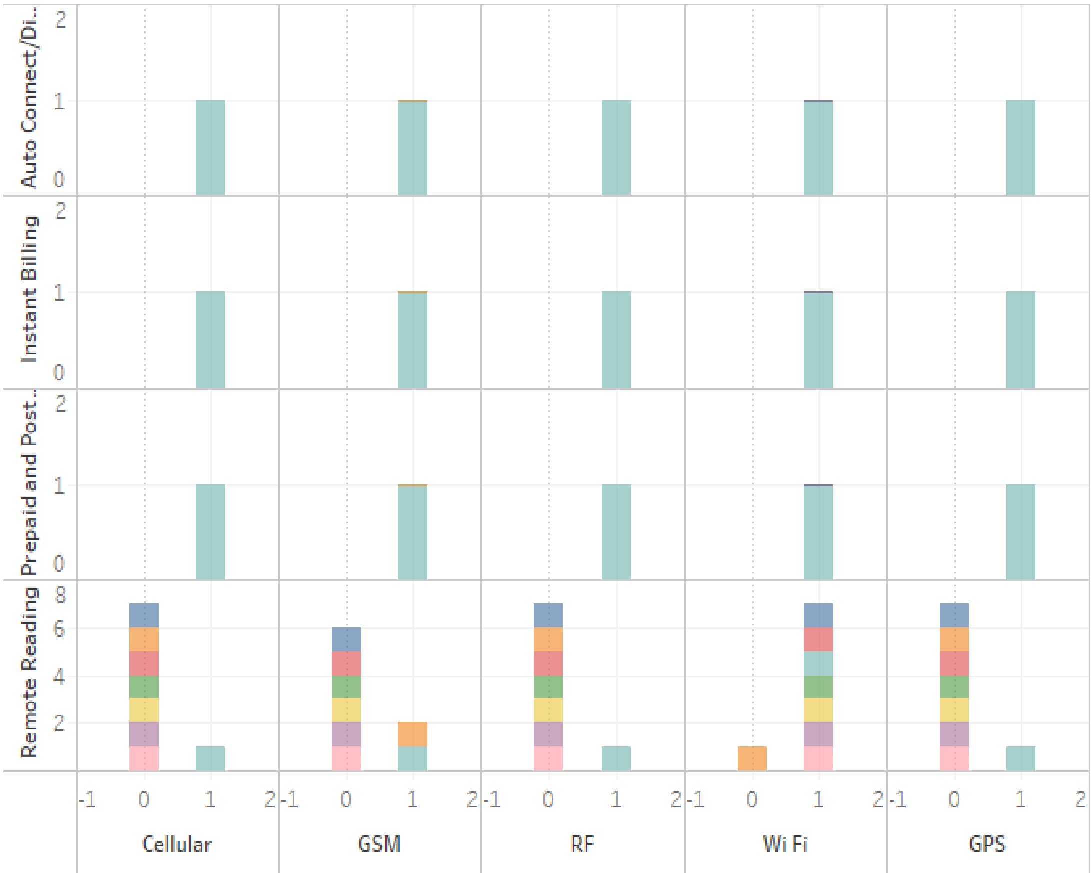


Figure 2.1: Compatibility of Proposed IoT Device with Existing Metering Techniques along with their Development and Functionality variables

Comparision of Related Patent References



Sum of Cellular, sum of GSM, sum of RF, sum of Wi Fi and sum of GPS vs. sum of Auto Connect/Disconnect, sum of Instant Billing, sum of Prepaid and Postpaid and sum of Remote Reading. Color shows details about Sources. Details are shown for Sources.

Sources

- Automatic Meter Reading Terminal Based On WIFI Network
- Automatic Metering System For Power Remote Meter Reading
- Intelligent Meter Reading System Based On Wi-Fi Wireless Communication Technology
- Propoed System
- Remote Meter Reading Data Collecting System Based On WiFi (Wireless Fidelity)
- WIFI-Based (Wide Fidelity-Based) Remote Meter-Reading Data Acquisition System
- Wireless Fidelity (WIFI) Wireless Intelligent Electric Energy Meter
- Wireless Meter-Reading System For Smart Electric Meter Of Smart Home Based On Wi-Fi

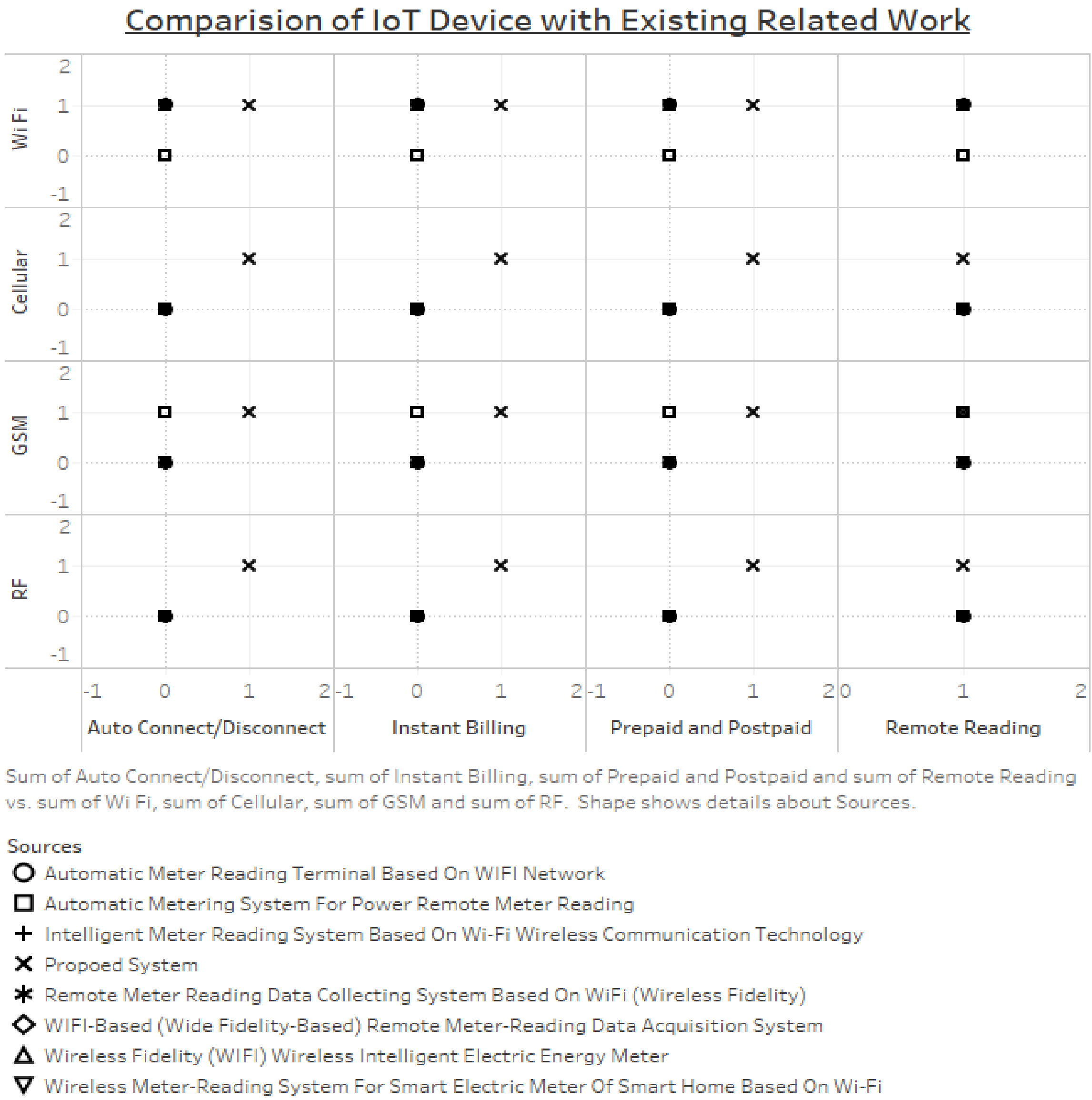


Figure 2.2: Comparison of IoT devices with Existing Related work

In the same domain of the inventions, the related works are present in the recent literature of the electricity meter readings, which are enumerated as below:-

CN104616471A describes an Automatic Metering System for Power innovation. Distance metre Only a data collecting system with GSM and GIS modules is being read in this system. However, this invention only offers remote metre reading capabilities and cannot be used in prepaid mode.

The patent application CN105045130A elaborates a smart and intelligent wireless meter-reading system smart homes based on Wi-Fi technology. It is made up of a Wi-Fi System for electric metres, a Wi-Fi module, a wireless interrupter module, a wireless AP module, and a

CPU. The innovation, however, omits the fact that the system is primarily intended for a smart home setting and uses solely Wi-Fi networking, with the microcontroller wirelessly coupled to an AP Module and an interrupter Module.

CN203165184U, which describes an innovation of a remote metre reading data acquisition system (DAS) based on Wi-Fi, is a kind of accurate, firewalling remote metre reading data collection system. The innovation, however, omits to mention that it is merely a data gathering system that records the metre image sensor and falls short in metre reading accuracy.

The innovation described in CN201903585U is a Wireless Fidelity (WIFI) Wireless Intelligent Electric Energy Meter, a data collection system that transmits operational signals and metre readings to grid operations. The system's reliance only on Wi-Fi connectivity, however, and the fact that the billing engine for the system's automatic disconnects and reconnections is not tied to the prepaid or postpaid billing modes is not disclosed in the invention.

The metre reading accumulation system specified in CN103208174A is a remote metre reading data collecting system that uses WIFI (Wide Fidelity). However, the invention omits to mention that imaging sensors, which are susceptible to inaccuracy, are employed to capture the results.

A remote metre reading system using Wi-Fi and radio frequency technology is disclosed in CN201322987Y. It is the creation of an innovative wireless communication-based intelligent metre reading system. The innovation, however, is merely a data recording system based on Wi-Fi wireless communication technology, without the ability to operate as a prepaid or post-paid mode of the billing system as required by the user.

The patent application number CN105513329A describes an automatic metre reading terminal that uses sensors and a wireless network to process metre reading data. However, this invention merely functions as a WIFI network's automatic data logging terminal and does not employ any load-control strategies. The current invoicing system does not support automatic connect or disconnect modes for prepaid or postpaid payments.

Sasane, Nikita & Sakat, Swati & Shital, Nemane & Pallav, Prabhat & Kaushik, Vipul. (2017). IOT Based Energy Meter Billing and Monitoring System-A Case Study. International Research Journal of Advanced Engineering and Science. 2. 2455-9024, reveals an IoT-based metre billing and monitoring system that uses sensors built into relay switches and communicates with LCD displays. However, the invention omits to mention that the postpaid payment mechanism is absent from the current system.

Kumar Pc, Kishore & Raja, J. & Abishek, Ebenezer & Vishalakshi, S. & Vidhya, G.. (2018). IOT Based Energy Meter Reading System with Automatic Billing. International Journal of Engineering and Technology(UAE). 7. 431-434. 10.14419/ijet.v7i3.27.17992, is a fault detection in metres based on IoT. However, this invention makes no mention of the usage of a WiFi module, i/v controllers, or an EEPROM for data memory storage. Meter billing feature is missing from the prior art.

K ASHNA and et.al , GSM Based AMR along with Instant Billing mechanism discloses an invention is effective GSM-based automatic metre reading. The prior art, however, utilises PLC/GPRS, Bluetooth, and GSM technologies along with a CMOS battery for power backup.

R Mohan Naik and et.al in IOT based Prepaid Metering , Billing and collection System, explains a new idea for a prepaid power monitoring system in which the power consumption is shown graphically on the dashboard. However, the innovation lacks intelligent auto connect/disconnect capabilities and is a postpaid automatic metre reading system..

SAKSHI PATIL and AAKSHA JAYWANT IoT-Based Power Security and Prepaid Electricity System discloses an invention for the prepaid electricity system as it composed of the load control system for stepper motor operations by using GSM module. However, the invention omits to mention that the self-assessment done is limited and that it may not be to link neighbouring systems for collecting of the readings in case of network connectivity failure.

2.5 IoT based Missed Call Messaging System

The urban environment is so far along these days that consumers are well known and aware of the power portals and website, apps based on android IOS operating systems of the mobile-handsets based applications, etc. They can obtain a variety of information regarding the amount and due date of their electricity bills, and they can then pay / deposit the outstanding dues against electricity consumption online with anyone from the enumerated list of services offered through allotted time frame. They can even benefit from paying electric bills via online mode ahead of time by receiving discounts on those bills. However, consumers in remote areas are less aware of internet services and are often unable to receive their physical energy bills within a few months of the year. As a result, they are unable to pay their bills on time. They may also lose their physical bills at home. Consumers who continue in this manner become irregular paying consumers and as a result, entered in the ghost consumer list. Even worse, difficulty in the memorization of the complex and bigger consumer account number, the resolution was the missed-call services based in the mobile-registered, for receiving a duplicate-bills in the electronic form, instantly. As a solution missed-call-messaging-services are recommended where a mobile number is playing a candidate key in place of the consumer id for fetching the various dues details along with the consumer-profile. The big task of arranging the physical papers of the invoices was tagged in a sequence and placed on the wall of a small house of a village. After successful implementation of this proposed work,the citizens i.e. end-user electricity consumer, who has opted this facility after registration with this messaging-system will receive a quick text-message (SMS) in response to a missed call they make to a certain number, which will include the customer number, the balance due amount, and the due date. The letter also contains a link to the most recent soft copy PDF version of the bill or invoice. By hitting a link provided in the text of the SMS, the client end-user can even download the most recent power bill if they are using a smart phone. Customers will get a response back with the complaint number for their unique customer if they call another specific No-Power-Supply line. Customers no longer need to memorise their customer numbers as a result. The most current-status of a complaint of the no-power which is already submitted against the formed candidate-key(RMN) , will be provided in response to the consumer who calls the same number after complaining about no electricity, together with RMN from where call is placed. An SMS consisting of a link for the consumer account number/candidate key/ consumer account-ID with RMN and an OTP for registration will be received, if RMN is not linked to end-user account-id at the central database maintained at the data center of utility. The client can sign up for the same service through that SMS link.

In this framework, the two services listed below are recommended for electricity users and may be expanded to assist users without Android phones. Because the majority of these services rely on missed calls and messages. These two essential services are free and available on all mobile devices. First is the message through a Missed-Call on number provided for such service. And second is receiving the current outstanding dues against electricity consumption. In the case that a consumer misses a call to the utility's mobile number, the service is started for receiving the billing related information specially the outstanding dues details on the registered mobile number because a database of customers and their mobile numbers is maintained.

When a mobile registered consumer of the electricity consumption places a Missed-Call on designated number (especially given by the electricity office for no-power-complaint), the complaint for the no-power against that consumer will be registed with the company. To make it easier for customers who don't use Android devices, a message should be sent along with the registered complaint number.

The major goals of power distribution firms are the 24x7 quality supply of electricity and collection of revenue. When it comes to electricity usage, there are two different forms of losses. The first type of loss is called transmission-loss sometimes known as technical-loss and it occurs when moving power from one location to another. There is no avoiding this loss. The other is a financial loss brought on by the trade of power. In some parts of India, customers hold the attitude that they will not pay their electricity bills. The majority of these customers contend that they are unable to pay the invoices because they are unavailable, and that their lengthy arrears prevent them from paying the large amounts all at once. On top of the large sum, late payment fees are imposed. In order to inform these clients when their mobile phones are due, the missed call services are provided to them. A small number of clients are currently unable to pay their outstanding electricity bills because they have lost or never received their monthly invoices. This is particularly true in rural areas where people are unaware of online resources like the internet, websites, Android apps, and smartphones. Giving a missed call to such customers is quite simple and comes with no additional cost. Customers can receive a duplicate bill in the form of a text message for free, along with the due amount and due date. Such facilities can raise the standard of services by considering the no-power complaints gathered via this facility for later decision-making/policy development.

The review of literature in the field of IoT and Big Data in the field of Electricity consumption is carried out by the year of the publications of the papers of the SCI/SCIE/Scopus indexed journal up to date. Personal visits to a few power distribution companies in India, along with discussions with the electricity consumers as well as home appliances consumption. The summary of the selected pares is enumerated year wise in the table 2.3.

Table-2.3: Summary of Selected Papers for Review of Literature (IoT and Bigdata in Electricity consumption)

YEAR OF PUBLICATIONS	TOTAL NO. OF PAPERS SELECTED
before Year 2010	20
2010	6
2011	6

2012	12
2013	7
2014	8
2015	6
2016	10
2017	4
2018	7
2019	10
2020	12
2021	8
2022	6
Total	**122**

A details literature survey of the selected papers from the literature with main findings or the conclusion relevant to the proposed research work along with the details of the journals, books, book chapters, web site links are tabulated in the following table 2.4 .

Table-2.4: Literature survey of 66 selected papers from IoT and Big Data Analytics in the field of the Electricity consumption

Journal/Conference/ Book Details	**Publica tion- Year**	**Journal- Indexing (SCI/SCI E/Scopus index etc.)**	**Observations or findings in proposed-research-work**
[1] True poly-phase Callibration-Meters	1998	Scopus	One of the authors' most significant findings is that the two types of adjustments exhibit

Journal/Conference/ Book Details	**Publication-Year**	**Journal-Indexing (SCI/SCIE/Scopus index etc.)**	**Observations or findings in proposed-research-work**
			systematic differences (three-phase and series-parallel). The fact that there are two separate global standards in use contributes to this issue as well.
Revenue Improvement From Intelligent Metering Systems	1999	Scopus	APSEB has improved its revenues considerably by adopting innovative technology solutions using Intelligent Metering Systems
Improve Job Ordering & Slot onfiguration In Big-data	2000	Scopus	A series of tasks that include more matching jobs and job reduction make up a Mapreduce's work..
WiMAX Forum. (2001) online available and retrieved from: http://www.wimaxforum.org/	2001	Scopus	WiMAX is a wireless communications standard which has been designed for providing data rates of 30 to 40 Mbps and in case of fixed station it provides up to 1Gbps. WiMAX is a IEEE 802.16 standard and has been created by WiMAX Forum
Vector Machine [2]	2005	Scopus	Explained the modes supported

Journal/Conference/ Book Details	Publication-Year	Journal-Indexing (SCI/SCIE/Scopus index etc.)	Observations or findings in proposed-research-work
			in EN13757-4:2005 ([45]) are as follows. In paper [45], author explains the IEEE802.15.4 (communication standard), this is also called by the term ZigBee, its cost is comparatively lower, its power consumption os also lower as compare to others. It is also wireless mesh network standard.
Map reduce framework for the data simplification and large clusters processing	2008	Scopus	Considering the parameter of volume/size , the same is when compared with parameter of data-quality, then, the main concern is integration of the available tools for extraction /analysis of the big data for various decision making reports for higher management
[2] ZigBee technology.	2008	Scopus	Also the cost involved in the wired communication & the maintenance of a wired communication is very next to impossible especially in Indian regions as per current situation.

Journal/Conference/ Book Details	**Publica tion- Year**	**Journal- Indexing (SCI/SCI E/Scopus index etc.)**	**Observations or findings in proposed-research-work**
			In this case are wireless communications extremely useful.
Big data management [4]	2009	NA	The main concern is integration of the available tools for extraction /analysis of the big data for various decision making reports for higher management
ARM-based power-meter	2009	Scopus	The authors explains the Wireless Fidelity or short Wifi which is one among the reputed communication protocols, this uses 2.4GHz or 5GHz frequency due to which it can communicate upto 100 meters range devices like LAN(Local Area network). This is also a wireless network which makes it easy for installation and deployment
Reduction of Power-Loss in Distribution	2009	Scopus	Discussed about the reduction of AT & C Loss in power distribution companies by use of

Journal/Conference/ Book Details	**Publica tion- Year**	**Journal- Indexing (SCI/SCI E/Scopus index etc.)**	**Observations or findings in proposed-research-work**
			different techniques.
AMR in Smart Meter.	2010	Scopus	The author shown the variety of Electric Meters are available in the utilities. Even one power utility may have number of electric meter make and model. As of now the following types of the electric meters are available. Mechanical Meters Electrical Meters AMR AMM AMI Smart Meters.
AMR-based System.	2010	Scopus	Propose AMR system which is using WiMAX technology along with WSN(wireless sensor network). Due to its feasibility and affectivity it can be used in the IoT to communicate the various meters installed at long distance in the utility.
Road-Traffic prediction	2011	Scopus	For Innovation/advancement/development of the Big-Data technologies & IoT techniques.

Journal/Conference/ Book Details	Publica tion-Year	Journal-Indexing (SCI/SCIE/Scopus index etc.)	Observations or findings in proposed-research-work
AMR system in Smart Grid. [3]	2011	Scopus	This tree-network structure can be divided into three layers: 1. The Application-Layer:- This is communication link between Utility Billing Engine versus the concentrator 2. The Middleware-Layer:- This is communication link between concentrator versus collector 3. The Device-Layer:- This is communication link between collector versus metering devices.
big data [4]	2012	Scopus	The author explains various HDFS tools for applications such as reporting & Preparation of ad hoc queries/reports, we can use Map Reduce / HDFS (Hadoop Distributed File System) based tools, such Impala, Apache Hive [28].
Wireless communication protocols.	2012	Scopus	The author shown the variety of Electric Meters are available in the utilities. Even one power utility may have number of

Journal/Conference/ Book Details	**Publica tion- Year**	**Journal- Indexing (SCI/SCI E/Scopus index etc.)**	**Observations or findings in proposed-research-work**
			electric meter make and model. As of now the following types of the electric meters are available. Mechanical Meters Electrical Meters AMR AMM AMI Smart Meters.
wireless M-Bus protocol.	2012	Scopus	Elaborate the AMI applications. The wired variant of M-Bus is mainly base of the wireless M-Bus. As the name indicates that M-Bus or Meter Bus, as this communication protocol is specially created for remote meter reading, hence the name is Meter-Bus or M-Bus. In recent years, wired communication replaced with wireless communication in many applications. That is the main reason of wide spreading of usage of Wireless communication over wired communication, the ease of installation and extendable capability might be the boosting

Journal/Conference/ Book Details	Publication-Year	Journal-Indexing (SCI/SCIE/Scopus index etc.)	Observations or findings in proposed-research-work
			factor for this.
TinyOS-based Wireless M-Bus implementation.	2012	Scopus	Specifies about the physical layer and data link layers of communication among devices/meters in wireless variant is operating at 868 MHz. Due to simplicity of the protocol, this can be used with lifetime of over 10 years as it is compatible with tiny battery operated 8-bit microcontroller.
ZigBee-over-the-air-upgrading-cluster.[5]	2012	Scopus	AMI is mainly concentrated on the wireless which is composed of low-speed-wireless protocols, like, Wireless M-Bus, ZigBee
WiMAX for advanced metering infrastructure.	2012	Scopus	Wifi, GPRS & WiMax protocols as suitable in the AMI and it is very popular to use such protocols in the Advanced meters infrastructure
Traffic-engineering-analysis.	2012	Scopus	Explains the GPRS or General Packet Radio Service. This service is the packet oriented services for mobiles.

Journal/Conference/ Book Details	Publication-Year	Journal-Indexing (SCI/SCIE/Scopus index etc.)	Observations or findings in proposed-research-work
Extensions-wireless-M-Bus protocol	2012	Scopus	Shown the variety of Electric Meters are available in the utilities. Even one power utility may have number of electric meter make and model. As of now the following types of the electric meters are available. Mechanical Meters Electrical Meters AMR AMM AMI Smart Meters.
Losses-in-Radial-Distribution-System.	2013	Scopus	Analyzed the Commercial & Administrative Losses in Distribution System along with economic consequences.
Big-data-system for massive-traffic	2013	Scopus	Trying for solving the same bye use of a MapReduce framework (a big data technique for fast processing of huge data
Wireless communications in smart metering	2013	Scopus	Shown the variety of Electric Meters are available in the utilities. Even one power utility may have number of electric meter make and model. As of now the following types of the electric meters are available.

Journal/Conference/ Book Details	**Publica tion- Year**	**Journal- Indexing (SCI/SCI E/Scopus index etc.)**	**Observations or findings in proposed-research-work**
			Mechanical Meters Electrical Meters AMR AMM AMI Smart Meters.
Big-Data-Analytics (Review)	2014	Scopus	From the above it is recommended by big data experts the three Vs. (Volume, Velocity and variety) exists in the problem, hence the big data is suggested to be implemented in the utilities to face such issues
Data-intensive(survey on bigdata)	2014	Scopus	As far as the volume/size is concerned the same is when compared with the quality of data, then, Volume is not reported as a prominent problem, as number of solutions that deal with this problem. however, the main concern is integration of the available tools for extraction /analysis of the big data for various decision making reports for higher management

Journal/Conference/ Book Details	**Publication-Year**	**Journal-Indexing (SCI/SCIE/Scopus index etc.)**	**Observations or findings in proposed-research-work**
Efficient-traffic speed-forecasting [6]	2014	Scopus	solving the same bye use of a MapReduce framework (a big data technique for fast processing of huge data)
Finding in fog-computing	2014	Scopus	Fog-computing approach of earlier Born-Connected approaches and it would be ideal in the long-term to move the composition of the OM-JSON documents very close to the devices
Big-Data-as-a-Service Platform	2015	Scopus	Author represents the requirement of very costly resources and professional expertise or knowledge related to big data technologies. For providing such decision making reports/ MIS/ Decision Support Systems requires these analytics services promptly, It traditionally carrying out many steps at different levels separately, for example, data acquisition / information gathering/ data accumulation,

Journal/Conference/ Book Details	**Publica tion- Year**	**Journal- Indexing (SCI/SCI E/Scopus index etc.)**	**Observations or findings in proposed-research-work**
			storage, manipulation, pre-processing, retrieval / extractions of the same and representing the facts/analysis visually. That's why, for analyzing this huge data (big data), different separate systems are developed for each process.
Prepaid Electric-Distribution-System	2015	Scopus	The various technologies framed various solutions to meet the issues related to metering,billing&collection issues in the power distribution companies as represents the smart meter for prepaid mode
Big-Data–Concepts	2016	Scopus	Derived the 3V of the big data and discussion about bigdata analytics, hadoop distributed file system along with its various challenging tools
Big-Data-Analytics(A Review)	2016	Scopus	Evaluation of the 3V used for the big data and bigdata analytics, hadoop distributed file system along with its

Journal/Conference/ Book Details	**Publication-Year**	**Journal-Indexing (SCI/SCIE/Scopus index etc.)**	**Observations or findings in proposed-research-work**
			various challenging tools
BIG-DATA – AN OVERVIEW	2016	Scopus	about the bigdata, its origin and use of the same in the current era for handling the huge data
Big-data-development a review	2016	Scopus	Incorporates the characteristics of the popular and commonly used definition of Big Data.
Big-Data-Quality	2016	Scopus	The author elaborates about the set of characteristics. As Big Data, the crucial problems of the bigdata are the data itself & the quality of the same. As a result, data preparation is necessary to strengthen and increase confidence in itself in order to guarantee a particular degree of quality.
Quality-Evaluation for Big-Data	2016	Scopus	The author gave a new quality assessment approach, this new approach was introduced. It is based on the consumer as well as the provider of the data, both are involved. Metadata data is providing the data consistency

Journal/Conference/ Book Details	Publication-Year	Journal-Indexing (SCI/SCIE/Scopus index etc.)	Observations or findings in proposed-research-work
			rules and is useful in the assessment of the same.
Outage-Management-system	2016	Scopus	It provides evidence of the outage management system, which is crucial to both AMI and the quality of the electricity.
IoT Based Smart Energy Meter	2016	Scopus	Represents the IoT based meter and its uses in current electricity consumption systems
Meter-Data-Intelligence	2016	Scopus	It reviewed the smart meter for data intelligence for future energy systems.
Sensor network infrastructure (AMI)	2016	Scopus	It focuses on the Advanced metering infrastructure for smart grids, how it can help in bidirectional communication.
Big Data Analytics and Its Applications	2017	Scopus	The paper derived the 3V of the big data. Authors discussed about bigdata analytics, hadoop distributed file system along with its various challenging tools
ANDROID BASED	2017	Scopus	Paper proposed the android

Journal/Conference/ Book Details	Publication-Year	Journal-Indexing (SCI/SCIE/Scopus index etc.)	Observations or findings in proposed-research-work
SMART ENERGY METER			based smart meter to measure the consumption of the electricity
Prototype-Design of smart meter[7]	2017	Scopus	paper represents the smart meter for three phases in electricity consumption
IoT Based Smart Energy Meter	2017	Scopus	Paper represents the IoT based meter for measuring the electricity consumption automatically and communicates to billing engine in real-time.
Challenging-tools in Big-Data-Analytics	2018	Scopus	The paper derived the 3V used in the big data. Paper also discussed about bigdata analytics, hadoop distributed file system along with its various challenging tools
Smart-Energy-Meter	2018	Scopus	Paper focuses on the Advanced metering infrastructure for electricity consumption
Design(Smart-Meter) and Theft Detection	2018	Scopus	Paper represents the smart meter for energy theft detection

Journal/Conference/ Book Details	**Publication-Year**	**Journal-Indexing (SCI/SCIE/Scopus index etc.)**	**Observations or findings in proposed-research-work**
IOT-BASED-METER	2018	Scopus	Paper represents the IoT based energy meter for electricity consumption
SMART-WIRELESS ELECTRONIC-ENERGY-METER	2018	Scopus	paper represents the smart meter for the quality of the power
GSM TECHNOLOGY BASED SMART ENERGY METER	2018	Scopus	Paper showed the smart meter based on GSM technology for communication
smart meter using Arduino and RF	2018	Scopus	Paper represents the IoT based meter for electricity measure in the electricity consumption system
IOT–CLOUD and COMPUTING–FOG [8]	2019	Scopus	The rapid expansion of IoT systems and the exponential growth of real-time data have had a significant impact on the development of the big data discipline, notably innovative approaches for data analysis and the integration of machine learning algorithms in decision-making processes.

Journal/Conference/ Book Details	Publica tion-Year	Journal-Indexing (SCI/SCIE/Scopus index etc.)	Observations or findings in proposed-research-work
Cybersecurity-and-Network-Performance (BigData & IIoT)	2019	Scopus	The paper included a cyber physical network communication diagram that illustrates how data and information from physical systems will be detected, actuated, and communicated with cyber systems.
Smart Home (Adaptive Cloud IoT Devices, Bigdata & Deep Learning)	2019	Scopus	a concept for delivering smart home personalization services through ITS that can learn the habits of every family member and produce appropriate turn-on and turn-off scenarios for every member of the family
STRATUM(BigData-as-a-Service)for IoT Analytical Applications	2019	Scopus	Applications for the Internet of Things (IoT) need real-time, reliable predictive analytics that are based on Machine Learning (ML) models.
Deep-Learning-Analytics [9]	2019	Scopus	develops a revolutionary architectural framework that offers methods for putting into practise effective and reusable security analytics based on a

Journal/Conference/ Book Details	**Publica tion- Year**	**Journal- Indexing (SCI/SCI E/Scopus index etc.)**	**Observations or findings in proposed-research-work**
			managed security (or SECaaS) approach.
MR-Edge	2019	Scopus	Due to the vast volumes of IoT data, edge computing is suggested as a solution to the cloud-only processing architecture for IoT. The difficulty is in deploying and carrying out data processing operations on a diverse IoT edge network.
IoT BASED-ENERGY-MANAGEMEN[10]	2019	Scopus	Automation process being an innovative application for IoT for controlling & monitoring energy-meter-data anywhere in the world today
The Prospect of the Internet of Renewable Energy (IoRE) in Electricity Networks	2019	Scopus	An effective, dependable, and comprehensive method of distributing renewable energy is the Internet of Renewable Energy (IoRE).
Bigdata: Search-Engine in Smart-Factory-Environment	2019	Scopus	It demonstrated the use of cloud systems among other data processing techniques in a smart

Journal/Conference/ Book Details	**Publication-Year**	**Journal-Indexing (SCI/SCIE/Scopus index etc.)**	**Observations or findings in proposed-research-work**
			factory. As a result, the accumulated data can be effectively stored, analysed, and used on the cloud.
Smart Home Personalizing Services	2019	Scopus	Automation of personal services in a household has gained popularity as a means of reducing energy consumption. Due to the fact that each family member has their own unique tendencies,
Cost-Benefit-Based Analytical-Study (AMR)	2020	Scopus	The cost-benefit analysis is the key focus. In the recent past, various studies have been carried out, especially on readings from smart metres, to reduce power losses.
Development of smart IoT Sensor[11]	2022	Scopus	To complete the source data entry for the model, the information management system and the cloud platform data automatic synchronisation channel are opened on the data source side.

Journal/Conference/ Book Details	Publication-Year	Journal-Indexing (SCI/SCIE/Scopus index etc.)	Observations or findings in proposed-research-work
Using Hybrid Plants [12]	2020	Scopus	Examines the question of utilising renewable energy sources in the Republic of Ingushetia in order to boost the quality of the country's electrical supply, offer sustainable electricity supplies, and fill capacity gaps.
Empirical-Study (Acceptance of IoT-Based Smart Meter)	2020	Scopus	The purpose of this study was to investigate the factors that influence people's decisions to accept and use smart metre technologies in the area of electricity consumption.

2.6 Electricity Theft Detection

The distribution businesses are strengthening their information technology (IT) and operational technology (OT) infrastructure in response to the exponential increase in modern electricity consumption. The first of these goals is to provide their valued customers with high-quality electricity while minimizing overall technical and financial loss. While the financial loss brought on by electricity theft can be reduced by using the most recent technologies, the loss brought on by technical issues cannot be avoided. However, even in the absence of advanced technology on the supply side, the suggested framework can detect electricity theft after being used. The power distribution firms can use this framework to reduce theft incidents and improve revenue collection from real-time electricity use.

The following research was done in relation to IoT devices and electricity usage and power theft.

In their research article from 2004 [13], Bernard Cole et al. offered the idea of connecting their smart metre unit to a satellite so that existing data from the metres could be gathered in a cubical box with an 8-inch side. This variant has a 15-minute gap between data handshakes for consumption. In order to prevent any blackouts, a model for load profiling and forecasting is used [13]. The author of [14] uses a hall effect current sensor to address the issue of power theft. The old-fashioned approach of stealing electricity was applied to pole-mounted DT (Distribution Transformers) and 11 Kilo Volt (11KV) distribution Low Tension (LT) cables [14].

The authors of [15], presented one hybrid approach to detect theft of electricity in 2021 by integrating two methods recently in practice to detect & prevent i.e. CNN & AdaBoost (adaptive boosting algorithm) ; both are combined to create this new, more advanced approach of theft detection (convolutional neural networks).

Electricity theft is being curbed by the power distribution firms using a variety of measures, including increasing the financial penalties for users and strengthening metres [16]. Any tampering with the smart metres can be triggered by an event by the sophisticated metering infrastructure along with smart metering technologies. With the use of big data analytics, these occurrences are crucial for determining how to tackle such issues because they are collected at a central storage location for data gathering of metering parameters.

The different stakeholders as well as power utilities can receive creative ideas in the form of an expert DSS (Decision Support System) in detection & prevention of electricity thefts as a result of the existing electrical metres being either replaced or upgraded due to the upgrading of infrastructure. In Paper [17], the abrupt decline in the load was identified for tracking the aberrant power use using the Bayesian classification method, decision trees, and the Pearson correlation coefficient.

Aswini R characterised power theft as a significant problem in [18], noting that utilities may experience significant energy theft when they adopt the smart grid. The author presented a tree-based architecture based on the behaviours of the AMI to combat electricity theft. Researchers in [19] explained need of security regarding the AMI as a result of that are increasingly susceptible to power thefts as a result of extensive usages. [19]

The development of smart metering infrastructure has made it necessary to employ emerging technologies like AI,ML & big data analytics in the identification & prevention of electricity theft. Machine learning applications including Artificial Neural Networks (ANN), Self-organizing Maps (SOM), Support Vector Machines (SVM), the pre-processing of data, feature extraction, and categorization are frequently carried out using Recurrent Neural Networks (RNN), etc. [20]. Training and modelling datasets for support vector machines, fuzzy classification, artificial neural networks, and other classification techniques are used to guide some functions [21–26].

With the substantial changes, the infrastructure on the utility side keeps growing. All of the equipment has been upgraded to be intelligent and is capable of two-way communication. To give consumers real-time usage information, the Advanced Metering Infrastructure (AMI) collects enormous amounts of data from electricity consumption monitoring devices every 15 minutes. Such a frequency is required for the pre-paid mode. As a result, the MDAS has amassed a lot of data (Metering Data Acquisition System). The information is arranged in the common data format (CDF).

2.7 AI based Energy Efficiency Framework

Modern consumers may now more easily manage their peak electricity needs in the smart grid thanks to the development of new electricity consumption techniques. The state-of-the-art for sampling techniques, machine learning algorithms, and HDFS approximation frameworks are examined. A comparison of the sample methods is shown in the table below.

Rapid technology advancements and the internet have completely altered how people use power by enabling and amusing everyone's requirements, particularly those related to smart homes, smart grids, and smart metres, among other things. Emerging technologies like IoT-driven compact portable devices with actuators and sensors and smart tools with gentle and sensible data collecting, exchange, and communication capabilities are driving the majority of the advancement and ease in the area of electricity usage. Thus, AI-based intelligent approaches are the key indicators that need to be acknowledged and promoted in the field of smart home power efficiency.

Unbelievable advances and the abundance of electrical assets—such as smart metres, smart grids, and smart home energy efficiency—have not only sparked the idea of smart and pervasive platforms but also increased QoE for consumers and improved QoS for networks. Researchers in [27–31] proposed the DL-driven edge computing platform for IoT applications, particularly those in industry and healthcare. IoT and edge computing are significantly advancing the fields of artificial intelligence, deep learning, and machine learning. The primary focus is on managing resources and keeping an eye on crucial tasks that must be carried out carefully.

Similar to this, cutting-edge technologies like 5G are essential for the current environment since they intelligently allocate bandwidth and transmission power while maximising battery longevity [32–34]. Several researchers have developed the ML-driven technologies in the literature [35–37]. Short-range networking scheduling and resource management are essential for NBIoT. A full analysis of network characterising tasks is carried out in publications [38] and [39]. Researchers in the literature [40] and [41] devised methods for allocating DL-based radio resources with cellular networking in terms of power, bandwidth, and dependability. The unmanned aerial vehicles platform was recommended by researchers for the aim of swarm-based edge cloud computing QoS optimisation [43]. As the actuations, sensitivity, and processing of the electrical assets with embedded sensors increase, the Edge computing resource allocation is intended to alter the energy efficiency of smart homes [44]. Wireless communications in smart vehicles must be very mobile and dynamic in order to convey data in a secure channel and private tunnel and defend against infiltration and the loss of crucial information by tampering [45]. Smart 6G-driven industrial NIB can be developed by combining and incorporating IoT-embedded outdated legacy transportation systems. The essential components for current and future electricity usage in the academic, industrial, and medical sectors are found in smart cities [46]. [47] suggests AI-enhanced scheduling methods for 5G networks to effectively manage the networks' QoS. 5G trends and tools [48], which are self-adaptive strategies recommended for optimal management and regulated optimisation, enable vehicle network mobility. Newly developed actuators and sensors incorporated into effective networked devices are primarily responsible for the electricity usage and energy efficiency in smart homes. The frameworks for electricity consumption, electricity theft detection, and quick balancing over missed calls were developed by authors in the [49] and [50] papers. The different relevant applications are displayed in the table below.

Table 2.5 Related Applications in the Recent Literature

Related-Applications	Out-Result	Component-being-optimized	Proposed-Techniques	Ref
Resource Allocation, QoE/QoS Optimization,6G, Deep Learning, IoT	QoE-Estimation	Delay ,Throughput	Intelliglent and Q Learning	[51-52]
AI Health Care, 6G	QoS	Energy and Battery	Network routing	

	Optimization	Related		[53-54]
Smart Mobile System, NIB	Power-Aware Healthware	Charge Optimization	Battery LifeTime	[55-56]
Energy Efficiency, NIB	Delay and Packet Loss Optimization	Time Scheduling	Q-Learning	[57]
sustainable and Smart NIB	Rate Control	Power and Data Rate	Adaptive Resource Allocation	[58]
Smart transportation and Resource allotment, 6G	Improve quality of health	Heat Absorption and energy consumption	Energy Efficinet Health Monitoring System	[59-60]
Radio-Resource in Mobile-Networks	Smart Mobile Systems	Battery & RSSI Life Time	Deep Leraning	[61-62]
smart Industrial NIB	Intelligent and preservtive system	High Reliabilit and low latency	Cloud and vehicular Network	[63-64]
Data transmission in 6G based vechicesl, IoT	Qoe and buffer healthware	to optimize the idle time, Buffer size and bandwidth	ML Driven data scheduling and Q-Learning based bandwidht managemet	[65-68]
Cloud vehicluar network	5G Based Mobile System	Power Packet Ratio	emerging deep Learning	[69-71]
5G enabled mobile platform	AI Driven Mobile Edge	Link and Route Optimization	Self Adaptive edge	[72-73]
Big Data and Massive IoT	smart Optical Networks	Sensing and computaiton	Statistical Signal estimation	[74-78]

Energy Efficiency, Fast Mobile Network	Delay-Aware Mobile Platform	Delay Monitoring	ML Based Latency Management	[79-81]

2.8 VenvMQTT Model

The Internet of Things can link to each other and share data thanks to the software, hardware, network, sensors, and actuators that are built into these devices [82]. This connection makes it possible for real-world-objects to be more easily coordinated with computer-based frameworks. This bond enhances commercial advantages, proficiency changes, and lowered human effort. There were 8.4 billion IoT devices in use in 2017, according to a 2017 poll, and there will be roughly 30 billion devices by 2020, according to the report [83]. By 2020, it is predicted that the global IoT market would be worth $7.1 trillion [84]. Kevin Ashton first used the term IoT in year 1999. The term Web-of-Things (WoT) is preferred by the author, albeit [85]. At that point, Radio-Frequency-Identification, a key component of the IoTs, would allow computers to handle specific objects. The current Cloud architecture alone cannot handle the torrent of data due to the increase in information, gadgets, and networking. For customers who can use the Cloud effectively and affordably, it offers enormous computing, storage, and networking. For devices far from a single Cloud data centre, these centralised resources can result in observable delays and performance deficiencies. Edge computing, commonly referred to as just Edge, does processing local to the data source rather than sending it to a far-off cloud or other unified frameworks. The amount of time required to transmit data to the source is decreased, which speeds up and improves the efficiency of data transmission [86]. A standard called fog-computing describes how edge processing ought to work. Additionally, it encourages end-to-end gadgets where data values are identified in the Cloud to share processing, stockpiling, and system administration responsibilities. There are also numerous additional uses for fog off-loading cloud operations to the edge [87].

For Industrial IoT (IIoT) applications, Edge can offer a variety of crucial skills that are outlined by the preceding examples seen in routine mechanical chores [88] and that take into account the requirements of the current difficulties. Computers and capacity structures are located at the edge with Edge, as close as is practical to the region, object, programme, or individual that generates the data being processed. The objective is to reduce latency because there is no need to transport data back and forth from the system's edge to a central organising framework [89]. The IoT-related device is a clear application for edge processing.

They generate significant amounts of data when remote sensors are partially or completely integrated into a machine. Data sent over a large network must be analysed, recorded, and tracked. This requires a lot more time than handling the information close to the data at the edge [90].

IoT necessitates a novel type of infrastructure that costs more money. The diversity, amount, and speed of information that these IoT devices produce are not anticipated by current cloud computing models. For instance, there are currently billions of disconnected devices, and they produce more than two Exabytes, or 2 billion GB, of data per day [91].

It's anticipated that billions of devices will be linked to the current network by 2025. A huge quantity of bandwidth would be needed to handle the amount of data from the products that would have to be sent to the cloud for processing. Some of them communicate with controllers using more recent protocols as opposed to Internet Protocol (IP). Since data must first be predesignated with IP before being transported to the cloud for processing or storage, these alterations lengthen the transmission delays. When the anticipated response is delayed and the manufacturing line stops, milliseconds can be crucial in some situations. For instance, each week 500 GB of data are produced by seaward oil rigs [92], and 10 TB of data are produced during ordinary airline travel by commercial aeroplanes.

In these circumstances, it is crucial to exercise appropriate restraint that adheres to information-age standards. The Internet of Things (IoT) framework is plagued by numerous problems with network latency, processing delay, and bandwidth over the crucial data supplied by end devices [93]. Like cloud computing, fog computing extends processing and management to the system edge. Fog provides end users with data processing, storage, and application administration services. Since there is no suitable routing system in place, the data from sensors cannot be securely delivered to the fog where the analytics are being carried out. The majority of IoT routing techniques are not intended for IoT but rather for wireless sensor levels up to sensor gateways or cluster heads[94]. Connecting to the cloud allows IoT sensors and other devices to use a number of IoT communication protocols and techniques [95]. Fog computing was not taken into account by IoT protocols because the cloud was intended to be the source for analytics in IoT. Data types used by IoT include those pertaining to agriculture, energy, and other industries. As a result, it is challenging to identify a single established standard routing method or protocol for IoT models today [96]. It takes at least a basic degree of analytics to manage such heterogeneous data from many sensors, forecast the data pattern, and autonomously coordinate among the fog routers for quick data processing and transport among the objects. This study presents a virtual environment-based MQTT paradigm for processing data from the Internet of Things. Experimental investigation demonstrates that the suggested VEnvMQTT model achieves decreased latency when compared to the traditional MQTT protocol.

Resource limitations, frequent topology changes, and multi-hop networking are just a few of the extremely tough problems that the Routing-Protocol for Low-Power and Lossy Networks (6LoWPAN) attempts to solve. Both 6LoWPAN and IPv6 components should take specific application requirements into account [97]. The Routing over Low power Lossy Network, or RPL, was suggested by the IETF's Routing over Low power Lossy Network Working Group [ROLL WG]. The RPL protocol offers a lot of support for limited, lossy, etc. connection layers. RPL is typically used in host or switch devices and offers substantial advantages in building/home automation as well as urban applications [98]. It can organise routes fast, learn paths between hubs efficiently, and swiftly change the topology. The root node or other devices that are routed in a multi-hop fashion are connected to the system hubs in the most common RPL configuration. The root node's additional duties include data coordination and aggregation [99]. In its most basic form, Bluetooth is a short-range exchange technology that is now required in a wide range of consumer goods. For wearable technology, which is closely related to the Internet of Things, it is essential [84]. Bluetooth was initially a feature of cell phones. Bluetooth Low Energy (BLE), sometimes known as Bluetooth-Smart and is a well-known standard in the IoT sector. BLE has been developed to use less power [85]. The two ZigBee profiles that can be used are ZigBee Remote Control (RF4CE) and ZigBee PRO [86]. Zigbee operates at 2.4 GHz and is typically used for applications that require a fairly erratic information flow at a lower data rate over a 100-meter range, in accordance with the IEEE 802.15.4 protocol [87]. Zigbee/RF4CE has a lot of strong focal points in complex systems, including high security, no barriers to entry, low power consumption, incredible adaptability, and more nodes. This protocol is rapidly being used in wireless sensor networks for M2M and IoT applications because of the characteristics indicated above [88]. Connectivity over Wi-Fi and cellular networks is Sigfox's primary goal. It makes use of ISM groups, which don't require any security authorizations to communicate with one another. Due to the fact that some M2M applications only need a minimal quantity of power backup and don't require a high level of information sharing, Sigfox was developed. Sigfox is a desirable solution for m2m applications due to Wi-Fi's limited coverage and the high cost of mobile connections [89]. Sigfox uses Ultra-Narrow-Band (UNB) technology to communicate small amounts of data at speeds ranging from tens to thousands of bits per second. Although it is only a few months, or 0.2 years for the cell, Sigfox can transmit a regular standby period that is almost 20 years by using a 2.5Ah battery as opposed to 5000 microwatts for mobile information transmission. The technique is currently gaining popularity in urban areas around Europe, for instance, 10 urban locations in the United Kingdom [90].

This system is suitable for a variety of M2M applications that depend on integrating in Smart metres, silent screens, security devices, road lighting, and natural sensors because it has a robust, controllable, and flexible system that can communicate with numerous battery-operated devices over a large geographic area [91]. For example, Silicon Labs' EZRadioPro remote handsets offer sub 1GHz-band remote systems administration frameworks industry-leading remote performance, expanded run, and ultralow power consumption [92]. The Sigfox system utilises several chipsets.

2.9 Prediction and Recommendations of review of Methods

Review of methods for the technologies behind the smart grids and the IoT are enumerated in the following sections.

2.9.1 Path towards an Intelligent Smart Grid

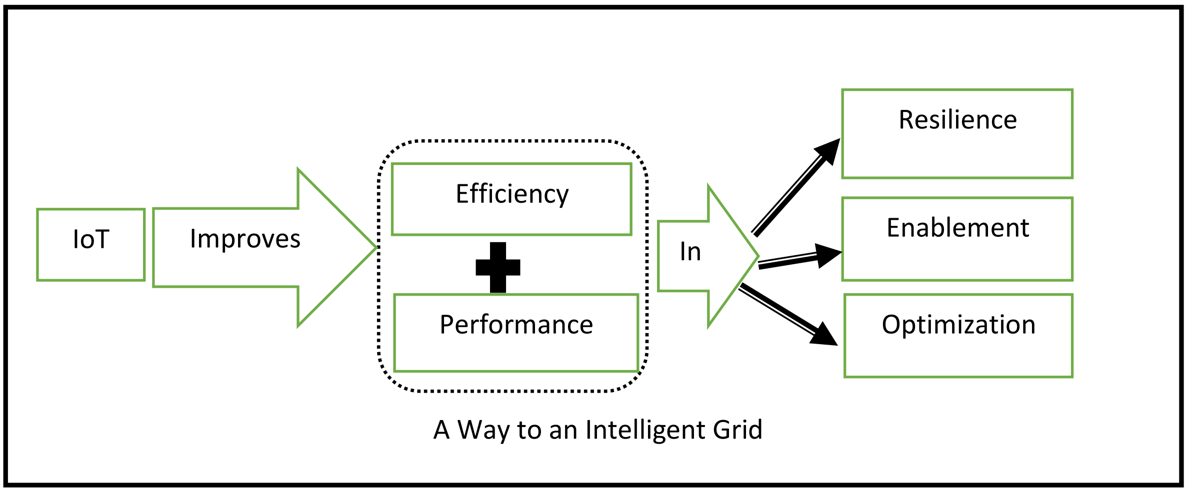


Figure 2.3 : A way to an Intelligent Grid

IoT can enhance the effectiveness and performance of the power grid during the following three phases of modernization:

1. Resilience, Phase -I
2. Enablement, Phase -II
3. Competition / optimization, Phase -III

known improve the resilience of the grid, the first phase, referred known as the resilience phase, involves collecting data from sensors. Utility companies use this data to actively manage various resources in the second phase, which is referred to as the enablement phase. The third phase, called the optimisation phase, involves enabling all stakeholders to make decisions about the use and production of power. With the aid of these phases, IoT provided some examples of how utilities might thrive in this new competitive climate rather than just endure it.

The next sections outline the three phases of grid modernization, give specific examples of IoT applications that could be used at each level, and show how relevant data flows across the IVL to create value.

Phase 1- Resilience: - Resilience is the first stage of grid modernisation. Grid dependability and durability are key components of resilience, a goal that is made more challenging by the expanding trend towards decentralised energy sources. As a result, reliability cannot be guaranteed by just maintaining the functionality and operational limits of existing facilities. Instead, resilience demands understanding of the grid's condition, which can only be attained by widely dispersing a range of networked sensors and control devices that converse via standards-based protocols throughout the grid. The distribution grid will ultimately need to be versatile and adaptable enough to handle all DER types.

Phase 2- Enablement :- In the second phase, referred to as enablement, the collection and analysis of collected data offers enhanced intelligence and new perspectives on grid operations and customer interactions. During this stage, a platform must be developed that can link all resource kinds, including those held by utilities and other parties as well as occasional consumption and production assets. When talking about the technological challenge, it involves:-

• Distribution system operators need control points that can control the expanding number of IoT-enabled devices and grid applications without requiring human intervention.

• These control points must oversee utility assets as well as assets held by customers and other parties.

• This heightened situational awareness is necessary to optimise distributed resources and embedded IoT technology and promote overall grid efficiency.

Phase 3: Competition/optimization:- The utility is then better able to assist and survive in more competitive business environments and marketplaces thanks to the last phase's opening of new optimisation techniques. Grid stakeholders can use the data and insights generated during the enablement phase to make smart business decisions. Interoperability between the utility and the customer's metres enables new optimisation capabilities and a more efficient use of resources. For Future-proofing the grid is a legacy of the electric utility industry. To overcome the challenges of today and build a more intelligent grid, it is crucial to draw on this history. Utilities may make use of the exponential technologies made available by the Internet of Things in order to learn about and extract more value from the intelligent grid. However, the way forward is not always evident. The Information Value Loop provides a systematic framework to help with understanding how to create and gather value from information in order to better determine the future course. Applying the value loop to electric utilities, we identify three key phases in the continuing usage of and value realisation from IoT technologies:

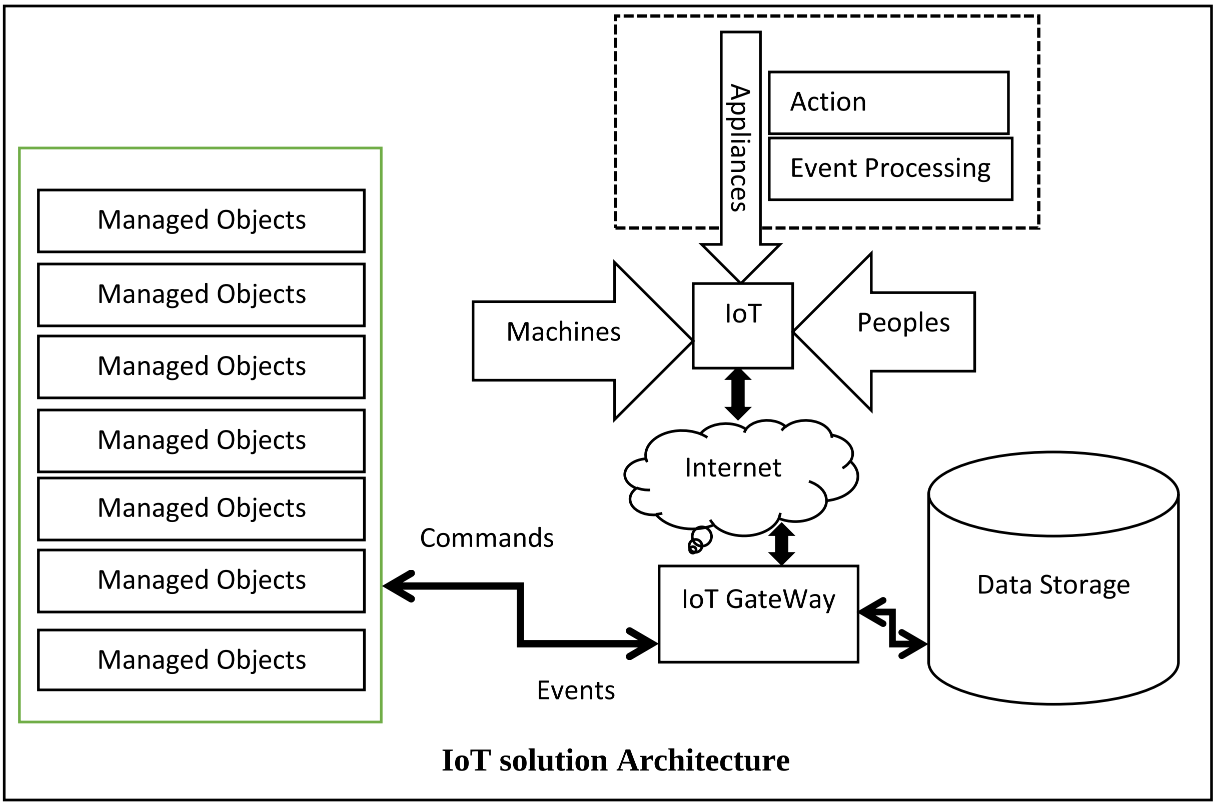


Figure 2.4 : IoT Solution Architecture

- The first and most crucial stage is resilience, where the widespread deployment of grid sensors connected via standards-based protocols forms the basis for grid durability and reliability.
- Through the collection and analysis of collected data, utilities can actively control a variety of devices that are both power consumers and generators on the grid in the second phase, known as enablement.
- The third and final phase offers new methods of competition and optimisation using the data gathered from the earlier phases, allowing all stakeholders to make informed decisions about power demand, generation, and future investments.

Based on its starting position and a thorough assessment of what comes next, each electric utility must evaluate its own course towards IoT value realisation. Instead of being the only area of management's attention, technology needs to be reviewed and planned for within the framework of a utility's capabilities model. Although the utility may face significant obstacles in adopting these new IoT tools, the risk and cost of doing nothing are greater.

2.9.2 Drivers of IoT

a) **Internet Connection:-** For interconnection of the various devices and sensors, there is requirement of the network connections, it may be either via IPV4 or IPV6 or from any wireless media like infrared/Bluetooth/radio frequency/WiFi etc. By strong communication, the efficiency of the IoT device will be comparatively more. The reliability of the device will also enhance with this drivers of the IoT to form strong solution.

b) **Sensors and communications:-** Significantly lower costs for wireless chipsets, Wi-Fi chipsets, and a variety of other sensors, including accelerometers, cameras, sound systems, and temperature sensors. The TCP/IP protocol, 3G, 4G, and 5G cellular networks, as well as the addressability of numerous devices utilising IPv6, all underwent standardisation during the modern era of the digital world. Artificial intelligence technology is quickly spreading to other industries as a result of consumer applications like facial recognition, driverless cars, algorithm-based financial advisors, and others that leverage smart devices and services. Cloud computing, artificial intelligence (AI), and security standards were produced as a result of cloud computing and cyber-security. It is now possible to consolidate and economically provide software-as-a-service, platforms as a service (PaaS), and infrastructure as a service (IaaS) because to the rapidly growing use of cloud computing. Both of these software developments have made it easier and more economical to build IoT solutions. Industrial IoT is a different perspective on IoT and has been defined as the convergence of enterprise ICT and operational technologies. Operational technologies, such as process logic controllers (PLC), process automation, and supervisory control and data acquisition (SCADA) systems, are frequently used in factories and processes to boost productivity, quality, and output. A value chain can now be managed, expenses can be reduced, and customer service can be improved with the use of decision support systems, resource planning, customer relationship management, and other enterprise IT solutions. To completely actualize a business's objectives, the two systems have not yet been linked in an efficient manner.

c) **Components of IoT**:- IT Component covers the enterprise Software, ERP, Finance, HR, Leave, PayRolls, GIS, Assets Management, Plant Maintenance, Customer Care Center, Energy trading and risk management. Where OT(Operation Technology) Component includes centralized, distributed supervisory control and data. Automatic generation control, energy management, distribution assets analysis, advance protection relays, sensors, monitors, various fault indicators and control networks. Smart metres and other line sensors are operational technology components that provide near real-time information that can be integrated with information technology accessories like geographical information system to identify the information's source. IT components can alert the crew to the need for sensors and replacement parts that are needed to finish the job but are not present on the truck. Before work on the line can start, IT apps on a compute device like a smartphone, tablet, or laptop can show locations of assets like relays, switch gear, and other equipment on a map that need to be handled. The IT system (GIS-based map on tablet) can get instructions from operational technology regarding the direction of power and voltage flows in nearby buses. The crew can therefore repair and restore the circuit effectively and safely thanks to IoT. IoT-enabled operation and maintenance (O&M) can be used to improve the effectiveness and dependability of assets. By lowering the minimum capacity factor and raising the ramp rate, IoT can improve generation flexibility and cut fuel consumption and emissions. IoT initiatives that can result in the achievement of the dual goals of lower costs and lower emissions include automatic generation control, active voltage management to reduce technical losses in the transmission and distribution network, the installation of actuators on smart transformers, and the reduction of other nontechnical losses through a network of smart metres. IoT devices can be quite helpful in condition monitoring and proscriptive and predictive maintenance of the various assets at the other end of the maintenance process. One of the most common industrial IoT use cases is asset performance management (APM). High levels of inefficiency and unreliability in the power industry in emerging nations have led to the maintenance of outdated equipment. At the moment, the power industries' operation and maintenance are plagued by problems like the average age of the assets, which is above 40 years, and their high cost, bulk, and difficulty in replacement.

d) **Operation & Maintenance strategies enabled by IoT:- Condition-based Maintenance:** In condition-based maintenance, sensor data patterns are gathered and examined to determine an asset maintenance strategy. Predictive maintenance is a process that identifies impending failures and problems by analysing trends in sensor data to anticipate time to failure. This process is known as predictive maintenance. Risk-based maintenance optimises the use of resources for maintenance across all assets while making decisions about an asset's upkeep. This strategy allocates maintenance resources based on risk of failure. Here Risk is the result of the likelihood that something will go wrong and the financial costs that will follow. IoT-enabled proactive maintenance would replace reactive maintenance. This method replaces planned preventive maintenance with risk-based maintenance and predictive maintenance, increasing availability and reducing cost. It also reduces the inventory of spare parts needed for emergency repairs while increasing productivity and securing the future of the assets.

e) **Development of an IoT Road Map :-** Creating an IoT road map would involve the following steps: Key players. Create a team with representatives from several departments inside the company, and a steering committee including the CEO and heads of departments. business argument. Connect with important strategic goals, such as loss reduction, improved dependability, cost and emission reductions, achieving the aim of renewable energy, new metering, and others. Processes. To increase performance, develop new IoT-enabled workflows. Technology. Utilise operational and information technology that is offered or otherwise present in the nation. The road map is being developed using a variety of techniques. Since an organisation has ongoing projects, it can be helpful to map these projects to the maturity level that would be reached and repurpose them to reach a higher maturity level. An outline can be used to map the strategy, objectives, and development of IoT efforts. Smart grids can exist thanks to the Internet of Things (IoT). The visibility and responsiveness of grid-connected devices are improved by IoT applications as power networks become more complicated and decentralised.

dependability and technological maturity Essentially, IoT refers to allowing machines to communicate. Before removing human involvement, the principles must be sound and proved, hence strict standards must be met for every deployment. This implies a multi-stage implementation procedure, ranging from the installation of sensors, data collection, processing, testing, and risk management for cyber security, through the handling of (new) regulatory regulations.

f) **Data Privacy in IoT:-** Data rights and privacy are becoming more crucial as we move towards a linked, digital society. Electric vehicles, for instance, may provide information about their precise positions or the hours of the day when they are recharging or using energy that may be regarded as private. Smart home devices may record details of your daily activities, such as when you arrive home and when you go to bed.

Privacy has two issues:

- *Commercially: On the one hand, data may be lawfully and commercially used;*
- *Illegally: On the other hand, data may be illegally taken and utilised.*
- *It is important to appropriately address issues like liability, standardisation, interoperability, and secure authentication. The privacy of IoT data can be examined by answering the following questions*:
- Cybersecurity To the extent that IoT technologies are to be widely used, security is a critical problem that must be resolved. Several risks and challenges are brought on by the digitalization of the energy sector, not the least of which are the need to guarantee network neutrality, ensure fair competition, protect individual privacy, ensure data security, and combat cybercrime and cyberterrorism. Procedures, standards, and protocols for communications The ability of all parties to share information about their consumption/production states and to react (automatically or not) to price signals is necessary in order to take advantage of this growth in decentralisation. The success of such a system depends on players adhering to agreements with one another and being fairly compensated because these benefits are distributed among so many people. The IoT's growth is correlated with the growth of artificial intelligence, which is

fueled by big data and provides the precise data required to fuel machine learning algorithms. In the upcoming years and decades, the explosion of data generated, partly as a result of the spread of IoT devices, will fuel new technologies and open up new sectors.

2.10 Security an important aspect for electricity consumption

In the recent era, studies focused on cyber-security in electricity consumption especially within Advanced Metering Infrastructure (AMI) domain can be categorized into two main groups.

2.10.1 Locating Cyber Threats in AMI and SCADA Environment

The first set of research group focuses on locating cyberthreats and related weaknesses in the AMI environment. AMI and SCADA related to smart metering system solution for the rural and remote area, energy analytics, distribution networks are discussed in literature [198-213] In their cyber-security analysis of AMI, Foreman [214] and Hansen [215] identified potential surfaces for cyberattacks within its constituent parts, including smart metering devices, data concentrators/collectors, smart home networks, and a range of cyber threat types, including distributed denial of service (DDoS), theft of power (ToP), distribution of grid (DoG), and denial of power (DoP). Haider [216] investigated cyberattacks and attack vectors aimed to AMI wireless networks, specifically focusing on smart home networks, in a comparable manner. A thorough cyber threat model including these recognised attack types was provided by Haider [216].

2.10.2 Creating Defenses in AMI and SCADA

The second set of research group focuses on creating defences against any online attacks that come via the AMI system. Kamal [217] presented a technique that uses Received Signal Strength Indication (RSSI) pattern analysis to identify anomalous events, like hostile node access and metre tampering. In the meantime, Park [218] presented a method that uses Anomaly Pattern Detection based on Hypothesis Testing (APD-HT) to examine patterns of energy usage taken from smart metre data streams in order to detect energy theft. Furthermore, using a distributed fog architecture and a hierarchical and distributed intrusion detection system (HD-IDS), Chekired [219] proposed a novel method. This system used a stochastic Markov chain and data from smart metres to measure electricity consumption in order to differentiate between legitimate states and fraudulent data injection attempts. By addressing possible threats and putting in place efficient countermeasures, these studies together improve AMI's security posture. The use of artificial intelligence (AI) and deep learning technologies to recognise and detect cyberattacks in Advanced Metering Infrastructure (AMI) setups has been the subject of several research. In order to determine intrusions, Marbet [220] presented a technique that uses deep learning to analyse network packet data in AMI's Network Intrusion Detection System (NIDS) and Host Intrusion Detection System (HIDS). Zhang [221] presented a system that uses an Extreme Learning Machine (ELM) to learn from network packet data with an emphasis on intrusion detection. The goal of this strategy is to improve the system's capacity to identify and neutralise possible cyberthreats. Using Self-Organizing Maps (SOM) and Multiplayer Perceptron (MP)-ANN to create models of residential and commercial users, Souza [222] offered an alternative way for identifying energy theft. This method is figuring out how much energy certain consumers use in an hour, which helps to spot unusual patterns that could be related to theft. Bendiab [223] proposed a framework that uses the Binivis approach to visualise AMI network traffic as images. With the use of classification algorithms, this visualisation technique helps identify dangerous codes. Together, these research demonstrate how cutting-edge technologies like artificial intelligence, machine learning, and deep learning may be integrated to strengthen cyber-security measures in AMI systems. This presents potential methods for identifying and reducing cyber threats. Because the Advanced Metering Infrastructure (AMI) environment is distributed, it might be useful to examine user behaviour in the context of demand response in a distributed energy infrastructure to identify anomalous patterns. Yao et al. [224] introduced a technique aimed at identifying anomalous activity in smart metering equipment. Using a Convolutional Neural Network (CNN) to analyse long-term energy data patterns, this method made it possible to spot variations in user behaviour from what was expected. Similarly, Irtija et al. [225] suggested a way to categorise different user kinds in the AMI system according to patterns of energy consumption. They also presented a modelling approach for classifying user types that was based on contract theory from an economic standpoint. This novel method models a cost function for particular behaviours in a distributed system, using economic principles in addition to classifying users based on patterns of their energy consumption.

This takes into account optimising the function to handle the detection difficulty in the optimisation domain. These studies highlight how crucial it is to use cutting-edge methods like economic modelling and convolutional neural networks to study user behaviour and spot anomalies in the distributed AMI environment. This will help to secure and optimise the energy infrastructure. Cyber Threat Intelligence (CTI) is a framework that may be used to collect, analyse, analyse, and share data on cyberattacks in an efficient manner. CTI implementation techniques were first made available via the Automated Threat Intelligence fuSion framework (ATIS) [226]. The five planes of ATIS's architectural approach stand for analysis, collection, control, data, and application. Every plane in ATIS has a specific function that interacts with other planes to enable the efficient and simultaneous processing of heterogeneous data. The Mantis framework was proposed by Gascon et al. [227] and is intended to combine cyber threat information by employing several standards. Mantis uses an attributed graph-based similarity determination technique to find correlations between threat data. utilising 14,000 CyBOX objects, Mantis impressively showed that it could monitor relevant threat information with an average accuracy of 80% utilising only one batch of cyber threat data. This demonstrates how well Mantis handles a variety of cyber threat data and creates insightful relationships between the data. These frameworks—ATIS and Mantis, for example—showcase the value of organised methods and sophisticated algorithms for organising and interpreting cyber threat intelligence. They offer a framework for the methodical management of cyberattack data, encouraging improved cooperation and reaction systems in the face of changing cybersecurity threats.

2.11 Discussion

In India, power Distribution Company of every state faced a lot of challenges and has to customize their standards of assessing energy accounting on the daily basis. The reduction of Aggregate Technical & Loss, previously called as Transmission & Distribution losses, which was result of technical as well as commercial loss due to technical loss in transmission sector and theft or commercial loss at distribution level.

Paper [100] elaborated the various challenges of a novel method related to security in context of meter readings of smart machines/ electricity meters. A fresh technique approach towards identifying & rectifying irrelevant/unreliable reading of smart devices/ metres is proposed. The authors also talked about securing the electricity usage via electrical metres reading from tampering or malfunctioning. The method essentially consists of minor adjustments and the ability to employ error-correcting block codes in communication systems for the protection of binary data transmission.

In Paper [101], authors carried out a broad survey of electricity smart devices/meters keeping the main focus on key aspects for electricity meter reading processes in context with different stakeholder interests along with technologies.

Paper [102] elaborated the recharging of energy meters remotely, Customers can avail the facilities of paying their electricity invoices/bills in case of postpaid electricity meters and on the other hand in case of the prepaid electricity meters, they can recharge via sending a message to the service provider. The electricity consumption in the form of meter readings are sent via RF Link to nearest central station which propagates the same to compute devices i.e. web server using GSM (Global System for Mobile) Technology.

Proposal of a method for collection of electricity consumption via Meter reading in paper [103] and based on that generation of the invoices for the same. In this contour algorithm is used for preprocessing the camera captured images and recognizes the characters, in the form of the readings which are sent through wireless technology.

Paper [104] used GSM network for communication in electricity metering system, as the medium which provides a wireless, cheap, connected seamlessly, full duplex with communication from utility to electricity metering system and vice versa to flow the information related to electricity consumption, power excellence & outage related alerts , finding any tampering in device/system. Author proposed to use of GSM network for transmitting information/message of electricity consumption to the utility billing engine/server at DC/Cloud for generation of the soft copy (text or PDF Copy) for sending this via email/short messaging services (SMS).

Papers [105] & [106] proposed android as well as web based application for collecting Electricity meter reading at server and informing electricity consumption in forms of units(KWH) along with bill details like amount. The optical character recognition (OCR) is used for processing the meter reading images taken my meter readers via android application.

Paper [107] proposed Electricity consumption meter reading system via GSM & ZigBee technology for communication by implementing a low cost secure AMR

(Automatic Meter Reading System) for measuring and transmitting the electrical consumption to Central utility billing engine/ Server. The proposed system has three parts i.e. accurate digital meter, a communication and the backend server i.e. utility billing server at DC/cloud to make inexpensive a low cost system.

In paper [108], Authors presented the remote wireless Electric Meter Reading System using GSM and ZigBee communication through GPRS system which is popular as a medium for machine to machine integrations/communications wirelessly.

Paper [109] addressed the limitations of the technologies used in traditional electricity meters by amalgamating the characteristics of IEEE802.15.4 standard and ZigBee technology for communication protocol. ZigBee optimized the system in context of lower cost as well as lower power consumption.

Paper [110] Timed controlled switching of street lights by A GSM based smart light for improving the efficiency which automatically switch On/Off as per the day and night. These systems are less costly for the implementations and has a major advantage. A smart solution for the lighting system through single touch.

Paper [111] Researchers developed a system for replacing traditional/legacy/conventional electricity meter reading system GSM based energy metering system through IoT which sends the sensed units on cloud automatically. The system reduced the miscommunication between the controller and the user which makes it very efficient and low cost.

Paper [112] proposes a design & implementation of an IoT based on smart energy meter which measure the energy consumption with accuracy and helps in reduction of energy wastage.

In [113] paper researchers developed system for electricity consumption meter reading for bill generation system. The high accuracy in the reading can control the energy supply with real-time load on the infrastructure.

In paper [114], researchers developed a system for reading automatic from an Arduino based system which counts the LED blinking and stores in EEPROM and communicates with server side (utility billing engine) with GSM connectivity. System sends the information to consumers via SMS.

In this paper [115] a smart meter is constructed with the help of Arduino module with ESP8266 for data transmitting. Hall sensor is used to measure the consumption using sensing theory. SMS is used for communicating any information to its consumers. Relay switch is used to interrupt the electricity in case of non-paying consumers.

In this paper [116] , an energy monitoring system is proposed , based on a low cost wireless networking system i.e. ZigBee on mesh topology. The system also caters the tempering and theft detection cases via sending the message to system via ZigBee wireless communication and the power system is cutoff based on the information passed.

In [117], author presents an IoT Based electricity bill generation system used to accumulate the energy consumption data to the central database where it analyses this information for generation of the bills/invoices. Kernel programming is used to get battery status and sends the same to the central system via GPRS gateway. This system is paper less and not involving any human interface also for reading or generation of the invoices. Here we take laptop battery for reference.

In this paper [118] the author presents the wireless system with GSM technology with web-based infrastructure where periodically data readings are taken and invoices are generated monthly with complete electricity consumption details.

In paper [119], author presents a GSM based power meter and control system for tracking of electricity consumption each day. Each energy meter is uniquely identified with a unique key which is interlinked with consumers' mobile number for the reading and generation of the invoices accordingly. The system tried to reduce the wastage of the electricity consumption and made it cost effective method.

In paper [120], author proposes a microcontroller & GSM based system for energy metering to detect & control the energy meter from power theft and remotely disconnection and reconnection of the supply with solid state relay (SSR).

In [121], author presents a GSM technology based system to automate electricity consumptions system for large number of consumers for billing at a central point by automatically sensed unit readings.

In paper [122], researcher presents a metering application using electronic current sensor design to build it. Sensor is constructed of low permeability core material with a current transformer to yield a tolerance and ensures immunity to powerful dc magnetic fields.

In [123], the author discussed the requirements of the smart energy concept as the non-renewable energy sources are limited on the earth. Keeping the concept very critical in nature in future, the paper also focused on cloud environment role in this smart metering infrastructure.

The paper [124] designs an AMR system based on ZigBee, an implementation of WSN in indoor environment. The electricity consumption data is accumulated by this system at a centeral place of all the consumers and used for power monitoring and remote control over the various power services and quality of power supply to help the consumers to opt for prepaid billing system also.

In [125], author presents a prepaid-system for automatic billing to control the power theft in an efficient manner and sending alert messages by using GSM technology to its consumers on reaching the maximum amount to recharge the system in time and enhances the revenue collection on the other end.

In [126], author proposed a method for analyzing the consumer load profile from the data accumulated from smart meters via TCP/IP over client server architecture and established an interface between the consumer and the utility.

Demand side management (DSM) is a key component of this paper's [127] home energy management system, which uses Evolutionary Algorithms (EAs), Genetic Algorithms (GAs), Binary Practise Swarm Optimisation (BPSO), and Kukoo search to schedule various devices, apparatus, and appliances for residential consumers. It aids in the utility's regulation of high peaks and measures each appliance's current and voltages using a sensor. If the user consumes more than expected, the power cut notification might be provided.

In paper [128], author used four wire, three phase energy meters to sense the readings by Hall Effect Sensor in the digital form with communication over wireless GSM technology and controls all the functions of the meter.

In [129] , author presents a system on intelligence of regular energy meter for highly efficient monitoring ad control with low cost and high mobility with the use of blue tooth technology and smart phones by using the current and voltage sensors with respect to applied load.

In paper [130], the author proposes the smart meter based on GSM technology in which sensed values at power are used to calculate total power consumption.

Every activity in the present day depends on electricity, but there are still defects in the procedures used in the system, leading to theft and leakage, which results in significant energy losses to the society and the electrical supply utilities [131]. Energy theft is a serious problem that utilities may encounter when implementing the smart grid, according to Aswini R in [132]. To combat electricity theft, the author presented a tree-based architecture based on the actions of the AMI (Automated Metered Infrastructure).

Revenue loss is one of big challenge to the state government to provide a better service of electricity distribution in India. Due to unexpected huge value of AT&C loss the direct impact on the Discoms commercial is visible and also on the consumers like us who pay for the electricity bills in the form of tariff. As data in the DISCOMs is increasing like accelerates kept in the bigger database like IBM DB/2, MS SQL Server, Sybase, SAP HANA, ORACLE etc.

The traditional used database as Hierarchical database, Network Database or Relational Database management system (RDBMS) is unable to handle this huge data produced daily with high speed or velocity along with different verities of data structures like text, images or videos. As in the Power Distribution Companies, the metering data is accumulated in the form of the text as the reading captured. In a few distribution companies in India like both distribution companies of state of Bihar. i.e. North and South Bihar Power Distribution Company, the reading of the consumption of electricity usage measured by the electric meters are also taken in image format by the Meter Readers by the android mobile devices by the spot billing application developed in house by the respective Utilities. In the previous time, there was a huge complaint from the consumers regarding the non-delivery of the energy bills to the consumers which further caused the revenue collections from the consumers. Then at higher level, it was decided to take the reading of the energy consumer meters via android application and also store the images of the readings shown by the meter. By this the reading is saved in text as well as in image format.

Big Data is mainly mingled with the existing technologies e.g DBMS/RDBMS/HDBMS/NDBMS and often called as amalgamated, but also for the complicated processes/methodology solutions to handle stream processing of the big data. The variety, volume and velocity in the data accumulated identify the implementation of the big data. The initiatives taken by the various IT solutions/software companies to use big data story to formulate various trends to predict analysis and predict the various analytical trends which impact on the business for various decision making steps and even society as a whole. As metering data is accumulated to analyze periodically for taking various decisions, hence data warehouses resulted to handle the big data in the time with the technologies. Such type of problem of handling large data with variety of data mainly scaling up the performance of modern hardware to meet the requirements with define time framework. To tackle such type of the issue 'Big Data Gap' , getting the solution of big volume is not enough, but also the extraction/processing of the huge amount of data in the real time with the variety of the data for analysis of the same is very much focused onto analyzing structured data modeled within the relational schema, 'big data' is also about recognizing value in non-uniform format data or unstructured sources like text, images etc. as explained above in case of meter reading.

In[133], the author derived the 3V of the big data. Authors in [134-137] discussed about bigdata analytics, Hadoop distributed file system along with its various challenging tools. These sources are largely uncovered, yet like GIS, MDM, Billing and Collection data in distribution companies along with consumer's complaints collected from 1912 toll free number. Furthermore, data gets created daily with a high speed and it is often necessary to process the data in near to real-time to maintain competitive advantage and agility. As billing is to be done daily, and collection is also on daily basis via various online payment options like android application, BBPS, Banks payment gateways etc. the use of distributed databases e.g. plain-text, graphs, charts, image or video sources. Therefore, big data technologies need not only to handle the volume/size/magnitude of data but also its speed/velocity/rapid IOs of data stored and its variety as far as diversity of data is concerned. Gartner comprised those three criteria of Big Data in the 3Vs model [133].

RESTful or REST (Representational State Transfer) web APIs and their purpose (Application Programming Interface) are described by the author of paper [138]. A collaborative big data analytics platform may increase the value of big data as a service. Application/program developers can collaborate, communicate, and engage with one another while sharing the platform's value, such as stored data, processes, steps, methods, and services (REST API), through the platform's numerous soap/wsdl/REST Web APIs. [138] The 3Vs pose a challenge for decision makers via its representation/analysis of stored data, it creates the constraints in handling the respective data sets with the traditional legacy database management systems/ RDBMS/NDBMS/HDBMS and analysis tools: processing large volumes of heterogeneous, structured/un structured /non uniform format data in a short duration of time to allow fast extraction of facts/execution of methods and rapid response to trends and events as and when occurred. These different challenges, lead to a variety of technologies and products labeled as ‘big data’.

In paper [138], author also represents the requirement of very costly resources and professional expertise or knowledge related to big data technologies. For providing such decision-making reports/ MIS/ Decision Support Systems requires these analytics services promptly, It traditionally carrying out many steps at different levels separately, for example, data acquisition / information gathering/ data accumulation, storage, manipulation, pre-processing, retrieval / extractions of the same and representing the facts/analysis visually. That’s why, for analyzing this huge data (big data), different separate systems are developed for each process and getting to require very high cost and processional knowledge on big data technologies [138].

A number of solutions to deal the problem of bigdata are explained in paper [139-141]. As far as the volume/size is concerned the same is when compared with the quality of data, then, Volume is not reported as a prominent problem, as number of solutions [139-141] that deal with this problem. however, the main concern is integration of the available tools for extraction /analysis of the big data for various decision-making reports for higher management.

In paper [142], the author explains various HDFS tools for applications such as reporting & Preparation of ad hoc queries/reports, we can use Map Reduce / HDFS (Hadoop Distributed File System) based tools, such Impala, Apache Hive [142].

For Innovation/advancement/development of Big Data technologies & IoT (Internet of Things) techniques, ITS have more opportunities to users for providing smart services [142-145]. Researchers are trying for solving the same bye use of a MapReduce framework (a big data technique for fast processing of huge data) [146-148]. In Map Reduce Framework, the inputs at HDFS files are taken as input, the tracker automatically splits the input and maps the splits keys. The output further reduced and hence the name of the technique is map reduce framework. As the distributed file system, each node has the data as well as the processor and hence the huge data can be processed at large scale of nodes independently and at last aggregated by the framework itself.

In publication [146], Xing-Yu et al. developed a K-Nearest Neighbour & Gaussian Process integration/combination in MapReduce to estimate traffic speed in close to real time. Road transport mining using the conventional/legacy a-priori association approach is analysed and put into practise [147] along with its optimised version, also referred to as Eclat.

In paper [148], author has proposed RTIC-C architecture to facilitate road traffic data mining service over a modern and big data infrastructure like cloud.

In paper [149] the author incorporates the characteristics of the popular and commonly used definition of Big Data [149]:

• **Volume: -** The quantitative size of data i.e. quantity of data produced & accumulated.

• **Variety:** the categorization of data for example the type & nature of data.

• **Velocity:** fast extraction/execution or Instantly availability of data, demand based timely availability of data without delay. The Data acquisition is very quickly & rapidly, processing also required to be speed up to meet the demands and challenges which directly influences the growth and development

• **Variability**: Data consistency is to be maintained. Inconsistency of the data set can influence processes negatively to control/handle/manage it

• **Veracity**: Variance in the quality can vary greatly, and can affect accurate analysis of data acquisition.

It would be ideal in the long run to relocate the authoring of the OM-JSON documents extremely close to the devices, as the author discusses in paper [150] when discussing the FogCcomputing method of earlier Born-Connected techniques.

In paper [151], the author goes into detail on the characteristics that directly affect the data's quality. The quality & quantity of the data themselves are the main issues with big data. As a result, data preparation is necessary to improve and increase confidence in itself to ensure a specific degree of quality.

In paper [152], the author gave a new quality assessment approach, this new approach was introduced. It is based on the consumer as well as the provider of the data, both are involved. Metadata data is providing the data consistency rules and is useful in the assessment of the same.

In paper [153-156], the author shown the variety of Electric Meters are available in the utilities. Even one power utility may have number of electric meter make and model. As of now the following types of the electric meters are available.

- ✓ Mechanical Meters
- ✓ Electrical Meters
- ✓ AMR
- ✓ AMM
- ✓ AMI
- ✓ Smart Meters.

In the evolution of the electric meter reading, the first one is the mechanical meters where the round metal plate was revolving and the numbers were shown on the three or four metal plates and showing the digits as per the mechanical phenomenon.

The next version was electrical meter and was able to show the electrical display instead of the mechanical digits. The next version of the metering came in to force as Automatic Meter Reading or simply known as AMR. By AMR, the reading was able to be taken remotely and sometimes also known as RMR (Remote meter reading). It was able to record the reading remotely over the interval of the time like Monthly/ half monthly/ weekly etc. the purpose of the reading was to generate the monthly electric bills, the communication in these meters were the unidirectional i.e. one direction only. That was the disadvantage of the meter and gave the birth to the successor Automated Meter Management also known as AMM. It was also defined as an extension of the unidirectional AMR, as this came with two-way communication technology to exchange the consumer data of meter with the utility data of billing engine. The utility can remotely manage the meter also and hence the bidirectional communication mad it quality of information enriched. The next version of the AMR came as infrastructure and hence was named as Advanced Meters Infrastructure. The system mingled up all the features of AMR and AMM with their functionality. The performance the technical measurements, functions and was mainly customer-oriented services via system. The AMI is both way communication and it not only communicate from electric meter of consumers to utility billing engine but vice versa also for sending the various instructions from the utility side to the consumers' side. It can stop or virtually disconnects the power supply if the bills are overdue or the recharge is under flowing in the case of prepaid meters.

To make theses meters successful, the communication plays a vital role there are two way of communication i.e. wired or wireless. As the geographical conditions of the India, where the diversity in the geology exists and hence has the issues with the wired communication and is not possible in major regions, hence the wireless communication is to be adopted. Also, the cost involved in the wired communication and the maintenance of the wired communication is very next to impossible especially in Indian regions as per current situation. In this case are wireless communications extremely useful. [157]

AMI has a tree network structure. The system can be divided into three layers [158]:

1. The Application-Layer:- This is communication link between Utility Billing Engine versus the concentrator
2. The Middleware-Layer:- This is communication link between concentrator versus collector
3. The Device-Layer:- This is communication link between collector versus metering devices.

GPRS, Wireless M-Bus, and ZigBee[159] are only a few examples of the low-speed wireless protocols that make up AMI. These are typically employed for system-level communication at lower tiers, from the metre device to the data concentrator. This protocols are lighter and requires only low end hardware with more energy efficient which are usually battery operated on the other hand higher layers consist of huge/big data volume, so a computing infrastructure is to be of scalable computing letacny and high network bandwidth for faster connections vital. So Wifi, GPRS & WiMax protocols as suitable in the AMI and it is very popular to use such protocols in the Advanced meters infrastructure [160].

In papers [161-162], the authors elaborate the AMI applications. The wired variant of M-Bus is mainly base of the wireless M-Bus. As the name indicates that M-Bus or Meter Bus, as this communication protocol is specially created for remote meter reading, hence the name is Meter-Bus or M-Bus. In recent years, wired communication replaced with wireless communication in many applications. That is the main reason of wide spreading of usage of Wireless communication over wired communication, the ease of installation and extendable capability might be the boosting factor for this. authors also specifies about the physical layer and data link layers of communication among devices/meters in wireless variant is operating at 868 MHz. Due to simplicity of the protocol, this can be used with lifetime of over 10 years as it is compatible with tiny battery operated 8-bit microcontroller.

Operating at 868MHz provides: better tradeoff between RF range and antenna size which may cover long distance for Communication. There is no over-crowded-band and GSM / WiFi interference also not required.

Wireless M-Bus has the nomenclature with alphanumeric nme in which , the wireless mBus mode is denoted by a letter followed by a numeric character. The alphabet denotes the mode and the numeric part specified the mode of transfer i.e 1 for unidirectional where 2 for bidirectional exchange.

Author of paper [163] explained the modes supported in EN13757-4:2005 are as follows.

i) Stationary-mode, in short, mode S – exchange of data between meter and stationary device like mobile has set

ii) Frequent-transmit-mode, in short, mode-T, – the electric device sends a very tiny-frame (3 to 8 ms) in a cycle of few seconds, hence allowing easy readout of reading by walk-by method or/ and drive-by method.

iii) Frequent-receive-mode, in short, mode R – for this, Only R2 is relevant, as R1 makes no sense as bidirectional is relevant. The meter frequently after a delay time listens to receive a wakeup message from a device/ meter transceiver. As soon as after the reception of wakeup signal/message there is a gap of a few seconds for exchange of data or communication dialog.

iv) Compact-Mode, in short, mode C – in comparison to mode T, it has very close similarity except the consumption of the energy to send the equal volume of data/messages/signals. Both mode T and C modes, reception frames are supporting only single receiver.

v) Narrowband-VHF, in short, mode N – it is a long range communication by use of frequency band of 169 MHz. by its multi-hop repeaters.

vi) Frequent-Receive and Ttransmit-Mode, in short, mode F -similar function as of mode R for wakeup technique, but it is used in the long range of 433 MHz frequency band.

Due to the support of its range, the M-Bus was particularly popular for wireless sensor networks in Europe in 2005. Because Wireless M-Bus operates in the 868 MHz band. This band's benefit is greater penetration. More than 2,4 GHz can pass through concert walls as well. NRZ coding is used in simple mode C as opposed to 3-out-of-6 coding in mode T. due to its half bit transmission, the energy also required half, also it supports full and compact frames which is again approximately half of full frame, resulting four times data sent with same energy hence useful in battery operated devices.

In paper [163], author explains the IEEE802.15.4 (communication standard), this is also called by the term ZigBee, its cost is comparatively lower, its power consumption os also lower as compare to others. It is also wireless mesh network standard. This is mainly used in the wireless control utility tools for controlling as well as monitoring purpose. as the power consumption is very less, which makes its life longer with support of smaller batteries. it provides high reliability with more extensive range which results it most appropriate for mesh networking. it is used in many industrial devices. it also not require license as 868 MHz, 915 MHz and 2,4 GHz in approx all parts of the world, nation-wide, the rate of data transmission is about 20 kb/s for 868MHz and 250 kb/s in 2,4GHz frequency bands. zigbee protocols are used for the devices embedded where the power consumption is very low and the rate of the data transfer is also comparatively low. The network as a result constituted will consume the power comparatively very small in quantity of power especially from battery (the storage devices). ZigBee protocols standard supports various network topologies mainly three are structures as Star, Mesh and Tree topology.

In paper [153] and [164] , the authors explains the Wireless Fidelity or short Wifi which is one among the reputed communication protocols, this uses 2.4GHz or 5GHz frequency due to which it can communicate upto 100 meters range devices like LAN(Local Area network). This is also a wireless network which makes it easy for installation and deployment. Wifi Protocol was in one of the IEEE802.11 standard family protocols, and was established as a part of this family.

From paper [153], the advantages and disadvantages of WiFi may be enumerated as below:

The primary benefits include unlicensed radio spectrum, Power consumption is fairly high, unlicensed frequency may interfere with other protocols, and reduced associated costs of network connection and expansions are the main drawbacks. due to simple access, less secure.

In Paper[165], WiMAX is a wireless communications standard which has been designed to give data rates of 30 to 40 Mbps and in case of fixed station it provides up to 1Gbps. WiMAX is a IEEE 802.16 standard and has been created by WiMAX Forum.

The WiMX may be used for outdoor connectivity whereas the WiFi is for indoor connectivity. It supports from 40MBps to 400MBps and can rage upto 48KM which may be used for the connectivity of the meters with the data concentrator at widespread geographically diversified areas with low population density like hilly area, especially like the North East Area of the India.

In paper [166], author propose AMR system which is using WiMAX technology along with WSN(wireless sensor network). Due to its feasibility and affectivity it can be used in the IoT to communicate the various meters installed at long distance in the utility.

In paper [167], the author explains the GPRS or General Packet Radio Service. This service is the packet oriented services for mobiles. This technology developed between two technology of GSM namely 2G & 3G. Due to which, it is also known as 2,5G. Unlike the previous technologies like Circuit Switched Data Services (or CSD), GPRS, mainly uses 4 coding schemes as CS1 to CS4 (packet switching), coding scheme is opted as per signal/noise ratio to effective communication. The data rate per timelslot (TS) vary from 8 to 20 kb/s in these schemes whereas highest CS4 coding scheme 80kb/s data rate as it used clss 10(Two Uplink TS and four downlink).

Supported protocols in GPRS are Internet protocol (IP) and Point-to-point protocol (PPP). The IP Protocol made GPRS is very important as each and every modern telecom operator with combination of TCP can have internet accessible. GPRS in electrical metering devices used to connect device or data collectors or data concentrators to utility billing engine. Data Concentrators used TCP/IP protocol for communication between meters/devices and billing engine/servers at data center.

In the latest technologies of the electric meter reading, the smart grid concepts are runners up. The smart electric meters are being used in the almost all the part of the world. The developed countries are switching over to the smart grid infrastructure.

The electric meters legacy meters are replaced with the smart meters in the post paid as well as the prepaid mode. The smart grid meters requires not only the electric readings but also the various parameters required for the near to real time costing of the electricity supply. In the prepaid mode of the electricity supply, the virtual auto disconnection of the electric connections are performed by the advanced infrastructures. The developing countries like India is also planning for the smart meters in the post paid or prepaid mode in the near by future. As the consumers are very huge in the villages, the advanced technologies are lacking at these places, due to geographical diversity in the country. Now a days, most of the electric meters at the remote area are the legacy electric meters. The human meter readers are taking the readings once in a month, keys in the data in the utility billing engine and generates the electric bill in most of the part of the country.

Table 2.6: Review of Existing Literature Survey of IoT Device as Meter Reading

Publications	Descriptions	Limitations
CN104616471A	discloses an invention of an Automatic Metering System For Power Remote Meter Reading is system is only an data acquisition system with GSM and GIS modules.	However this invention cannot be used for the prepaid mode and has only remote meter reading facility.
CN105045130A	discloses an invention of a Wireless Meter-Reading System For Smart Electric Meter Of Smart Home Based On Wi-Fi is composed of a Wi-Fi System for electric meters, Wi-Fi module and a wireless interrupter module, wireless AP module and a microprocessor.	However the invention fails to disclose that system is specifically designed for smart home environment using only and uses Wi-Fi connectivity with the microcontroller interconnected wirelessly with an AP Module and interrupter module.
CN203165184U	discloses an invention of a Remote-Meter-Reading-Data-	However the invention fails to disclose that it is only a data

	Collecting-System Based On Wi-Fi (Wireless Fidelity) a kind of data transmission accurate, firewalling remote meter reading data acquisition system (DAS) based on Wi-Fi.	accumulation system which records the meter image sensor and lacks in accuracy of the meter readings.
CN201903585U	discloses an invention of a Wireless Fidelity (WIFI) Wireless Intelligent Electric Energy Mete is a data accumulation system in which the meter reading and the operational signals are passed to the gird operations.	However the invention fails to disclose that this system is only based on Wi-Fi connectivity and the Prepaid and postpaid modes of the billing are not connected with the billing engine for the auto disconnects / reconnects of the system.
CN103208174A	discloses an invention of a WI-FI Based Remote Meter Reading Data-Acquisition-System(MDAS) is a meter reading accumulation system.	However the invention fails to disclose that Imaging sensors are used for capturing of the readings which may be prone to errors.
CN201322987Y	, discloses an invention of an Intelligent Meter-Reading-System Based On WiFi Wireless-Communication-Technology is a remote meter reading system with Wi-Fi and radio frequency technology.	However the invention is only an data recording system based on the Wi-Fi wireless communication technique which lacks in capability of functioning as the prepaid as well as post-paid mode of the billing system as per user require.
CN105513329A	discloses an invention of an Automatic Meter Reading Terminal Based On WIFI Network which is using the	However this invention is only automatic data logging terminal of WIFI network and not using any load control method . The

	sensors and processing the meter reading data with the MCU .	current system lacks in billing payment modes of prepaid or postpaid automatic with not auto connect or disconnect mode.
Sasane, Nikita & Sakat, Swati & Shital, Nemane & Pallav, Prabhat & Kaushik, Vipul. (2017)	IOT Based (MBC) -A Case Study. discloses a system is for meter billing and monitoring system on IoT based which is composed of relay switch sensors and interfaces with LCD Display.	However the invention fails to disclose that it the current system is lacks payment through postpaid system.
Kumar Pc, Kishore & Raja, J. & Abishek, Ebenezer & Vishalakshi, S. & Vidhya, G.. (2018)	IOT Based (MBC) with Automatic Billing. is an IoT based meter reading system for fault detection .	However the invention fails to discloses that it uses Wifi module , i/v controllers and EEPROM is used for storage of data memory. The prior art lacks in meter billing functionality.
ASHNA.K and SUDHISH N GEORGE	GSM-Based (MBC) with Instant Billing based on GSM .	However the prior art y works on the PLC/ GPRS, Bluetooth and GSM technology with the CMOS battery for the power backup.

Mohan Naik R, Harish, Dipreeth, Krishna Lokre, Sandeeep, 0, ICRTT – 2018 (Volume 06 – Issue 15),	IOT based Electricity Controlled Prepaid Energy-Meter-Monitoring and Bill-Payment-System, discloses an invention of a prepaid system for monitoring the power usage in which the power consumption is displayed on the dashboard in the form of graphical presentation.	However the invention is an Automatic Meter Reading system with postpaid mode and lacks in smart functionality of the auto connect/disconnect.
SAKSHI PATIL and AAKSHA JAYWANT	IoT-Based Power Security and Prepaid Electricity System discloses an invention for the prepaid electricity system as it composed of the load control system for stepper motor operations by using GSM module.	However the invention fails to disclose that it may not be to connect nearby systems for collections of the readings in case of failure of the network connectivity and the self-assessment performed is limited.

2.12 Open Research Issues

Metering Data Acquisition: - In the power distribution sector, the measurement of the electricity consumed is the main parameter in the assessment of the performance of the power distributions. It is the key performance indicator to assess the trading profit and losses in any power utility. A robust system is required to accumulate the metering data generated by metering devices per day for instant real-time decision making. The demand of the electricity supply is increasing day by day. Even in the transport vehicles, the electricity charging point is a main aspect. For providing the real-time consumption data and their patterns, the metering data acquisition system must be robust, reliable and consistent. The today's research challenge is to get the electric meter's various parameters for the power supply quality and electricity trading.

The objective of power distribution companies is to provide uninterrupted supply of electricity with minimum transmission and distribution losses. Most of the power utilities are running with a huge aggregate commercial and technical losses. The infrastructure used by these distributions are legacy and lacks the intelligence. The modern assets must be replaced with the existing traditional infrastructure for smart operations. The intelligent electric devices, smart meters can server the purpose of the accurate and near to real-time accumulation of the electricity consumption parameters like load, units consumed, power factors etc. for the purpose of the revenue aspects as well as for the outage point of view also.

Processing: - The data generated by numerous smart devices and accumulated at a central place is as dump if no any processing is applied on the same for effective analysis and prediction of the consumption patterns. So there is an open challenge for managing the huge data accumulated for real-time analysis. The processing must be with high speed to provide the instant decision at right time.

2.13 Research Gap and Challenges

After study and analysis of past surveys along with determination of possible potential and challenges in revenue management system of the power utilities, the meter reading, bill generation and revenue collection processes requires an IoT based efficient frameworks and models for mitigating the issues to reduce the aggregate technical and commercial losses. We have studied and analyzed the existing technologies behind the smart girds, and IoT applications, methods and system architectures which accomplish current research work and point out the possible potential gaps in the literature as well as in the industry of the power distribution.

This section should include the research gaps on the basis of literature survey which has led to the proposed research work plan:-

- Manual/Electrical Meters are unable to serve the purpose of proper reading. The manual interruption is required to read the reading on the physical device and then write the reading on papers and then typing/Keying in the data of meter reading on the billing solution. This results in the errors in reading as well as errors in typing the data to billing engine.

- Manual monthly reading by a meter reader. While taking reading, the human being is approaching door to door for collection of the meter reading. If any door is locked, the reading will not be taken. The meter might be out of reach of the meter reader, may be due to installation of the meter at a big height.

- Errors in Meter reading, results in the Billing errors, wrong bills, bills not received, etc problems resulting the consumer dissatisfaction and even disputes.

- Due to non delivery of proper energy bills, the consumer is not paying their due bills, and at a result, the revenue collection low. The direct variable to count the AT & C Loss in the energy sector in India.

- Tracing of the Consumers is a challenge, the GIS delta change is again a big challenge to the power utility, the GPS in the IOT-based-framework-model may serve to locate the consumer and may plot the consumers on the GIS/Map and will be helpful in the tagging of the consumers via GPS long lat.

- The various technologies framed various solutions to meet the issues related to metering billing and collection issues in the power distribution companies as [168] represents the smart meter for prepaid mode, but the geographically diversity exists in the Indian subcontinent, and resulting the communication issues between the smart meter and the utility recharge or card vending systems.[169] demonstrates about the outage management system which plays a vital role in the quality of the power and in AMI. [170],[174-177] represents the IoT based meter. [171] represents the smart meter for data intelligence. [172],[173],[178-180] focuses on the Advanced metering infrastructure for smart grids.[181-182] represents the smart meter for three phases. [183] presents the smart meter for energy saving. [184-185] showed the smart meter based on GSM. [186] Represents the smart meter for energy theft detection and [187] represents the smart meter for the quality of the power.

- But the IoT based solution must have the alternate to the geographically diversified area also. the visible GAP exists in the technologies elaborated in the various papers as represented above. For the prepaid meters as demonstrated above, should have the option to be communicated with the android based applications via WIFI or Bluetooth or R/F, so that the meter may be recharged via the consumers mobile handset immediately after the online recharge of the smart meter in case of any cellular or internet or modem communication failures. There should also be GPS module embedded in the IoT so that the location of the consumers may be tagged in GIS automatically without any survey. If the device is changed its location, the GPS module in the IoT may tag the GIS tagging automatically.

- The existing system of electric meter reading , bill generation, revenue collection, GIS analytics and arriving at a decision at higher level, the system is limited to traditional & legacy system of human meter readers. The data keying in error, locking of premises of meters of consumers etc resulting the disputes in consumers for any billing issues raised due to the human intervention / lock of the premises. A system is proposed for automated collection of the electric meter reading of all consumers/ Distribution Transformer meters, Feeder meter reading to build the Decision Support System for MDAS/Metering Data Acquisition System, all the data may be collected via IoT devices from the electric meters installed at the Feeders/Distribution Transformers (DTs) and at the Consumers premises. Feeders are supplying the electricity to DTs which are further supplying the electricity to their Consumers. All the data is collected at MDAS/ the map reduce framework will enhance the processing near to real time to various MIS/analytics after integrating the GIS with Metering, Billing and Collection data.

• IoT-based apps need a strong IT and connectivity infrastructure since they are data-hungry. Strategic planning, an evaluation of the current ICT infrastructure, the identification of deficiencies, and the establishment of benchmarks based on global best practises are additional requirements for IoT adoption. Additionally, to increase awareness and comprehension of IoT applications and their advantages, IoT implementation in Indian DISCOMs must be advanced incrementally, with a focus on organisational capacity building and training. The implementation of IoT is not without difficulties. The execution of it is successful due to a number of elements.

The biggest obstacles to IoT adoption in utilities in developing nations

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Interoperability issues:- Interoperability issues are very common in the developing countries' power utilities.

Reliable Communication: **-** In the developing countries like India, the communication is not that much reliable and hence is the biggest challenge while implementing the IoT Based solutions.

Cyber Security :- The cyber security is required at the top most priority. The challenge is widespread and needs to be given importance while implanting the IoT based solutions.

Capacity Building:-The way of using the IoT devise, the hands on training to the operators is also a big challenge in such countries.

Financial Constraints: A large amount of cost is incurred in the smart meters/ IoT devices to be incorporated/ infrastructure enhancement in the power sectors. For customer satisfaction, achieving higher reliability and efficiency will automatically increase the operations cost over the power utilities.

Poor Internet Connectivity: Strong internet communication technology is required for the proper functioning of the IoT / Smart meters, otherwise, the consumers will be very highly dis-satisfy if the smart prepaid electric meter is not giving power supply even if the recharge is done successfully. If by any reason, if the IoT device is not communicating with the utility billing engine, then consumers may face the issues in the automatically reconnections of the electricity supply.

Geographical Diversity: due to the geo graphically diversity, the communication may affect between clouds / data center to the IoT device and vice versa.

Climate Challenges: As due to climate, the communication to the IoT devices may affect, hence the communication media may be robust enough to cater such situations.

Policy impediments: Power policies in many countries composes of the power subsidy which may be a challenge towards adoption of IoT devices/ Smart meters.

Another a few Challenges in IoT in the Developing Countries' Power Sector may be enumerated as below:

- ✓ Insufficient RF spectrum prevents the interaction of smart grids and smart cities.
- ✓ The power sector lacks well implemented innovative business models.

- ✓ The lack of cyber security requirements for IoT devices used in the electricity sector
- ✓ Lack of IPv6-based last mile connectivity demos in the electricity sector;
- ✓ Majority of utilities' ignorance of key IoT concepts.
- ✓ Lack of compatibility in IoT devices in the electricity sector Inconsistency between smart grids and smart cities from an IoT perspective

2.14 Problem Formulation

The Power distribution companies are with heavy AT & C Loss in present time. The loss may be reduced with the help of IOT based framework-model and big data analytics services. The consumers as well as power utility will be beneficial after implementation of the IoT based framework-model and big data analytics. The top management level Decisions may be taken RealTime after the implementation of big data analytics. As the Volume is very high, generated by the crores of transactions by meter reading, bill generation etc. every month. Fast and speedy extraction and execution cannot be met by traditional legacy database management systems due to heterogeneous & non structured and non-uniform data.

The environment variables are mainly the

- Meter reading of all consumers data.
- Billing efficiency
- Collection efficiency
- Power theft
- The problem exists in the manual reading of the energy meters.

AT & C Loss is directly proportional to the

- Less Revenue collection
- Less and Inaccurate bills generated and distributed
- power theft
- transmission loss

2.15 Hypothesis

My hypothesis is that with the usage of IoT Devices, the electricity consumption can be measured accurately at near to real-time. I surmise that use of Artificial

Intelligence and machine learning can help the distribution companies to take instant decision at new to real-time with great accuracy. The big data analytics can analyze the accumulated electricity meter readings with high speed for real-time analytics.

For replacing the huge assets, in one go will be near to impossible, so an alternative approach for mitigating the gap between the traditional legacy infrastructure and modern infrastructure. In the electricity meter reading activity of the revenue management system of the power distribution companies, an IoT based device working as converter for the legacy meters to be smart. The proposed device has a micro-processor with communication media which can communicate with the central server like metering data acquisition system for real-time data acquisition.

2.16 Objectives

- To study and analyze the existing techniques for meter reading, bill generation & distribution and collection of energy bills.
- To automate the energy bills generation process using IoT Devices.
- To develop a model for enhancing the Decision Support System of MDAS using the bigdata concepts.
- To compare the performance of developed model with the existing model.

2.17 Summary and Conclusion

The state of art in the emerging technologies in electricity consumption literature is discussed in this section of the thesis. A deep analysis carried out after study of the technologies behind the intelligent electronic devices used in the smart grids along with IoT and its smart applications. Challenges are discussed in details and research gap is assessed. Problem is formulated based on that and a hypothesis is given to electricity consumption for its core methods of revenue management syatem.

CHAPTER 3

Methodology and Implementation

3.1 Introduction

THIS chapter is presenting the various designs to achieve the research objectives of the thesis. The frameworks based on the IoT techniques along with amalgamation with emerging technologies like artificial intelligence, big data analytics etc.

Recently, the study of Electricity Consumption domain in perspective of the energy efficiency is important. It is a fact that units generated at the power generations is never matches with the units invoiced at the customers' end, and this mismatch is termed as the transmission and distribution losses. Now a days, a new term is used for the same and that is AT & C Losses (Aggregate Technical and Commercial Losses). The proposed research tried to contribute towards the new generation of development in energy efficiency. Accurate accounting of the electricity consumption at near to real-time is achieved through the IoT device proposed. The meter readings are accumulated at the central data lake place. The Artificial intelligence and big data analytics are applied over the data lake for the instant and accurate information generation for the prompt decision-making. After systematic review of the emerging technologies behind the smart grids and IoT, Various models like VEnvMQTT model, electricity theft detecting framework, missed call messaging frameworks are directly enhancing the revenue collections against the electricity consumption in the power trading companies. The proposed work contributed to the reduction of the AT & C Losses for the energy efficiency in new generation of development in energy efficiency under electricity consumption.

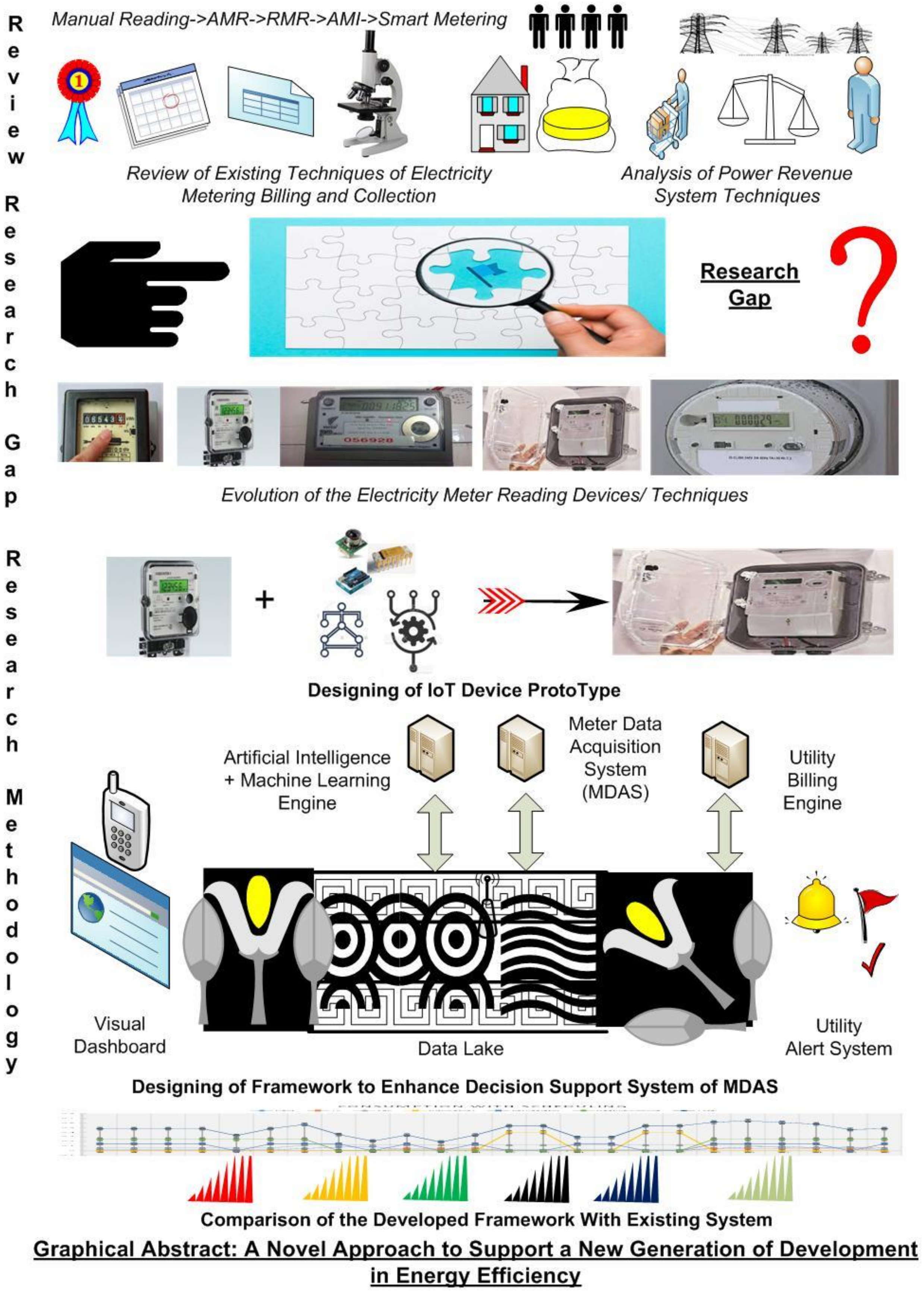


Figure 3.1 A Novel Approach to Support a new generation of development in energy

efficiency

The work is planned with the following four objectives consisting of the literature review, proposing of the prototypes and frameworks for efficient and effective processes in the energy trading and finally the comparison of the existing model with the developed model.

Proposed Methodology: The following are the methods/Techniques proposed in the topic.

Design and Development of an IoT Based device for Integration of Electricity Consumption Meter with proposed model:- In this method, the current digitized meter storing the whole data in the XML format, will be taken by the IoT-based framework-model, as the IoT based framework-model is supposed to be embedded with the Infra-red/ Blue tooth/ R/F and GMS SIM modules. By use of these modules, we will get the XML data from the Electric Meter via the physical connection and the IoT module will be attached with the electric meter permanently. One inbuilt battery like mobile battery is also proposed so that in case of the power failure, the IoT Module may be functional and may carry out the function in time. One android mobile application is also to be developed which connect to the IoT device via Bluetooth/infrared/R/F or GSM Mobile data and will hand over the meter data to the mobile application. This data will be further analysed by the mobile application logics, the mobile application is also to be integrated with the billing / informative servers via open cloud services, which may provide the necessary tariff related information and the consumers may be able to analyse their daily basis consumptions to plan their consumptions based on their budgets / requirements. The same module will also help the distribution utilities to take the XML data over their open cloud servers/ and may be used for the further analysis of their billing related information. By use of the mobile application the consumer will be happy by viewing their own dashboard, and by the use of the application, the GIS locations of the consumers meter, reading of the electric meter will be captured free of cost. The IoT device further may be integrated to make the electric meter in prepaid mode like mobile SIMs. If the charged money is consumed, the IoT will automatically disconnect the electric supply and will be resumed after the payment (especially online payment integration for prompt supply resume). The R/F module may be used to create mesh among the group of meters within 1KM and can be received via another R/F receiver over the radius of the 1KM. any meter if connected to Billing engine via GSM Module may send the entire mesh's data to the billing engine. And vice versa.

Use of Big data analytics: - As there is requirement of fast analysis, very clear to real-time analysis of different type of data altogether to formulate any prompt decisions. For this the huge data needs to be processed over the single framework, the data is in the format of the Images/Maps/Text/Audio/Videos etc. such data may be of different variety of structured as well as unstructured data type. So *variety* of data needs to be integrated. As the report should be analyzed quickly, so *Speed* is also required. And the data is daily generated exponentially; hence the *volume* of the data is also high. From the above it is recommended by big data experts the three Vs. (Volume, Velocity and variety)[5] exists in the problem, hence the big data is suggested to be implemented in the utilities to face such issues. The open cloud or the in house data center may be recommended for this activity. As the data is collected over the RDBMS, due to huge data volume and variety of data, the extraction and processing also needs more IOs, the execution and service time should be very less, so the Hadoop Distributed File System may be incorporated. T he Sqoop will work as the connector between the RDBMS the structured data. Flume will be interface between the HDFS and the unstructured or semi structured Data. The YARN will be the resource manager. In HDFS, the hBase the No SQL database will be used to store the billing engines, the spark in memory data flow will also enhance the availability of the data. Map Reduce will be the programming language with the different languages support. To build the Decision Support System for MDAS/Metering Data Acquisition System, all the data collected via IoT devices from the electric meters installed at the Feeders/Distribution Transformers (DTs) and at the Consumers premises. Feeders are supplying the electricity to DTs which are further supplying the electricity to their Consumers. All the data is collected at MDAS/ the map reduce framework will enhance the processing near to real time to various MIS/analytics after integrating the GIS with Metering, Billing and Collection data.

Consumer Android Application integrated with IoT-based framework-model:- The Power Utility has to give an android based application to their consumers so that they can view their energy bills on real time as and when required. The same application may be used for the following functions:-

a. View the Energy Consumption on real time.

b. View the outages due to maintenance for any other reason with the tentative time of restoration.

c. View the Energy bills of the current bill along with the previous history for at least one year.

d. View the detailed Electric devices mapped with the consumers like Meter Sl No. etc. with full details related to the consumers. Like load, maximum load utilized, trends of the usage of the electricity. So that consumer may take necessary steps to control the usages of the electricity to save the same. The consumer may be able to change the load as per the requirements via the application.

e. Online Complaints related to Supply/ Device or Billing related may be incorporated in this application.

f. The application to be integrated with the online load management, the instant rate of the electricity may be displayed to the consumers if billed on the bases of the instant billing scheme if any, by this the consumers will not use their air conditions in the hard summer for longer time if the rate is too much high at that time, if the load is reduced, the rate will also be reduced, and the consumer will opt the instrument to be on for optimum utilization of the energy. By this the load will be automatically balanced by the consumers by viewing the instant rates (rate will be high if the demand is more and supply has constraints. The rate will be low if the demand is less.)

g. The application should be integrated with the online systems so that the billing may be paid by the consumers by this application.

h. The application must have the bills payment history of at least one year.

i. The application should be integrated with this model to extract the Consumption of the Energy, instantly as well as the historical data as per requirements of the consumers.

j. The application is integrated with this model as well as the Utility billing engine, so the IoT may also provide the Billing Details to the Utility Billing engine which may be used for billing if the data communication between the meter and the utility is not maintained or lost for some time.

k. The application is integrated with the IoT-based framework-model as well as the utility billing engine, this may be used to communicate with meter in case of prepaid mode also. If the consumer has disconnected the electricity connection due to nil balance, and the consumer later on recharge, but due to poor communication channel between the utility billing engine and the prepaid electric meter/ the application may be used as in interface between both and the communication which was supposed to be sent to electric device, may be communicated via this android application. In such cases, the disputed of the prepaid meter after recharge will be nil.

Utility Billing via Android Application integrated with IoT-based-framework-model:- One android application to be developed for the utility to take the meter reading via this application if the AMI(Advanced Metering Infrastructure) in not incorporated. The monthly electric bill will be generated on the basis of the android application which will get the data of the meter via this model which will provide the data with unique key generated by the IoT for the purposed of the security. In case, if any meter is at a height, the IoT will provide the data via WiFi module inbuilt in the IoT. the IoT is also managed by the utility, so the connection will be made by the hash keys or encrypted keys maintained between the IoT-based-framework-model and the android application. Meter reading will be possible, in case, House is locked, the IoT-based framework-model will have the range of about 100 Meter to be connected like LAN. As GPS is also embedded in this model, so that, it can be used to find the Meter/Device where it is located. GPS will provide the approx Long Lat of the device with 10 to 50 meter approximation whereas the wifi-RTT will be used to identify the device near to 1 meter approximation. So the Ghost Consumers will be identified by use of the IoT based framework model. As GPS is embedded, the long and lat generated will be used in maintained of the GIS of the all electric meters. If the readings are collected on the regular periods, the data collected at the servers will be able to formulate the followings.

a. GIS Mapping:- the Long, Lat provided by the IoT based framework-model will be helpful in the delta change formulation of the Geographical information system.

b. DT/Feeder Level AT & C Loss. As the meters are installed at the DT and Feeders also. So the data will be accumulated at HDFS environment of all the Billing as well as the Revenue Collected via various online modes. The Meter Reader may also use mPOS devices along with him and may collect the revenue at the same time of the generation of the bill. As the bill is distributed via Bluetooth printers in such models, the same printer may be used for printing of the receipts for the same.

Utility Android Application for Meter Management via IoT-based-framework-model:- As this model is developed on the concepts of the utility, so the meter management if required may be done by the any application which may be verified by the hash key encryption by the keys maintained at IoT as well the android application. All the meter functions may be executed by this model if the definition along with the various invoke methods are enterd in the IoT-based-framework-model.

Missed Call services for(non-Android phone consumers) for Bill Details:- As proposed database is now equipped with the consumer details along with the mobile no. a service to be designed for the consumers at utility, if any mobile registered consumer calls on the specific mobile no., then the mobile no. to be attached with the PRI card at server. The missed number will be captured by the server. The search engine will get the registered consumer no. from the master database. With the help of the consumer no. the billing details like payment due with due date and a current bill PDF link may be incorporated in one SMS and the SMS may be sent to the consumer mobile no. by this the SMS may be read by the non android phone consumers and can get the instant current bill details .

Missed Call Service for No-Power Complaint: -As proposed database is now equipped with the consumer details along with the mobile no. a service to be designed for the consumers at utility, if any mobile registered consumer calls on the specific mobile no., then the mobile no. to be attached with the PRI card at server. The missed number will be captured by the server. The search engine will get the registered consumer no. from the master database. With the help of the consumer no. one fuse call complaint of No Power may be registered and the registered complaint no. may be incorporated in one SMS and the SMS may be sent to the consumer mobile no. by this the SMS may be read by the non-android phone consumers and can get the no power complaint.

Scalability in the IoT-based framework-model firmware: This model will be scalable to the firmware upgradation, so the any tariff related details or any regulatory related changes may be incorporated over the IoT.

An Ai Based Smart Electricity Consumption Monitoring Agent:- The smart electricity consumption system described in this disclosure uses artificial intelligence and a monitoring agent. The system offers a personalized mobile app with a dashboard integrated with the central middleware to provide real-time blink counts and which further relates this to KWH or units for the consumption aspects and calculation of the monetary aspects after multiplying the units with rate per unit through real-time monitoring. Through the ARIMA model, the system offers analysis and prediction. The smart devices connect to the middleware, which then gathers all of the data from the devices and stores it on a cloud server or data centre.

*AI Based Framework(Virtual Assistance For Electricity Consumption):-*Plenty of electricity consumers deal with a variety of problems on a daily basis, ranging from complaints about power outages to paying their energy bills. Millions of users at a power distribution company use the electricity for their daily needs and routine works. Users are eager to learn about all the information on the tips for the entire life cycle of the consumer service connection, from the application for a new energy connection to the termination or disconnection of the electricity connection. For information on what paperwork is necessary to create an electricity service connection, potential fees or charges for specific milestones, the rate of electricity consumption per unit, and other topics, they are physically going to the power utility office. A virtual assistant powered by artificial intelligence technology can provide this kind of general knowledge. By creating such a framework, users can access the virtual assistant suggested in this study on the basis of open-source technology from the comfort of their own homes.

*IoT-Based Electricity-Theft-Detecting Framework:-*The framework is made for electricity power trading businesses to identify any illegal consumption of the electricity or electricity theft. The (Internet of Things) IoT methodologies are the foundation for construction of this framework. The framework must examine the data for all consumers who have been assigned tags for a particular geographic area for a particular span of time. The framework in the first section examines historical consumption data for a certain area. This region may be at the level of the distribution transformer or the feeder, or it could be any place where there is a suspicion of power theft as per the scenarios. In the second stage, IoT devices are added to the metering units of the particular sources. This source will provide real-time information on all electricity delivered to the particular location. The electrical supply line will have IoT devices installed in various parts. depends on the scenario and the server's analysis of real-time data acquired by these IoT devices using GSM technology at either a data centre or cloud storage, as appropriate. The framework will identify the precise region where electricity theft is occurring. In order to monitor the exposed line and stop electricity theft, another Internet of Things surveillance device is used. The power distribution company officials are receiving alerts from these devices' Real-Time reporting to take the appropriate action to decrease losses brought on by energy theft. Modern infrastructure is more susceptible to theft of electricity. If the system is infiltrated, theft could happen thanks to the AMI, which is completely M2M functional. Over the past two decades, numerous researchers have proposed their expert algorithms to reduce electricity theft. The current research suggests improvements to the literature on detecting and preventing electricity theft.

*IoT-Based Smart Meter Refresh Triggering Framework For Electricity Consumers With Prepaid Or Postpaid Mode:-*This framework enables consumers to exclusively use missed calls to update or reconnect the smart metres that have been installed on their property. In the proposed system framework, the consumer will make a missed call to a specific mobile number, and the IoT Device for Missed Call composed in this framework will activate the head-end-system of the smart metre manufacturers / providers. There are consumers with electricity metres with smart metres where they recharge their metres but are still in disconnection mode. The hardware and software that receive the constant stream of metre data that the AMI transmits back to the utility is known as a head-end system. Before making the data available for other systems to request or sending the data out to other systems, head-end systems may undertake some data validation.

An Efficient AIBDTF Enhancing DSS of MDAS in Energy Efficiency:-Electric The power distribution system's many assets can exchange information and electricity in both directions using a smart-grid. There is a need for an environmentally friendly system that is transparent, sustainable, cost-effective, energy-efficient, adaptable, securely, and safe in order to monitor and regulate the quality of the power, reliability, scalability, and flexibility in an adequate manner. We present an overview of the cutting-edge technologies underlying the Smart Grid and the Internet of Things (IoT) in this article. They identified the dependent variables for electricity consumption while planning preventive maintenance with real-time criteria for the assessment of their legacy assets, such as power distribution transformers, in order to provide a consistent, uninterrupted supply of electricity. The traditional/legacy electricity grid, power generation, transmission, and distribution are also discussed in the paper, along with revenue management issues like reducing overall technical and commercial losses by switching from manual/semi-automatic to fully smart/automatic techniques. The research being done to create smart grid components, such as postpaid and prepaid smart metering infrastructure, internal structure comparisons of advanced metering methods/processes in existing settings, and communication system, is briefly summarised in this article.

System And Method for Missed Call Messaging Services for Electricity Consumers: A feature of the current invention offers power users a system for missed call messaging services. A user device that is a part of the system can dial a number from a list of numbers to make a missed call. An Internet of Things (IoT) component that is housed on an application server and is designed to handle missed calls is also a part of the system. The Internet of Things (IoT) gadget extracts a customer ID associated with a consumer's mobile phone number. The Internet of Things (IoT) gadget is set up to extract a service request related to the provided number. When a service request is connected to an invoice, the Internet of Things (IoT) device is further set up to create a first type of message with customer information. The due amount, the payment due date, the embedded link to the most recent invoice in PDF format, and/or a combination of these are all options for the first type of message's content. When a service request is connected to a complaint about no power supply, the Internet of Things (IoT) device is further set to create a second sort of message with a consumer complaint.

The following figures represents the proposed methodology for the collection of the electric meter readings and methodology to be used for the electric meter reading to achieve the maximum consumers assessment of the electricity consumption for the monthly bill generation as well as for the quality of the supply of the electricity. In this proposal, the electricity meter existing traditional legacy device can be used in the smart meter functionality after integration of the proposed IoT device. The IoT device will communicate between the electric meter and the utility billing engine in both directions.

3.2 Materials

The following subsection lists out the various materials used in the designing and development of the various models for achieving the objectives of this thesis. The model and framework wise materials and tools required are appended below:-

The following are the materials required for the development of the various IoT Devices and the frameworks along with the testing and deployment processes.

-ESP32 for Arduino:- This is the microcontroller, the brains of the Internet of Things-based gadget. It will regulate and keep an eye on the numerous attached components and establish coordination by integrating them. Bluetooth and Wi-Fi will be used to connect the IoT device to this module. It includes 34 GPIO pins, and each pin may be programmed to perform a variety of operations using specific registers. This board also supports I2C communication. Two IoT applications in the energy sector with Wi-Fi capabilities are energy metering and building energy management .

-GSM SIM800L Module:- This module is used to connect IoT devices to the cloud or a DC over the public internet using GSM technology. For cellular access, a SIM card is put into the GSM Module's SIM slot. This module will offer information on missed calls and message reading.

-IIC OLED 1036 Display:- this is also supports i2c Communication, is utilised in IoT-based devices for a variety of indications, messages, faults, and dashboard presentations.

-Programming ESP32 hardware(Arduino IDE):- The SIM800L's integration with the microcontroller. This IDE also allows you to programme Middleware APIs. It includes a text editor for creating hardware-specific software. It establishes a connection with the hardware of the Gnuino and Arduino to upload programmes to them. It is a cross-platform programme developed in C/C++ functions that runs on a variety of operating systems.

-Middleware:-The hardware server that houses the middleware has a four-core CPU, four gigabytes of RAM, and around 100 gigabytes of internal disc storage.

The open source software utilized for this solution is listed below.

Ubuntu (Cent OS)- Ubuntu Open source operating system Cent OS is based on the Unix system.

- Apache web server:- The open source web server is called httpd apache. However, the author of [225] paper evaluates the performance of the web servers, particularly Apache and Nginx. For a very long time, the two main web server providers, Apache and IIS, had the market to themselves. apache less requests are handled per second when there is high concurrency memory utilisation. handles 350–390 requests per second, increasing as the number of requests increases. It can process 7367 requests per second with a single worker, and workload improves CPU utilisation. [225]
- PHP:- PHP is an open source server-side language that connects well to large databases like MySql and Oracle. [222]
- MYSQL:- MySQL is the most well-liked open source database. This database has space for big data. Additionally, the database processing has been substantially

improved. It has many built-in commands that make database maintenance and data manipulation easier. [223]

- Asterisk:- This is the open source PBX/VOIP software. Asterisk is an open-source communication platform and toolkit used to build communication applications and systems. Due to the fact that it was first designed as a private branch exchange (PBX) solution, it is frequently referred to as Asterisk-PBX or Asterisk-Open Source-PBX. But Asterisk now provides a variety of communication services, going beyond a conventional PBX. The GNU General Public Licence (GPL), which Asterisk is released under, permits unrestricted use, modification, and distribution. Developers and organisations can access the source code, modify it to suit their own requirements, and contribute to its continued development thanks to the open-source concept. Call routing, interactive voice response (IVR), voicemail, call forwarding, conferencing, call recording, and other telephony functions are all available with Asterisk. The development of complex communication systems and applications is made possible by these features. SIP (Session Initiation Protocol), IAX (Inter-Asterisk Exchange), H.323, MGCP (Media Gateway Control Protocol), and other protocols are supported by Asterisk. Interoperability with different telephony systems, programmes, and service providers is made possible by this flexibility. Databases, online services, customer relationship management (CRM) systems, and message platforms are just a few of the additional technologies and systems that Asterisk can interact with. Through this connection, businesses can create unified communication systems that link telephony to other business procedures and apps. Customization and extensibility: Asterisk supports scripting languages including Asterisk Dialplan, AGI (Asterisk Gateway Interface), and AMI (Asterisk Manager Interface) and provides a robust API (Application Programming Interface). With the aid of these tools, developers can customise call flows, introduce new services, and enhance the capabilities of Asterisk. The worldwide community of Asterisk developers, contributors, and users is thriving and active. Users can share information and work together to improve the platform with the help of the community, which offers support, documentation, forums, and resources. Asterisk's functionality can also be enhanced by a variety of third-party add-ons, modules, and apps. When missed call service messages are created, this could be used. IVR or cloud telephony services are some alternative options. It allows for the sending of SMS messages, with the user's mobile number included in the response API for a missed call.

- Node.js:- This is the Java Script Framework's server environment. It can work on several operating systems due to its cross-platform compatibility. It is a typical addition to the JavaScript code that already exists. The Collaborative Projects initiative of the Linux Foundation helps to speed it. There are numerous Node.js frameworks in use today. [226] . are Express.js, Nest.js, Sails.js, Hapki, Feathers, Loopback, MEAN, Adonis, Kao, and Strapi.
- A REST API: Representational state Transfer Application Programming Interface is what it is called. It is the ideal method of communication with both the clients and the many heterogeneous servers. The API sends a request to the source with a few parameters, and the source responds with data as its response. Web services based on SOAP, XML-RPC, and REST, which are open standards and protocols
- RESTful: REST (Representational State Transfer) web APIs and their purpose (Application Programming Interface) are described by the author of paper [224]. A collaborative big data analytics platform may increase the value of big data as a service. Application/program developers can collaborate, communicate, and engage while sharing the platform's value, such as stored data, processes, steps, methods, and services (REST API), through the platform's numerous soap/wsdl/REST Web APIs.[224].
- Curl:- This is the cURL command-line programme. On Linux, the majority of APIs are called using cURL in php. But Linux also comes with a built-in command called uCurl. [227].
- JavaScript Object Notation, or JSON:- The APIs frequently use this data type for communication. the sending and response over the API. One API can accept arguments in JSON format for requests and return results in the same format for responses.
- Laptop i7 with 8GB RAM and 256GB SSD. With Arduino IDE kit:- Dell laptop i7 is used for the programming of the Arduino uno microprocessor with the help of the Arduino IDE in C/C++ programing. With the help of USB cable, the code burnt on the microprocessor Arduino Board.

- Server with 32 Core processor and 512 GB RAM.:- Server X-5 series is used for the experimental setup and processing in the various models designed in this thesis.
- Wi-Fi Network Router:- Wifi router is used for connecting the devices in the setup for communication between the devices.
- MAX 232 Serial Port connector:- the MAX-232 serial port connector is used for the connection of the electricity meter embedded with the RS232 port for communication with the Arduino board through this connector.
- GPS module:- GPS module is used for the geo coordinate system

After a systematic study of the technologies behind the smart grids and the IoT applications in the field of the electricity power consumption and analysis, the following key points revealed in context of the electricity consumption for minimizing the aggregate technical and commercial losses.

1. Effective Revenue management system with accurate and real-time energy consumption meter reading, bill generation and revenue collection timely against the electricity consumption.

2. Fast execution of the data-server functions and processes. A timeless prompt billing engine services for the instant and accurate decision making.

3. Enhancement in the edge computing for the smart intelligent electric devices for the accurate and real-time data acquisition.

4. Design of the framework for ease to the consumers to get the electricity invoices only a missed call away without visiting the utility offices due to COVID19 restrictions. Also convenient to consumers to lodge a now power complaint through the missed call messaging system without any extra cost to the consumer.

5. Design of an energy efficient framework for smart homes for scheduling their electricity appliances to control the maximum demand at a particular time to have a control over the penalty on crossing the maximum load boundary against the sanctioned load.

6. Design of the models for accurate and real-time data acquisition of the metering data consisting of the billing related parameters along with quality of the supply of the electricity in the electricity consumption is a broad and complex topic and touches the many aspects of the emerging technologies of computer science. This section will cover design and then implementation of the same.

   For the above pointed out suggestions based on the analysis carried out after the survey of the existing technologies behind the smart grids and the IoT technologies. To achieve the research objectives, The following methodology is applied in this thesis and elaborated accordingly.

3.3 Data Collection Methods

In the proposed research, the sampling strategy of the data collection is mixed in nature. The data collected in the VEnvMQTT Model is based in the experiments. The data analyzed for the core revenue management system is mainly depending on the survey and case study nature. The data from the missed call messaging system, electricity theft detecting system is based on the observations recorded in a database. The policy related activities like tariff of the electricity consumption in the post-paid mode and pre-paid mode, the demand and supply analysis of the electricity, peak load, distribution management system etc. are the interview methods with electricity utilities. The various following methods of the data collection are used in this research work.

- Experiments
- Surveys
- Case Studies
- Observations
- Interview

In these sampling methods, the Sample Size taken for the above methods are the chosen sample size based on statistical considerations or practical constraints in the electricity consumption and Instrumentation and Tools which specified the tools, instruments, or technologies used for data collection. In the statistical significance, it demonstrates the statistical significance of the findings and includes p-values or other relevant statistical measures. In the core revenue management, the comparison with existing literature is carried out and compared the empirical findings with existing literature in context of the electricity consumption, especially in the developing countries. It highlighted the similarities, differences, or contradictions and discussed their implications to the extent of proposed research work for empirical findings which generalized to a broader population or context and addressed limitations in generalizability and proposed areas for future research work in the electricity consumption.

3.4 Methodology to automate the energy bills generation process using IoT Devices

In electricity meter reading process in trading of electricity supply, the measurement of electricity consumption is very important. In the previous chapter, we studied and analysed that with the help of IoT devices, the gap in meter readings can be filled. In this section, the proposed model is elaborated.

This model will be for the data acquisition from legacy electricity meter with an IoT device converter for real-time instantly with accuracy. It is built on the open-source hardware and the software. This electricity metre converter invention describes the field of smart electronic metres, specifically how to convert a legacy metre into a smart metre using an IoT platform and a specially designed mobile application for user-friendly billing and payment options.

3.4.1 Design Goals

This device is designed to achieve the second objective of the thesis. The IoT based device is designed to facilitate the power utilities to measure their electricity consumption accurately and timely.

According to the aforementioned prior art, an IoT-based device or system is required to transform the operation of the conventional legacy metre into a smart electronic metre for simple billing and payment methods in accordance with user requirements with the help of load optimization. Due to a lack of internet or Wi-Fi connectivity, the system or device also needs to help the user by automatically re-connecting via a GSM technology.

There is no specifically designed mobile application that connects to an Internet of Things (IoT)-based device to offer the user a prepaid or post-paid paying mechanism based on metre reading or self-assessment of the metre reading.

A small, IoT-based converter device for all sorts of legacy power metres with RS232 capabilities is disclosed in the proposed invention. The device will connect to the utility billing engine via GSM technology, Wi-Fi, or mobile internet, and will communicate with the electronic metre through RS232.

The controller, Arduino, will control the operation of the proposed invention's device. A WI-FI module will assist in establishing communication with the utility billing engine as well as through consumer-tailored mobile applications. It can convert an existing legacy common electricity metre into a smart prepaid as well as post-paid mode. Data collection will be carried out using a customised cloud server connected to the internet or a Wi-Fi module according to the suggested invention. To automatically connect, disconnect, and rejoin the power supply to offer functionality for either prepaid or postpaid modes of the proposed invention, a relay switch will be used.. In the proposed invention, a GPS module will be used to geotag assets for GIS mapping of the metre reading data. In the event that GSM connectivity fails, the customised mobile application can also connect to the IoT via Wi-Fi connectivity. The GPS module is a detachable unit that can be mounted on top of the smart metre to reconnect in the event that GSM technology fails via the consumer customised mobile application through the Wi-Fi module and vice versa., Upon recharging from a utility billing engine through the internet, the prepaid metre will speak with the engine via a mobile network and then send the same information to the smart metre to establish reconnection. The proposed invention will save on the expense of removing the old metre and installing the new one. Data transfer to the specialised mobile application of the proposed invention will be established with the use of an API key, encryption, and decryption. the utility billing engine of the proposed invention will register the IoT-based device securely with the legacy electric metre using the hash key..

3.4.2 Case Scenarios

There are three major cases studied in the present scenario, the details are discussed in the following sub sections.

a) Case -I : GSM Reading(Automatic Meter Reading)

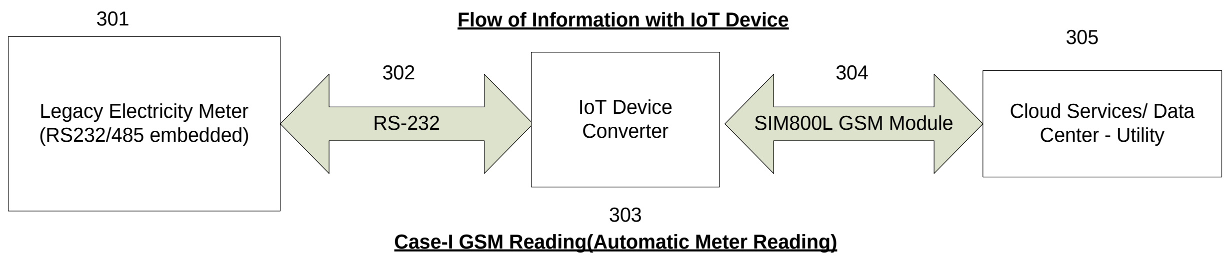


Figure 3.2 Case-I GSM Reading (Automatic Meter Reading)

Case 1:- Meter Reading via GSM Technology consists of the following steps :

i. In this case, a SIM from any of the telecom mobile operator is to be procured and the same is to be installed with the IOT provided.

ii. Fixing/installation of IoT based device with legacy electric meter (on RS232/RS485 Port i.e. Serial Communication Port).

iii. Registration of the IoT based device with legacy electric meter with the utility billing engine with unique hash key.

iv. Microcontroller in IoT based device will send a signal to legacy electric meter via RS232 and will get the reading and other parameters on a periodic interval and will send the same to the utility billing engine at data center of the utility or the cloud as applicable

v. The data received will be prefixed with UNIQSYSID and will be sent to the utility billing engine via establishing the GSM Network Connectivity via gsmAccess with PinNumber of SIM. Then SMS with <mobileno. Of utility> where SMS to be sent for readings, and then end the SMS. Here SMS text will be prefixed with IOT UNIQSYSID

vi. . Accordingly, utility bill will be generated at the utility billing engine and same will be delivered to the consumers via SMS and email or can be downloaded from the utility official web portal which is hosted by the Utility on cloud/DC

Revenue will also be collected via support of various online modes of collection as well as the collection counters at utility billing offices in case of hard cash deposited by the consumers on physical visit.

Figure 3.2 illustrates the process diagram of the case 1 meter reading of the proposed invention

Case – II: Reading by Utility Representative (Meter Reader)

Figure 3.3 in which the case 2 meter reading along with instantaneous parameters i.e phase wise V and KW, Billing parameters KWH, Load survey parameters ie. Average V, KVA, KVArh, Events parameters i.e Low PF, Voltage failure etc. will be read through a Wi-Fi module (115) , in a periodic interval of once in a month for the purpose of monthly electric bill generation.

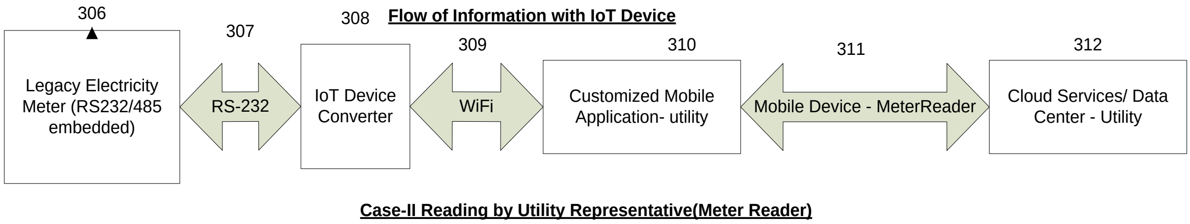


Figure 3.3: Case -II Reading by Utility Representative (Meter Reader)

Case II: Meter reading by the Meter Reader, human representative of distribution company with Wi-Fi used as per the following steps:

i. Fixing/installation of IoT with legacy electric meter (on RS232 Port).
ii. Registration of the IoT with legacy electric meter with the utility billing engine with unique hash key.
iii. Meter reader will read the reading via a customized mobile application through WiFi communication with IOT .
iv. Registered UNIQSYSID will appear as hot spot by the device and transfer of meter data between the device and the customized mobile application upon API key
v. Microcontroller at IoT based device will communicate the electronic meter and will send Command via MAX232 to RS232 (Serial Port) of Electric Meter via mod BusProtocol to collect the data.
vi. The data received will be prefixed with UNIQSYSID and data will be sent to the utility billing engine via cloud/DC of the utility through the API developed at Utility end. The Response from the API will confirm the bill generation along with notification.
   a. Android application will communicate the billing engine on successful message from above API and will request the engine for Current Bill and then will print the

Bill on the spot by Bluetooth thermal printer available with Meter Reader instantly.

b. Customized mobile application will provide the option to receive the current or previously bill amount (via debit/credit card via card swipe machine or cash as applicable) instantly and a receipt of the same will also be printed via Bluetooth thermal printer.

The meter reader will approach to next door for the next bill generation. In case of door lock, the bill will be generated and the print will be dropped to the house letter box

Case – III: Reading by Consumer (Self-Assessment)

Referring to figure 3.4 in which the case 3 meter reading when Consumer is reading via Wi-Fi module (115) , monitors the supply consumption over the customized mobile application or for the purpose of monthly electric bill generation if not done by the Meter Reader or GSM technology or both.

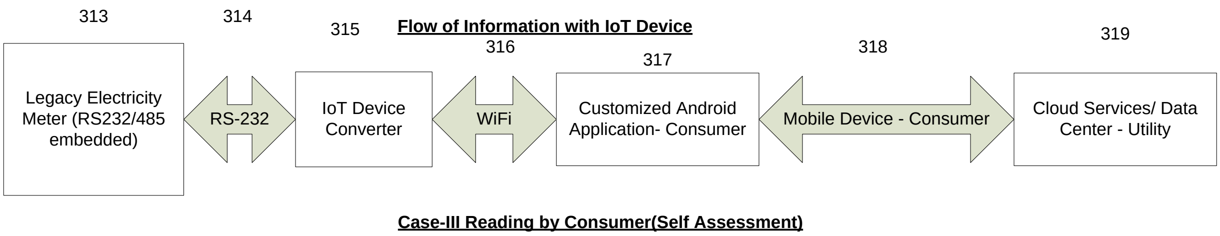


Figure 3.4 Case – III: Reading by Consumer (Self-Assessment)

Case III: Self-assessment by the Consumers in case of failure of case I or case II as applicable. as per the following steps:

- In case I, if the GSM technology fails, in case II, if the Meter Reader is unable to take the readings, due to numerous of reasons, the consumers can generate their bills through the customized mobile application which will communicate with the IoT based device via Wi-Fi / Bluetooth communication and will send the readings to the utility billing engine through the mobile internet network.
- The payments can be made by the user through customized mobile application provided by the utility or by the online payment options available.

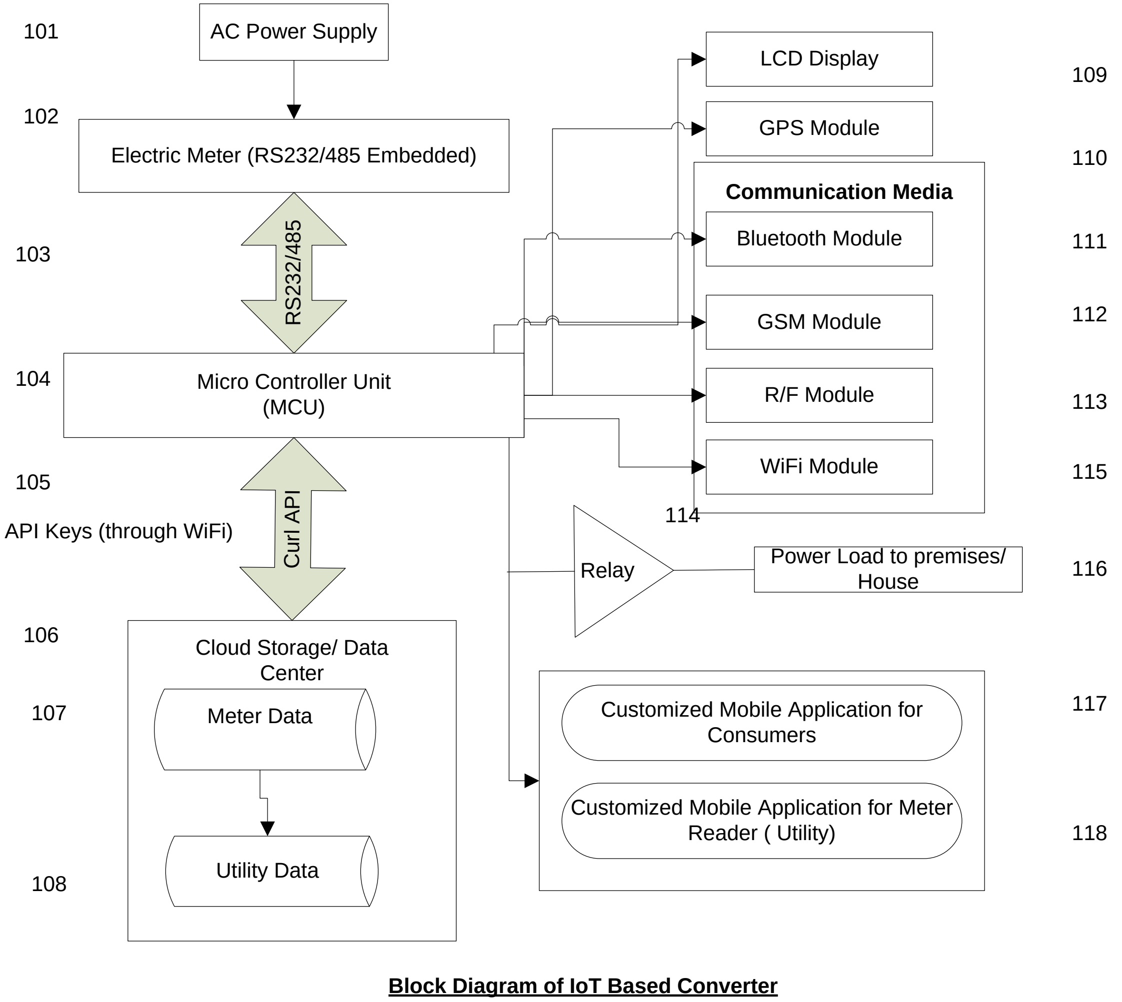


Figure 3.5 Block diagram of IoT Based Converter

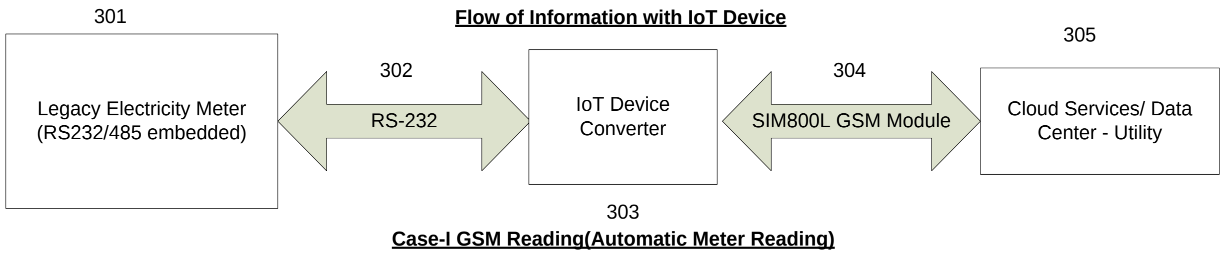
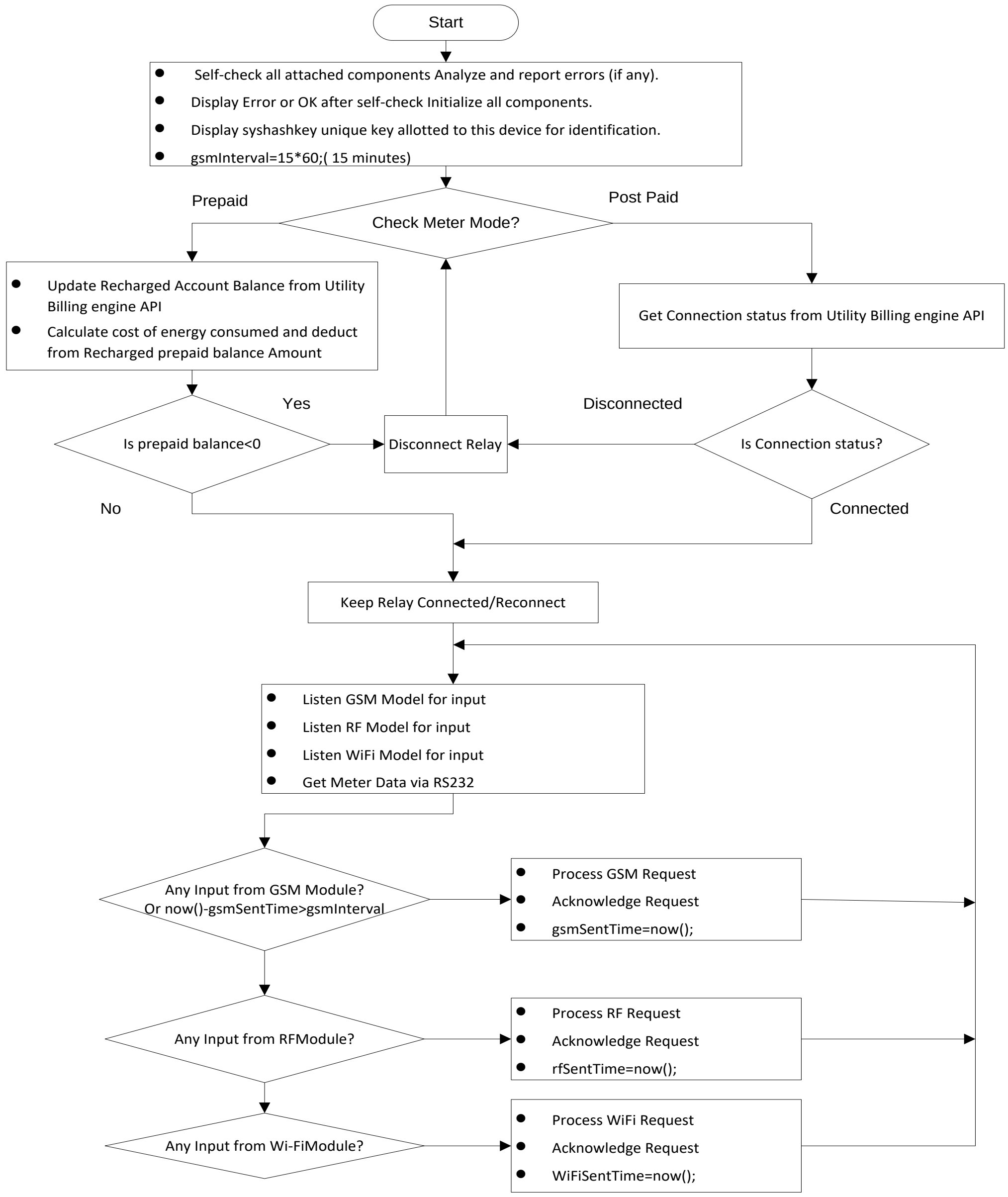


Figure 3.6: Block diagram of Case-II Reading by Utility Representative (Meter Reader)

The following figure is the block diagram of the IoT Based converter, the device is an interface between the legacy electricity meter and the utility representative or the consumer himself. The third case is of the automatic meter reading through the GSM mode.



Flow Chart of IoT-Device-Converter
Automatic Meter Data sent in interval of 15 minutes via GSM Technology

Figure 3.7 illustrates, the flow-chart of the proposed invention.

The above figure is illustrating the flow chart of the proposed inventions with different three case scenarios, the details are discussed in the following sub sections.

3.4.3 Implementation

In the above section, referring to figure 3.5 , is the block diagram in which the data acquisition occurs through cloud server through internet connectivity in which the data encryption and decryption occurs through an API key through Wi-FI (105) . The device receives power through AC power supply (101). Flow chart of the devices can be viewed in figure 3.8 of the above section. It is the flow chart in which the various cases of the meter reading of the proposed invention performs the evaluation of the meter data automatically through self-check by evaluation of the data or report any error occurred. Referring to figure 3.3 in which the case 1 meter reading in which microcontroller unit (104) will send the reading along with parameters in periodic interval (Range 15Minutes interval to one Month interval) via GSM Technology. Referring to figure 3.7 in which the case 2 meter reading along with instantaneous parameters i.e phase wise V and KW, Billing parameters KWH, Load survey parameters ie. Average V, KVA, KVArh, Events parameters i.e Low PF, Voltage failure etc. will be read through a Wi-Fi module (115) , in a periodic interval of once in a month for the purpose of monthly electric bill generation. Referring to figure 3.4 in which the case 3 meter reading when Consumer is reading via Wi-Fi module (115) , monitors the supply consumption over the customized mobile application or for the purpose of monthly electric bill generation if not done by the Meter Reader or GSM technology or both.

This system is easily adaptable to convert the function of the traditional legacy meter into a smart electronic meter through easy installation.

The prototype is positively impacting the power consumption. The accurate and real-time meter readings are collected instantly and stored at the central place, i.e. metering data acquisition system. In Power consumption, the basic revenue function i.e. meter reading is very important. The proposed prototype is enhancing the existing legacy traditional electricity power measuring device with smart functionality. This prototype is impacting the power consumption measurement mechanism in a positive direction by calculating the near to real-time power consumption by the end consumers. By this the billing efficiency is increased and reducing the aggregate technical and commercial losses in the electricity power trading.

The proto type is applicable to that lot of the electricity measurement device which are traditional legacy based mechanical and electromechanical meters, by using this prototype, the cost as well as the time is saved in the power distribution companies to switch over to smart billing system specially the smart pre-pad billing system.

The cost as well as the time is saved in implementation of the proposed proto-type and a significant saving in the expenses and ultimately reducing the aggregate technical and commercial losses arising in the electricity power consumption.

Rs. 900 which comes around 15% of total cost of these devices means each device costs Rs.6000.[188]. Price of the proposed device =2813 (118+ 380 + 255+2090) [189],[190]. ACS712 - 20A Range Current Sensor Module Rs. 118.00 [189]

A graphical analysis of the proposed device with the legacy traditional devices for measuring the electricity power consumption is shown in the figure below.[191]

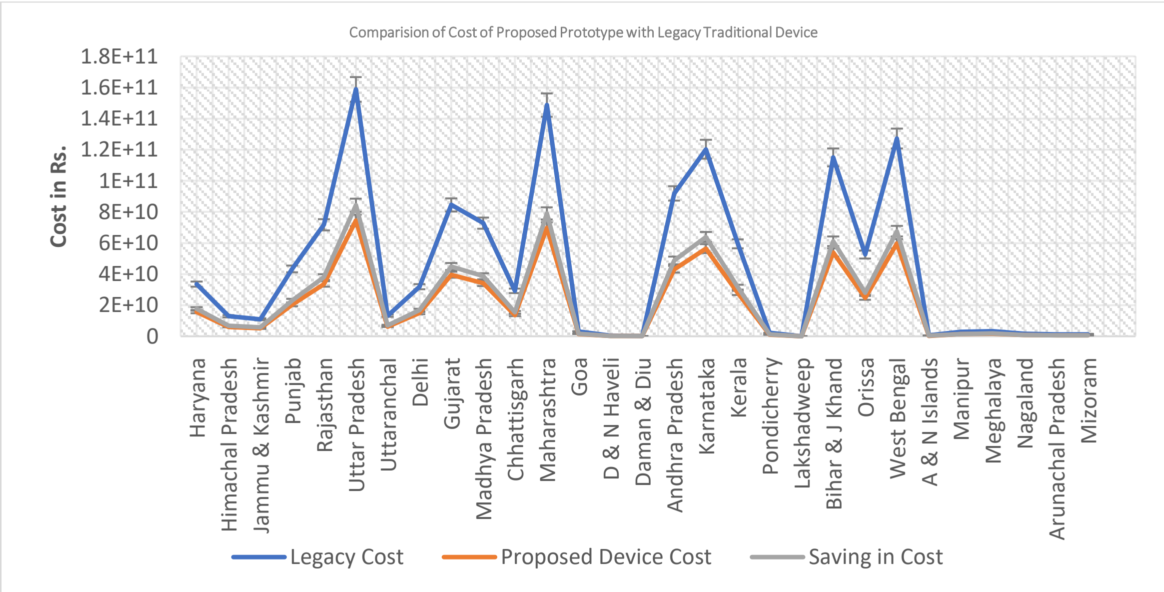


Figure 3.8 Comparison of Cost of Proposed Prototype with Legacy Traditional Device with data of 2021 reference [188-191].

3.4.4 IoT based module to Automated Invoice Checking

This framework is designed to help in achieving the second research objective. The IoT based missed call messaging framework is introduced to the electricity customers to get their duplicate invoices with payment due and due date. The cellphone number registered at the utility office is adequate, so customers don't need to worry about memorizing their long consumer ID number. Instead, they will receive information about their outstanding balances at the utility office once they make a missed call on a specific number. The consumer will receive a text message with a special complaint number when the user places a missed-call on the no-power-supply-complaint number. Text messages can be delivered to basic mobile phones. The architecture is built on open-source software..

Additionally, because of the time-consuming process of filing a complaint on the toll-free number offered for these services, customers were unable to take advantage of the features that had already been developed. In some cases, the complexity of the processes and the need for a lengthy consumer ID are other limitations of these services.

The survey identified the following general issues, particularly for customers in rural areas.

1. Periodic non-delivery or loss of the physical invoice bill:- Some customers in remote areas occasionally experience problems receiving their physical energy bill invoices because of a variety of factors. A few people have misplaced their real invoice copy even after receiving the same. Due to pandemic limits on human contacts, the duplicate invoice cannot be provided in the physical form. The eVersion of every service is therefore improved during this time. However, owners of basic phones are unable to access the internet, websites, online portals, Android applications for smart phones, and other similar things.

2. The No-Power-Supply complaint lodging process is complicated and drawn out. :- There are numerous ways to file a complaint, but doing so via the toll-free number of the customer care centre requires standing in a long line, explaining the issue to an agent, then providing some information about the division or subdivision of the electricity supply and a significant consumer identification number, and finally filing the complaint. The same can be done via the utility's websites, but it also requires logging in or registering the user, filling out some information online, and then filing a complaint.

Remembering Long Customer IDs:- The typical length of a consumer ID is 8 to 16 or even 20 characters. As a result, it is highly challenging to recall the electrical connection's consumer ID.

Creating incorrect bills based on door lock readings:- When human metre readers approach a closed building, they either enter incorrect readings or fail to produce bills, which results in bills not being immediately served based on real electricity consumption. The consumer may receive an average bill based on prior consumption, depending on the utility's rate. However, if the location is identified as locked, there should be some technique to deliver the readings by SMS and the same can be included in the bill production process.

Missed call messaging service suggestion:- The architecture for missed call messaging services is recommended as a fix for the aforementioned problems. The proposed system will automatically deliver the client ID to the linked mobile number. By doing this, the problem with remembering long numbers is fixed, and missed calls can now send a link to a PDF file that has a soft copy of the bill that includes the due date, amount, and due date. Therefore, a missed call might make the duplicate bill or the current outstanding bill of energy usage available in just a moment. This framework also suggests the no-power-supply complaint to circumvent the drawn-out process of submitting the online/customer care centre on phone services.

The structure of missed call messaging service for improving the operation of the current conventional heritage electronic no-power-supply complaint and issue of the duplicate energy bill consists of the following elements.

The following three primary components make up the framework:

- The IoT-based front-end device

Connectors/Adaptors (Mediator for Interface):-

The Middleware (Computing Infrastructure)

- Local Area Network/WifiZone

- The back end Data Storage (Utility Heterogenous Databases at differenct locations or same)

The Front End Device:- A GSM SIM800L, an IIC OLED 1306, an Arduino IDE (for programming the hardware), and an Arduino Uno microcontroller make up the hardware of this gadget. the middleware server's 100 GB of storage, 8 GB of RAM, and 4 core computing system. The Apache Web Browser/Node.js, PHP, MySQL, and the Asterisk VOIP/IVR/cloud telephony service are all included in the Linux Cent OS. Ethernet, WiFi, and local area network connections Databases for consumers and customer service can access the utility billing engine. Depending on the circumstance, internet access may be required for network connectivity if any databases are stored using cloud storage services.

The block diagram and flow chart of the missed call messaging system is explained in this section under following sub-headings.

a) BLOCK DIAGRAM OF missed call messaging service

Figure 3.9 depicts the organisational structure of the missed call messaging service. A utility billing engine and two separate databases—one for consumers and the other for customer care services—are included in this arrangement. The consumer database contains all information about electricity users and their patterns of energy use, including readings from electric metres, billing (the creation of invoices against the cumulative consumption of electricity), and collection data (revenue collection via various methods of invoice payment, such as cash collection counters, online websites, smart mobile phone applications, etc.). The REST API can quickly retrieve the consumers' due amounts (Real-time current outstanding amount against the consumer id) and due dates based on the billing logic described in the tariffs. In our illustration, the Arduino ESP32 microcontroller is coupled with the SIM800L GSM Module. The SIM800L is equipped with one prepaid SIM card from a nearby telecoms provider. The SIM card is there, functional, and available for use. The SIM800L's condition is regularly monitored by the ESP32 microcontroller. The module determines whether WiFi is available whenever a call is received and connects to the WiFiZone for the various network services. In this case, the microcontroller disconnects the request and makes use of a middleware API to maintain its focus on security. The middleware that uses the API takes the customer Ids from the consumer database and verifies the mobile number before moving on. If more than one electrical consumer tag is linked, each consumer ID's balance is evaluated individually, and two different notifications are generated. To use these services, it is possible for several connections to tag over a single RMN.

The consumer number and a few extra arguments, such as authentication tokens, are sent to the API in a JSON-formatted request. The API then responds with the various parameters as well as the payment due amount and due date. A link to the most current PDF invoice is included in the mail along with these two criteria. Additionally, this SMS content is created in JSON format and sent to the SMS gateway servers' API. With this, an SMS with the invoice information is sent to the customer. The MySQL database operating on Linux OS (Cent os) stores the requests and associated logs. The data processing is done using the PHP programming language. Curl, a REST API that is also included into PHP, is used to interface with the utility billing engine for both client billing and the submission of complaints. If such infrastructure is put in place, missed call data may be gathered using cloud telephony services or the asterisk VOIP/IVR API. The originator and destination of the missed call are provided by this API; based on the destination, triggers for low power or invoice information may be invoked. Both the Node.js and Apache web servers support the use of web services. The Apache server executes the PHP REST API when a cURL request is made.

These programmes can be used anywhere and are all free and open source. The Arduino IDE can be used to programme the easily available IoT hardware. Arduio, an open-source electronic platform, is constructed with hardware that is simple to use.

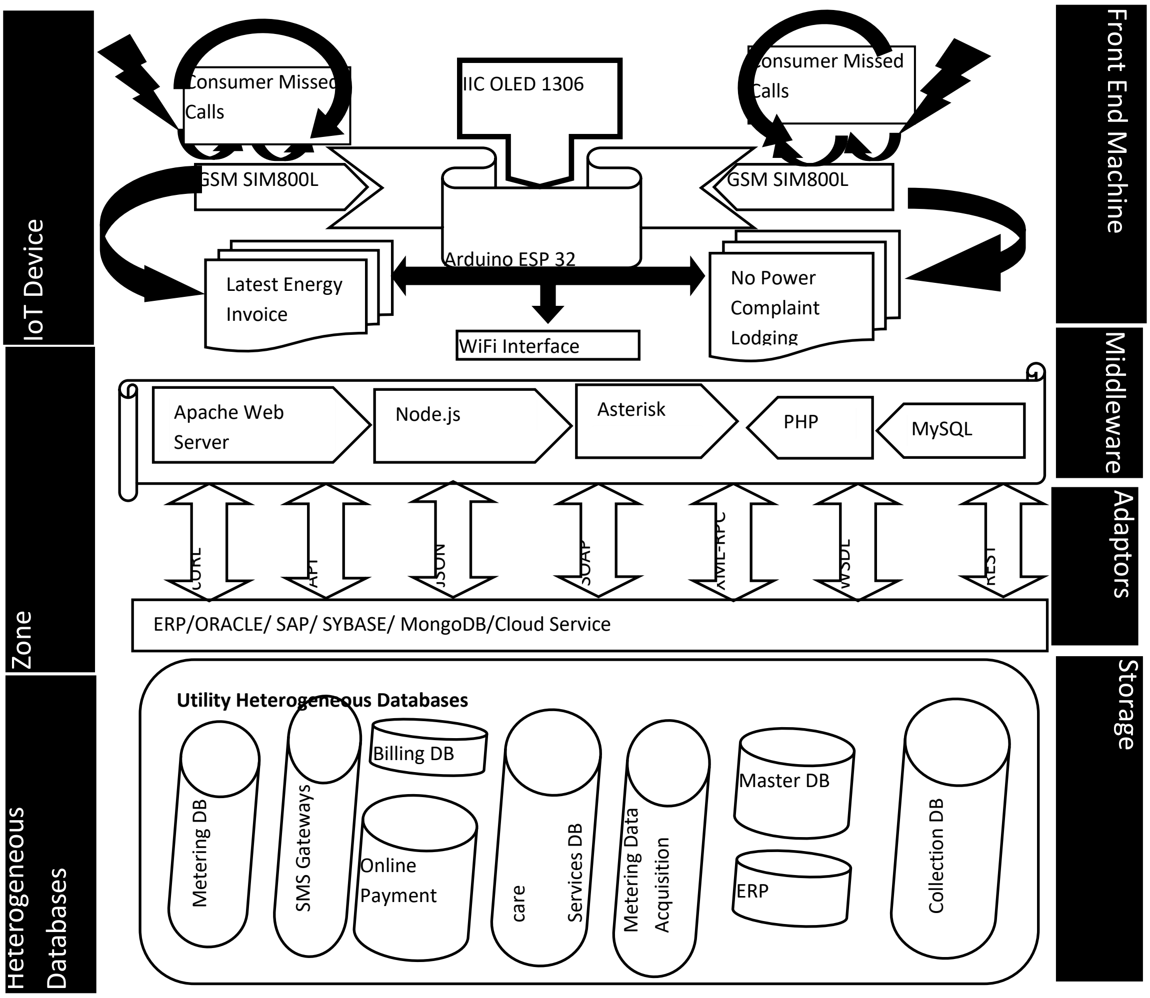


Figure 3.9: Algorithm /Working of IoT Based Device

Missed Call services for users of non-Android phones, according to an algorithm – The steps for handling the missed call services are as follows.

1. The customer phones the utility's missed call number in the first instance.

2. The device is made with an Arduino Uno and a GSM SIM800L module. A SIM card with a particular mobile number is placed inside the module. The device keeps an eye out for any incoming calls, disconnects the call, and sends the mobile number to an API created with Middleware and PHP. The parameters are the mobile number,

which represents the call's originator, destination, date, and time, as well as a token for accessing the API for authentication.

3. The middleware's REEST API is activated. The middleware enters the cellphone number together with the time and date stamp in the MySQL Database.

4. The defined IoT device's API will make use of the REST API included into the framework (or, if not utilising an IoT device, missed call services provided by Asterisk VOIP/IVR or cloud telephony provider). The API will receive the token number and other arguments in JSON format, and it will respond with JSON data. The information will consist of the customer's mobile number.

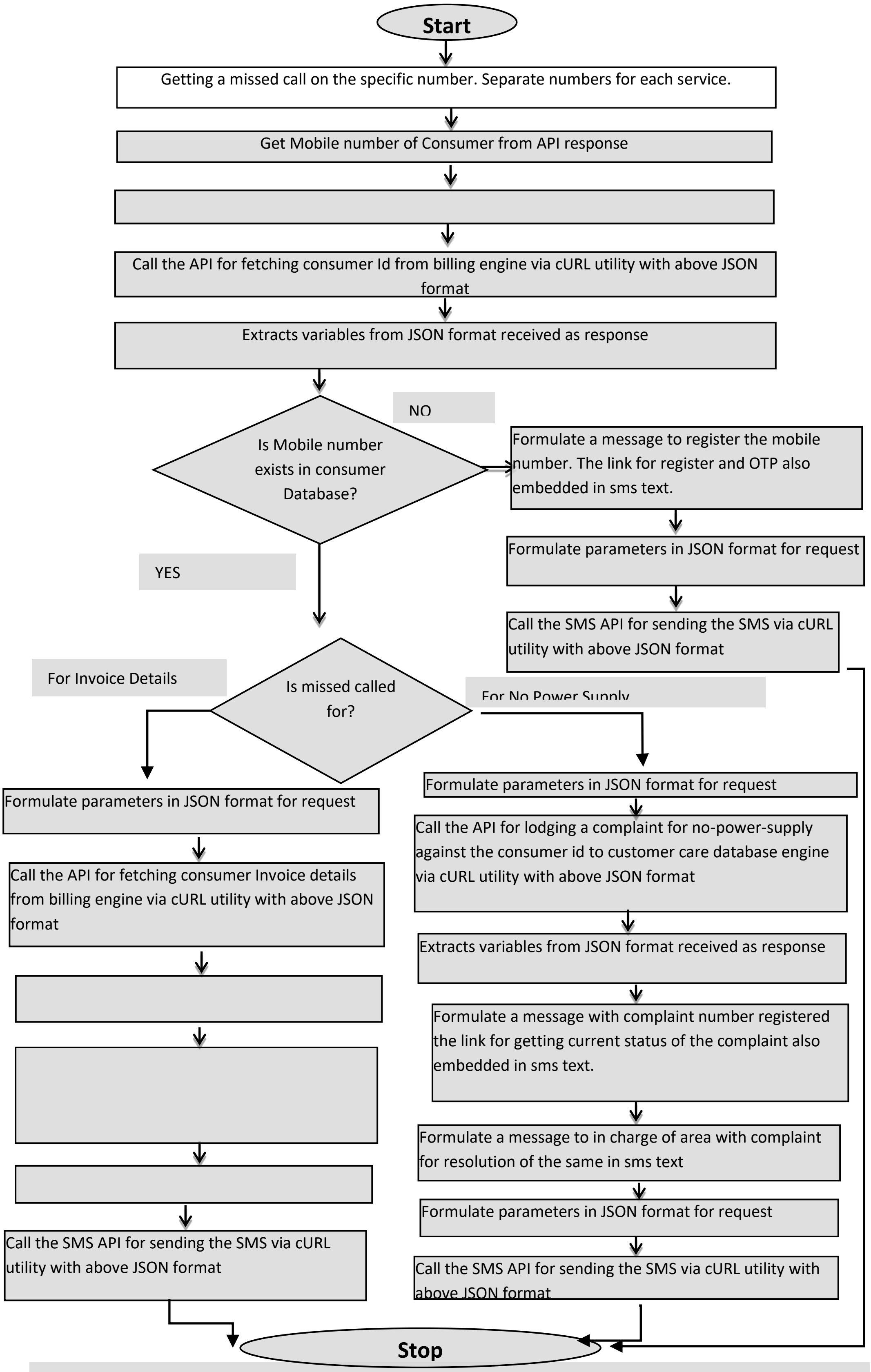
5. The utility end will use the REST API to search the consumer data base using the mobile number in order to find the consumer id.

6. Once the consumer ID has been obtained, the utility billing engine will be asked to get the most recent invoice details in PDF along with the amount and due date of the current payment.

7. The utility billing engine will ask you to submit a complaint of type no-power-supply against the consumer ID that was received if the destination number belongs to a system without a power supply.

8. The SMS will then be suitably prepared for the complaint number or the invoice details, as necessary. The SMS will subsequently be sent to the customer ID-tagged mobile device after calling the message API.

9. An SMS containing a registration link and an OTP for utility web portal registration will be sent to the mobile number if the phone does not already have a consumer ID.



Flow Chart of missed call services for invoice details and No-Power-Supply Complaints

Figure 3.10 flow chart of Missed Call messaging system

The connection between the 3V3 pin of the ESP32 and the VCC pin of the SIM800L is shown in Figure 3.11, which is a schematic representation of the IoT device used to deliver missed call services. The GND pin is attached to the SIM800L's GND pin. If the power supply is provided by an external device, the registers at the GND must be used; otherwise, the SIM800L module may malfunction if the voltages differ in any way from the recommended voltages (normally 3.7V). The SIM800L is a bare chip, hence the voltage controller mechanisms are absent. Always attach the power supply's GND component over the SIM800L before the VCC.

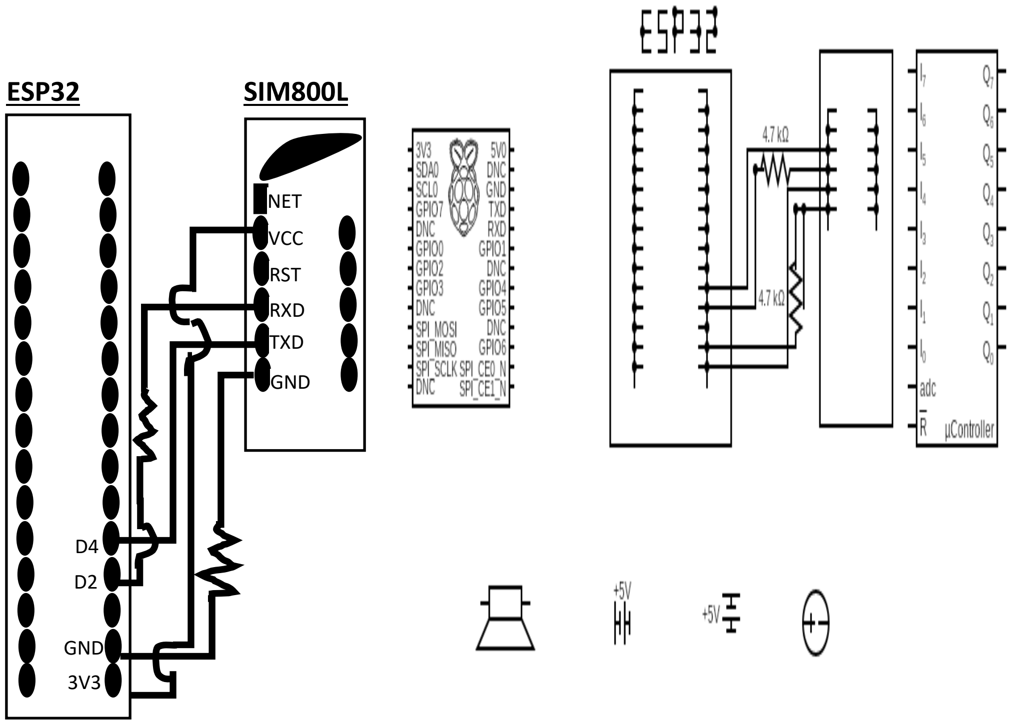


Figure 3.11 Schematic Diagram of IoT Device

If GND is not connected and VCC is reconnected, the gadget may be ruined, just like when disconnecting power supply connections online. Likewise, the SIM800L may enter deep shutdown mode if the current is insufficient. To display the state and functionality of the SIM800L, the module's LEDs can blink.

Working

An Internet of Things starter kit's microcontroller is an Arduino UNO. The mobile number from which the missed call originated can be determined by connecting a GSM SIM8000L module. A Middleware-developed API records the number after receiving the date, time, and caller as parameters. The Middleware API sends the final SMS after identifying the type of missed call, including the invoke data in the case of a balance that is past due and the complaint number in the case of a missed call without power. To obtain basic services with quick responses, the utility urges untagged customers to sign up.

At the middleware server, the data is received and stored in the MySQL Database. The following points were discovered after further analysis of this data.

Both types of missed calls—payment/invoice due and complains about no power supply—are subjected to analysis.

The power companies should implement the following measures in light of this analysis, especially for rural consumers who are unable to access online, Internet, website, and smart phone services.

Initiative for Self-Mobile SMS Registration: When an SMS is received, the Pull SMS capability also works by consuming the middleware's API using the parameters Message and Mobile_number. Further examination of the message's keywords facilitates the consumers' capacity to register via SMS. A customer can only register with this feature by sending ACT consumerid to the proper cellphone number that is used in the SIM800L module. At the next tier, additional operations will be performed using the middleware's API. The high level parameters of SIM800L are used for the fundamental triggering. i.e., the SMS contents and the mobile number.

Self-Meter Reading through SMS Initiative : - The Pull SMS feature also operates, consuming the middleware's API with the parameters Message and Mobile_number as soon as any SMS is received. After further analysis of the message's keywords, a consumer can send readings with the keywords Energy ***** KWH. The utility can then utilise the results to confirm the readings made by the human meater reader. This initiative has the potential to improve the metre reading's accuracy. To improve the quality of the metre reading services, necessary penalties may be applied to the metre reader if a customer uses this SMS capability to report readings and receives an invoice based on incorrect readings reported by the metre reader (Human Representative of the Utility office) in two consecutive invoices. This facility can encourage electricity users to conduct their own assessments.

If the consumer is aware of this facility, he can utilise it to perform the metre reading himself. If the consumer's premises are locked as the human metre reader approaches, he marks the location as a door lock or estimates the readings automatically. Additionally, in the event that the readings are not recorded or are recorded incorrectly, the consumer's correct readings can be compared to previous data to generate a bill based on actual usage rather than average usage.

Initiative for Automatic DT/Feeder Maintenance: If a particular DT's missed calls are more frequent in nature, a DT maintenance appointment should be made for safety considerations and maintaining a higher standard of energy supply for customers.

If the analysis reveals that the breakdown messages of DT/Feeders are extremely low for the given period, the initiative for rewards to the incharge of DT/Feeders may be given to the concerned incharge in order to maintain the employees' high morale. As a result, it can also evaluate how well the power utilities' human resources are performing.

- Realtime messages are available 24 hours a day.
- Missed call messaging is available automatically around-the-clock, without any human involvement.
- 24-hour real-time lodging complaint facility
- The No-Power-Supply complaint facility is available 24 hours a day, 7 days a week, automatically, without any human involvement.

a) Advantages to the power distribution

The following are the Advantages from the design of the framework to the power distribution companies.

1 Human mobility limitations are being applied as of right now because of the lockdown caused by the COVID19 corona pandemic. With the implementation of this idea, fewer people would need to visit utility offices in order to file complaints about insufficient power or collect duplicate bills when physical energy invoices are not received. The suggested model can now only satisfy the two needs for missed call services.

2 Instantly Extraordinary diligence Because the system is coupled with the utility billing engine, the customer will receive an SMS with the real-time outstanding payment and the due date on the mobile device from which the missed call was made.

3 No Power Supply complained in real-time, immediately As there is no login or registration required for the missed call service, customer complaints can be made via the internet using the Android application services on a smartphone. Customers using basic phones can also benefit from the service, particularly those who live in remote areas and are unaware of how smart phones or the internet work. Etc.

4 Automatically Recognizing a complaint

5 The No-Power-Complaint is automatically filed with the utility customer care services when a call is missed. The complaint number made to the consumer and associated with that mobile number is returned by the API used to file the complaint. As a result, an automatic acknowledgement of the complaint is sent.

6 Real-time analysis of a sudden failure

7 The study is conducted using data gathered from missed call services. The analysis can be used to track the performance of a particular DT or feeder. If the failure of a particular DT is discovered in real-time due to overload, a special task force can carry out surveillance duties to determine the cause of the rapid load increase. It may be due to theft by an unidentified customer on the particular DT. This enables real-time examination of the data in a variety of ways.

8 It can be activated for Smart Metres that are Prepaid or Postpaid. If the reconnection is not finished promptly, for instance, the missed call service for No-Power may cause the smart metre billing solution to trigger the event of the recharging of the smart metre to reconnect the customer after the smart metre has been recharged. By doing this, the missed call service can additionally trigger that event if the smart meter's power connection is lost for whatever reason and is not immediately restored due to a communication issue. This makes it possible for the framework to gain from automated reconnection.

9 Consumers' mobile numbers are automatically tagged: Both services provide the link to the webpage where the customer's mobile number may be registered as a web self-service along with the OTP that must be supplied in order to properly tag the mobile number with proper authentication to the customer's mobile number by SMS if the customer's mobile number is not already tagged. Information regarding the tagging process is also available at the linked URL. It is obvious how to use the page for registering a mobile number.

10 Customer service centre calls consumers automatically: - The patterns of missed calls from particular customers might be examined; for example, a regular missed call from a customer asking about their balance and no payment being returned suggests that the customer may be having trouble making good on unpaid debts. Another possibility is that an online transaction won't go through for a variety of reasons, such as a network problem when doing the purchase. Therefore, the customer service department might be automatically prompted with a list of such consumers after studying such consumers. The list of cellphone numbers associated with such incidents is automatically sent to the customer service representatives, which helps increase revenue collections.

3.4.5 IoT based model for Theft Detection

The framework is made for electricity power trading businesses to identify any illegal electricity theft. The (Internet of Things) IoT methodologies are the foundation of the framework. The framework must examine the data for all consumers who have been assigned tags for a particular geographic area. The framework in the first section examines historical consumption data for a certain area. This region may be at the level of the distribution transformer or the feeder, or it could be any place where there is a suspicion of power theft. The IoT devices are added to the metering units of the particular sources in the second section. All of the electricity sent to the particular area will be collected from this source in real-time.

IoT devices will be installed to various electricity supply line segments. depending on the situation, based on the analysis of real-time data gathered by these IoT devices using Global System for Mobile (GSM) technology at the server situated at either a data centre or cloud storage. The framework will identify the precise region that is impacted by electricity theft. In order to monitor the exposed cable and avoid electricity theft, another IoT vigilance gadget is employed to take pictures of the scenario.

The power distribution company's staff are alerted by these devices' real-time reporting to take the necessary steps to reduce losses brought on by energy theft. Modern infrastructure is more susceptible to theft of electricity. If the system is breached, theft may happen thanks to the Advanced Metering Infrastructure (AMI), which is completely machine to machine (M2M) functional. Many researchers have put out their expert algorithms over the past 20 years to lessen electricity theft. The current study suggests improvements to the body of knowledge on identifying and preventing electricity theft.

It is becoming smarter because to the two-way communication capabilities of the advanced metering infrastructure for electrical equipment. The most common problems in all the power distribution businesses of emerging nations like India are power theft, its detection, and prevention. It not only results in financial losses but also in inconsistent, high-quality electrical delivery. There are two different sorts of this theft: metre fraud and power tapping. Such architecture collects the metering data in a single location. Big data tools can process this enormous amount of data to understand and make the right judgements. However, there are still some areas of the distribution system where it is difficult to prevent electricity theft. The Aggregate Technical and Commercial Loss in their yearly reports is rising as a result of the electricity theft. The main goal for electricity distribution firms is to decrease aggregate technical and commercial losses (AT & C Losses).

Every activity in the current world depends on electricity, but there are still defects in the procedures used in the system, which leads to theft and leakage and results in significant energy losses for the society and the electrical supply utilities [8]. The framework put forth in this study is Internet of Things (IoT) based and demonstrates how readings gathered at the metering data acquisition system may be processed for the decision support system to detect and prevent power theft scenarios.

Architecture

A method for instant detection and prevention of theft of electricity supply with the help of IoT Devices is proposed in this framework. The improved framework is modelled, followed by the design and implementation of software and hardware. The energy supply lines are watched for theft under the proposed framework. The initial Internet of Things (IoT) gathers data from a centralized storage , and successive IoT devices are added at supply lines to get status information for pointing out any mismatch. The framework gathers all the data from the various IoTs, and then further analyses it using utility billing engines to compare the real usage with the total consumption of all the consumers tagged along that supply line. Theft is recognised over that particular segment in case aggregated customers over that specific supply lines is falling under the actual consumption tracked by the IoT devices at central computing device(middleware). With the help of the location, this identification section can be condensed even further to locate the precise location. After that, an IoT-embedded camera is put at the alleged supply line surveillance site to provide live site streaming. When power thefts are discovered, the setup can be moved to another location to allow for further detection.

A) Architecture of IoT device for theft detecting framework

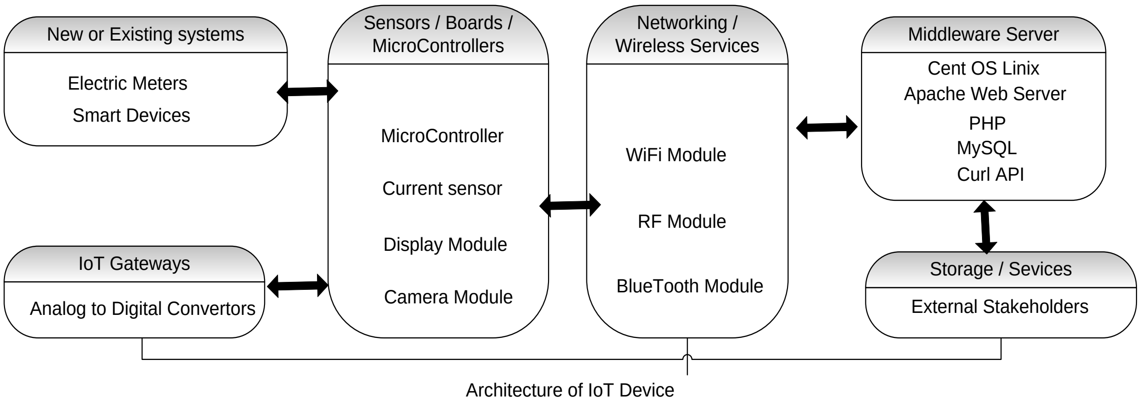


Figure 3.12 Architecture of IoT device for theft detecting framework

B) An effective IoT-based framework for electricity consumption theft detection

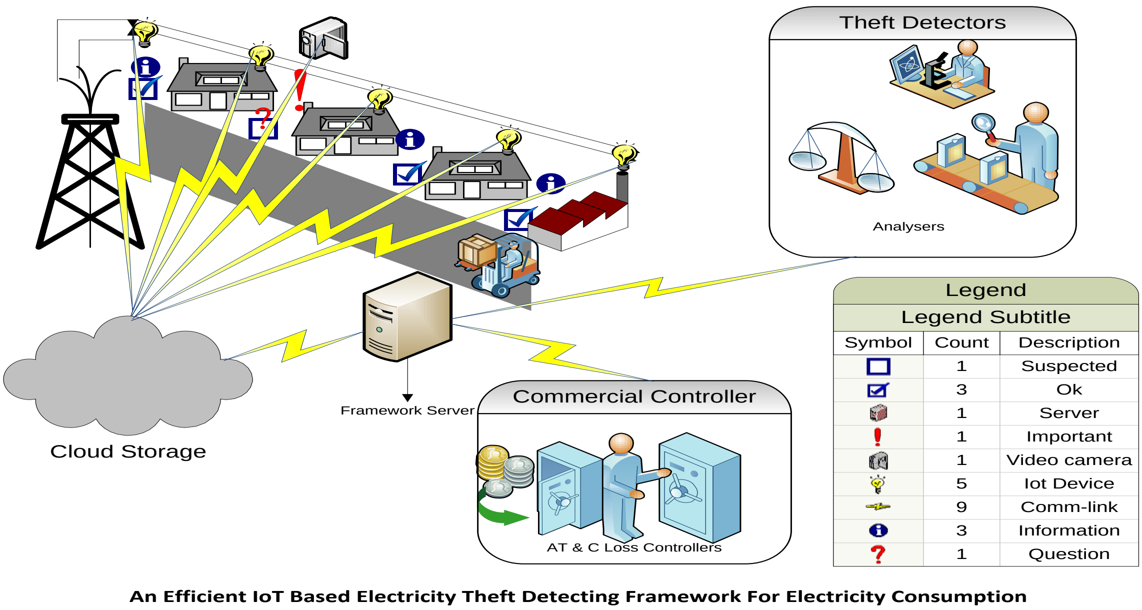


Figure 3.13 An effective IoT-based framework for electricity consumption theft detection

Working

The framework is implemented to detect the electricity theft across an electricity supply segment the IoT device. The data accumulated at a central storage and then analyzed on the visual graphical dashboard. The data can detect the power theft across the supply segment. The accumulated data must be analysed using big data techniques in order to produce helpful recommendations for management to make decisions quickly and accurately. This existing data is being used by the proposed framework to identify the discrepancy in recorded consumption against actual consumption recorded via the supply lines & invoiced units from AMI for the purpose of generating invoices. This unit's gap distinctly identifies the areas where electricity theft is detected. The camera module is also utilised in the suggested framework to feed live video through middleware for surveillance purposes, preventing unauthorised hookups for illicit electricity usage.

3.4.6 VEnvMQTT Model for the Real-Time Data Server

VEnvMQTT model in the IoT environment for the real-time data server is to facilitate fast processing in this research work. This model is helping in achieving the second and third objective of the research work. In the power consumption, the intelligent electronic devices have been linked together over the Internet to facilitate data processing and creation. The data produced by the cloud server/ data center compute infrastructure requires strong and dependable data storage (preferably data lake) as well as protection against illegal data access. Additionally, processing the data requires a wide range of computing power in order to produce useful information. The various business processes include technologies to boost productivity and effectiveness with lower IoT device operating costs. The data handled by edge computing technology results from the data processing. The improvement in response speed, cost-saving bandwidth, and battery life brought about by technological progress have a big impact on workplace security and privacy.

Model for IoT Quality of Service

The term edge-computing method refers to a decentralised system that is a Cloud computing extension with restricted management and control. With the help of the suggested VEnvMQTT model computing, cloud-based administration can expand its reach to the system's edge and provide close-by and active openness to edge devices. The two planes that an edge computing system typically has are as follows:

Forwarding and control planes are terms used to describe the data plane. This aircraft determines the information packets' results. Since they can be appropriated on the system's edge rather than being concentrated on a server, it enables registered assets to be placed anywhere inside the system.

Control plane

It provides a general overview of the system's capabilities and the directing conventions that are used by the building control component. IoT information can now be prepared in a location closer to the sensor that is producing it, such as a smart device or information centre [221].

The category for the edge:- It is consistently necessary in the proposed VEnvMQTT Cloud to rely on Cloud storage and obtain the necessary data transport speed and availability. Due to fog computing, data can be transported locally to the devices for processing instead of being processed on the cloud. The processing will help make gadget data more accessible, convenient, and generally simple to utilise. The development of fog computing will enable data centres and devices to work together in concert. The amount of digitally produced data coming from linked devices and smart things is flooding the planet.

Implementation

With the rise of smartphones, applications that enable them, and a growing number of users accessing data, CPU power, control, and communication with their end devices are continuously rising. The Python-based Virtual Fog Simulator known as PVFOG Simulator has been used to implement VEnvMQTT for Fog/Edge computing with Main and Remote brokers. Figure 3.17 depicts the control flow in the proposed Publish/Subscribe Model-based VEnvMQTT Simulator with Remote and Main Broker. Prior to diving into the specifics of the VEnvMQTT Simulator, the following section discusses discrete event simulation.

The following actions are taken in order for the suggested system to operate:

Step 1: To mimic real-world systems like Arduino and other microcontroller boards, numerous virtual sensors are constructed and compiled into a single class called IoT device.

Step 2: All of the sensor instances are operating in parallel mode, and they are all employing Simpy-derived discrete event simulation techniques.

Step 3: After that, the MQTT Client will be operational on the VirtualIoT devices.

Step 4: Using the IP address of the Remote Broker and the designated port, these clients are connected to the Remote Broker.

Step 5: To ensure that sensor data is posted to the virtual IoT devices at staggered intervals, all virtual devices are operating in parallel mode.

Step 6: Using the appropriate clients, this virtual IoT device will upload these sensor data to the Remote Broker.

Step 7: At the fog level, the Remote Broker will process the data after receiving it.

Step 8: The remote Fog router will relay the data to the primary broker if any value is below the threshold value.

Step 9: If not, the remote broker will transmit the message straight to the clients that have subscribed.

Each layer and each tier are assigned responsibilities in the proposed VEnvMQTT computational approach. This method's assumptions are as follows, and the resulting mathematical model is as follows.

•Each end node has the ability to send any other end nodes, as well as fog/edge nodes, the sensed data through the network.

•MQTT clients are available for a variety of embedded boards, including Arduino and Intel, with a selection of programming languages. Various MQTT client libraries are simple to install on these message boards.

•Nodes designated as Fog nodes have the capacity to share MQTT Publish/Subscribe method topics with one another in order to exchange information.

•One MQTT broker is set up at the fog level, while another is set up at the cloud level. Both brokers are Python-based. The backhaul network has been used to establish communication between the brokers using the MQTT protocol over TCP/IP. Below is a discussion of the components employed in this mathematical model to determine various latencies.

3.4.7 AI Based Energy Efficiency Framework

An efficient AI-based framework for energy efficiency in smart homes is created for the best possible use of electricity, moving the load throughout the day with a focus on consumer financial and electrical benefits for demand control during peak loads. This article presents a comprehensive examination of the instantaneous maximum load in a smart home. The suggested framework prioritises the smart appliances in accordance with tasks and schedules in that order, keeping load time of the day in mind, to avoid paying a tariff penalty for exceeding the sanctioned load. An embedded IoT appliance device uses an upgraded smart home architecture to control load. Big data is utilised by the framework's HDFS design to rapidly and precisely manage the demand for electricity. The framework automatically manages the patterns of electricity usage using machine learning and artificial intelligence approaches. In addition to helping power distribution companies meet customer demand for high-quality electricity, this tactic also helps consumers save money. Several sampling strategies, machine learning algorithms, and big data approximation frameworks are explored for analysing the patterns of power use and adjusting the schedules of the household appliances in compliance. This framework employs state-of-the-art automation and a standalone controller.

The ROPOSED ML-based system is state-of-the-art in terms of improvement across the board, from data ingestion through analysis to dashboard visualisation for energy-efficient smart home electricity use. The suggested architecture captures the interdependencies using knowledge-based building blocks from a variety of methodologies among the many sequential stages of the big data value chain. i.e., ingesting data from metered data collecting systems, storing data, analysing big data, and visualising it while taking the 3Vs' dependencies into consideration. The HDFS environment is used to process the very large files. For our improved architecture, Microsoft Azure supports capabilities like clustering tasks on R server for distributed processing. Numerous mathematical prediction algorithms from the statistics library are employed with this big-data module for the free and open-source statistical programming language R. Apache As part of the framework's applications, Kafka is listening to microservices that contain a number of data types, including structured, semi-structured, and unstructured formats. In the suggested framework, the three primary threads of the data intake process are extraction, transformation, and loading.

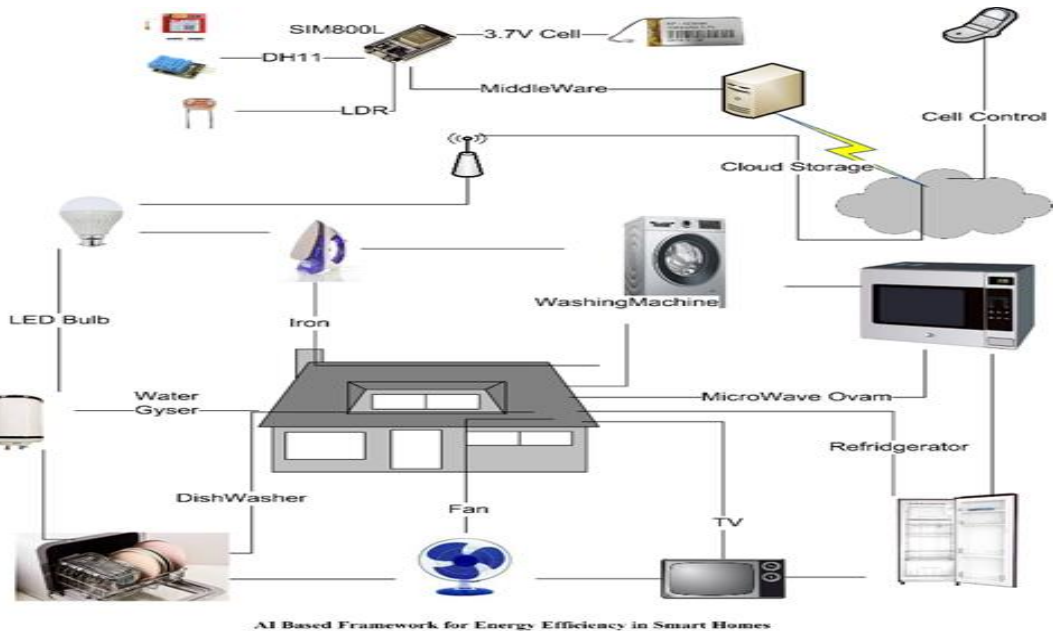


Figure 3.14 AI based framework for energy Efficiency in Smart Homes

Component

The above graphic depicts the Micro-Controller Unit (MCU) and different sensors that make up the IoT-based system. The DHT11 sensor is used for temperature, humidity, and Reed switches. The proximity sensor used by the Light Dependent Register, which is powered by an applied magnetic field and detects door openings, is incredibly sensitive to light. Since the sensor's resistance changes as soon as light strikes it, it can be used to measure outdoor light and regulate streetlight functionality by turning them on and off as necessary. This system collects real-time data from the sensors and transmits it to a middleware platform using the open-source Linux operating system, PHP, and MySQL as the database. The relay switch allows for the on/off control of many electrical appliances that are connected to the IoT device. This middleware server creates the curl APIs for a variety of purposes. This Internet of Things gadget connects all of the instruments to this middleware over Wi-Fi. To power the IoT gadget, a 3.7V battery is attached to this module. This Internet of Things gadget has Wi-Fi access because of the home network. Additionally, the IoT device includes an integrated SIM800L for cloud connectivity. The cloud and middleware are connected by internet access.

For instance, the framework will start the triggering events and switch on the lights if the sensor detects low light or darkness in the yard of the home. In a similar manner, the directive to turn off the air conditioner will be carried out if the temperature falls below 18 degrees Celsius. The light will turn off after a set amount of time if there is no activity in the room. Having the framework handle such situation-based triggering allows for several energy-saving opportunities.

The numerous sensors communicate with the middleware server, which then relays the information to the IoT devices coupled to the smart home appliances for effective control and management. Like When the air conditioner is turned on, IoT-connected windows will automatically close. It will switch off the light if there is motion or activity inside the room. The light in the yard will turn off as it gets brighter. If power prices are low, the real-time instantaneous tariffs will send instructions for the operation of laundry and other heavy loads. If electricity prices change to a high level, the connected appliances in the smart home will receive the appropriate commands.

Experimental Setup

The system is set up in two distinct layers for conducting the experiment: a processing layer and a visualisation layer. Database-based processing is carried out in the RDBMS (Relational Database Management System) using processing tools like SQL (Structured Query Language), whereas file-based processing in the processing layer is carried out in batch mode or in real-time mode depending on the circumstances. mLib and TensorFlow are integrated with Apache Spark to do real-time big data analytics and provide analytics services as data as services, while Hadoop Mahout is used for the operational side (DaaS). To capture the unstructured data produced at the numerous information sources, such as Twitter, Google, Facebook, or any other social media platforms, with real-time streaming, Spark clusters and Kafka clusters are utilised.

The reliability and value of unstructured data are the main topics of big data transformation. The urge for transformation of this unstructured data results in the loss of the value and veracity of the big data. Customer relationship management, corporate resource planning, and manufacturing resource planning all provide structured data sets. In contrast, unstructured data with a range of patterns, such as text, images, XMLS, and data gathered from actuators, sensors, smart metres, among other makes and models, make up the values, grievances, complaints, and concerns that are spoken on social media.

Model Stages

Srage 1: Collecting, Preprocessing, and Storing Data.

In this step, data from smart devices, such as smart metres, is gathered and accumulated in real-time at the MDAS in non-uniform data formats, such as XML,JSON, RawFormat, CSV, SDF etc. The weather/climate variables are gathered through the web API for stations' online real-time weather data in the JSON, CSV, XML, or RawFormat formats. as well as additional pertinent information gleaned from an online survey of social media platforms.

Before being fed into the framework in the Hadoop distributed file system in the NoSQL database, the data is taken from the aforementioned raw data acquisition servers, cleaned, validated, and filtered, and then transformed into pertinent information. This data is processed on the HDFS distributed nodes.

Stage 2:- Clustering & dimension reduction in stage two. The LD(load-profiles) are identified during clustering, and during dimensionality reduction, the most crucial attribute of the proposed framework is selected.

Stage 3: ANN-equipped proposed framework , For the suggested framework, the ML algorithms are being run concurrently by the processes, for the past day, for example. Then it chooses the algorithm that performs the best in terms of Root Mean Square Error and uses that algorithm to anticipate how much electricity will be used over the course of the next 24 hours.

By classifying consumers into pertinent groups and taking into account how closely their purchasing patterns resemble one another, the performance of the suggested framework is enhanced, with RMSE dropping from 4.12 to 1.42. Results are contrasted using measures including RMSE, correlation coefficient R, average, minimum, and maximum absolute error, timestamp, metre id, reactive power, perceived power, and active power (electricity usage), among others. Since the weather has a big influence on how much electricity is used, weather information should be used as input. On weather websites using web APIs or at weather stations close to the consumption place (apartments, residences), precise weather data and forecasts can be found.

Users with similar consumption patterns are then grouped into load profiles using the k-means algorithm. K-means organises instances (consumers) around k centroids according to how closely related they are. It is an unsupervised machine learning technique. Clusters result from this. The distance between two instances is determined using the classical methods of Euclidean, Manhattan, or Mahalanobis. We looked at three feature selection methods: lasso regularisation, recursive feature elimination (RFE), and univariate selection. Each cluster's centroid value (k) is initially chosen at random, and then steps are carried out iteratively to study their influence (LassoR).

Implementation And Experiments

The R parallelization and MapReduce packages are used to build this architecture. During implementation, the data set from the model trainer and the framework technique are mixed. The KWH (Kilo Watt Hour), V (Voltage), f (Frequency), pf (Power Factor), TOD (Time of Day), and KVAH, among other power consumption characteristics, are used to construct the data set. On the basis of desired parameters, such as U. (m,b,c), it generates training data subsets. This enables the gathering of historical electricity usage data in one place and the speedy processing of the data for real-time analysis using big data analytics. As we examined the information on electricity use in smart homes and applied the knowledge we had acquired, we discovered a number of ethical challenges that had an effect on our implementation decisions and strategies for solving the issues.

We first investigated various data partitioning strategies, including round-robin, hash, range, and random data partitioning before creating our AI-based platform. It is a well-organized, balanced data partition because round-robin uses a sequential scan method on the full dataset using range queries, making it difficult to examine. Hash partitioning also does a sequential scan of the full data set, even though it is more suitable for point-based searches than range queries. It is restricted to properties that can be partitioned because only one partition attribute has to be searched. Range partitioning scans the entire data set as well, and because all processes are running simultaneously, this could cause execution skew. Because only a small or single partition is searched, it is a well-organized, balanced data partition that works well for both point and range queries. When records are partitioned randomly, the data partitions are roughly balanced, they are dispersed randomly and without respect to order, and they need additional computations to calculate random values.

3.5 Methodology To develop a model for enhancing the Decision Support System of MDAS using the bigdata concepts

3.5.1 Design Goal

AIBTBF (Artificial Intelligence and Big data Techniques Based Framework) is a framework to enhance the DSS (Decision Support System) of MDAS (Metering Data Acquisition System) in electricity consumption for energy efficiency. The core processes of the Revenue Management System (RMS) i.e., Metering, Billing, and collection (Mare) are studied in the context of the Electricity Consumption. This paper proposed an efficient framework after reviewing & analyzing various methods in practice along with their impacts on electricity consumption. The framework is integrated with Information Technology (IT) and Operation Technology (OT) of the electrical system resulting in a high volume of data needs velocity in processing and accumulated variety of data in structured, semi-structured, and unstructured variables. The proposed framework implemented big data analytics and artificial intelligence to enhance the decision support sys-tem with real-time accurate and effective decisions. The direct variables for energy efficiency i.e. billing efficiency and collection efficiency are minutely studied in context with IoT techniques. Key indicators for energy efficiency and demand management are also studied to achieve the primary goals of the distribution companies to provide quality supply 24X7 to their valued consumers. The paper analyzed the current emerging techniques with limitations and suggested recommendations for best use case scenarios in the prediction and optimization of the existing business process. The AIBTBF framework is designed for enhancing the DSS of MDAS in energy efficiency with the Hadoop-based cluster environment, which includes Hadoop Distributed File System (HDFS) Hive, Pig, Yarn, and other components. Similarly, the proposed framework uses MapReduce and Parallelization packages. The data is stored at the data lake on HDFS.

3.5.2 Architecture

The framework is conceptually divided into the four parts as enumerated below: -

- ***Part-I:*** In the first part of the framework, the data of the metering extraction and preparation of input data from the consumers and electricity feeder meter data along with other master data of the utility billing engine.
- ***Part-II:*** In this part, the extracted data is transformed into meaningful information and loaded at the data lake built on the Hadoop distributed file system.
- ***Part-III:*** In this part of the framework, the data is analyzed with the help of the deep learning algorithms, the data patterns are plotted with the help of the historical data. The models are trained with the data set of the historical data consumption of the electricity. Similarly, the future demand is forecasted keeping the season, weather, working or holiday or any festival events etc. in the influencing parameters.
- ***Part-IV:*** In this part, the visual dashboards consist of the suggestions and recommendations are generated by a decision support system using artificial intelligence and big data techniques.

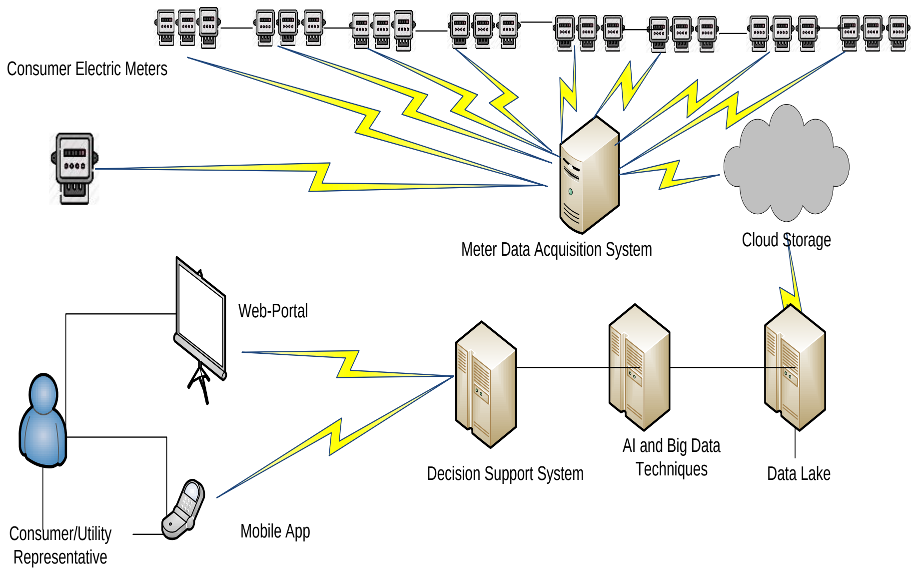


Figure 3.15 Architecture of metering data acquisition system

As depicted in Figure 3.15, the data from the electric meter (installed at the consumer premise along with the feeder) is accumulated at the central place i.e., data center or cloud storage. This data is landed over the Meter Data Acquisition System (MDAS) which further goes to the data lake with the help of the data loading methods. The data lake is on the Hadoop distributed file system for catering the storage of a huge volume of data, processing with the high speed with map-reduce framework, and non-uniform data format i.e., structure, semi-structured and unstructured. Artificial Intelligence and machine learning engines are used to provide efficient visual dashboards in real-time for prompt decision-making. These dashboards are easily available on the web-portals as well as in the customized mobile application dashboard for ease in the operations.

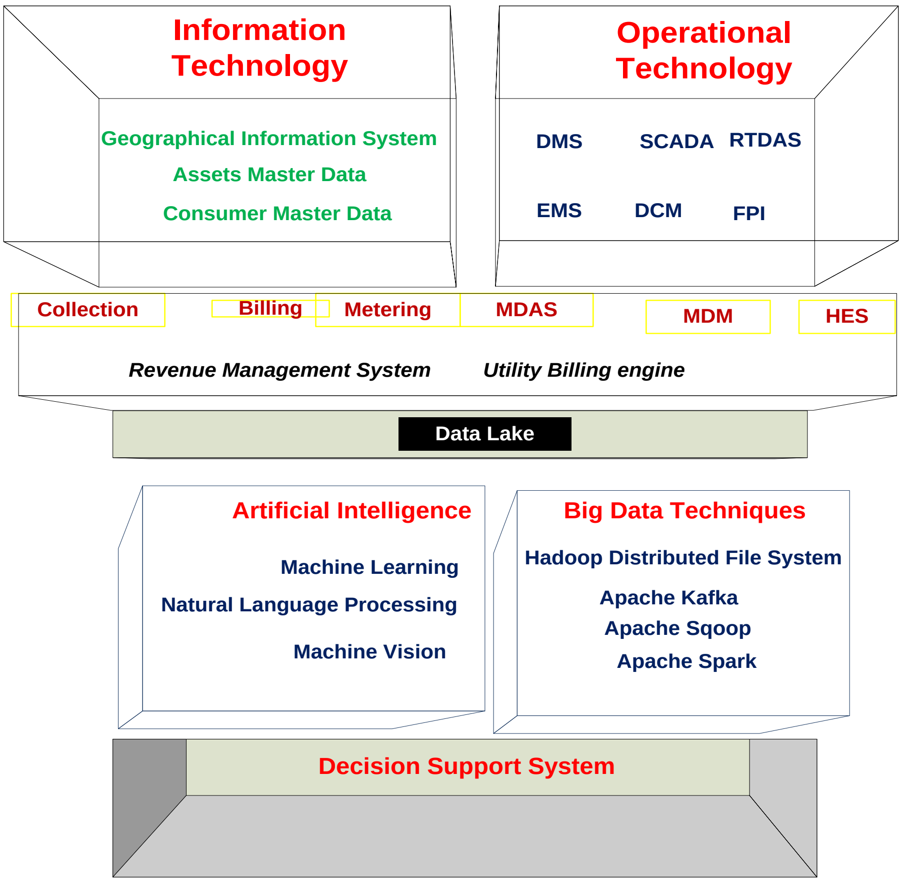


Figure 3.16: Block Diagram of AIBTBF

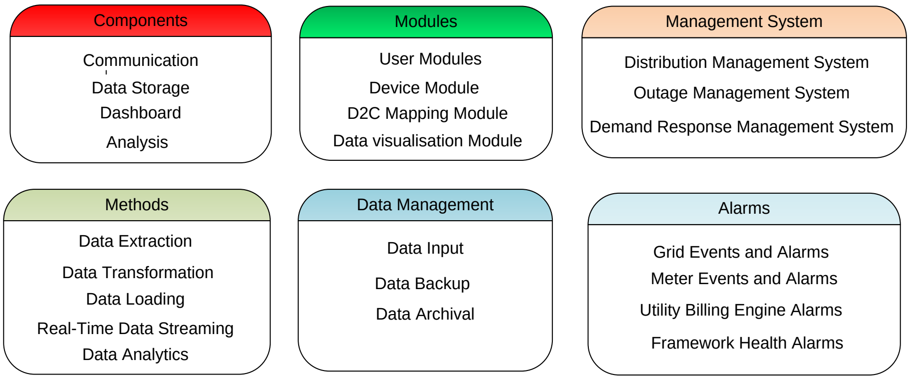


Figure 3.17: High Level Design of AIBTB Enhancing DSS of MDAS in Energy Efficiency

The block diagram of the proposed framework is given in Figure 3.17. The Information Technology, Operational Technology, Revenue Management System, Utility Bill Engine, Data Lake, Artificial intelligence, Big Data Techniques, and Decision Support System are the main technological components of the proposed framework.

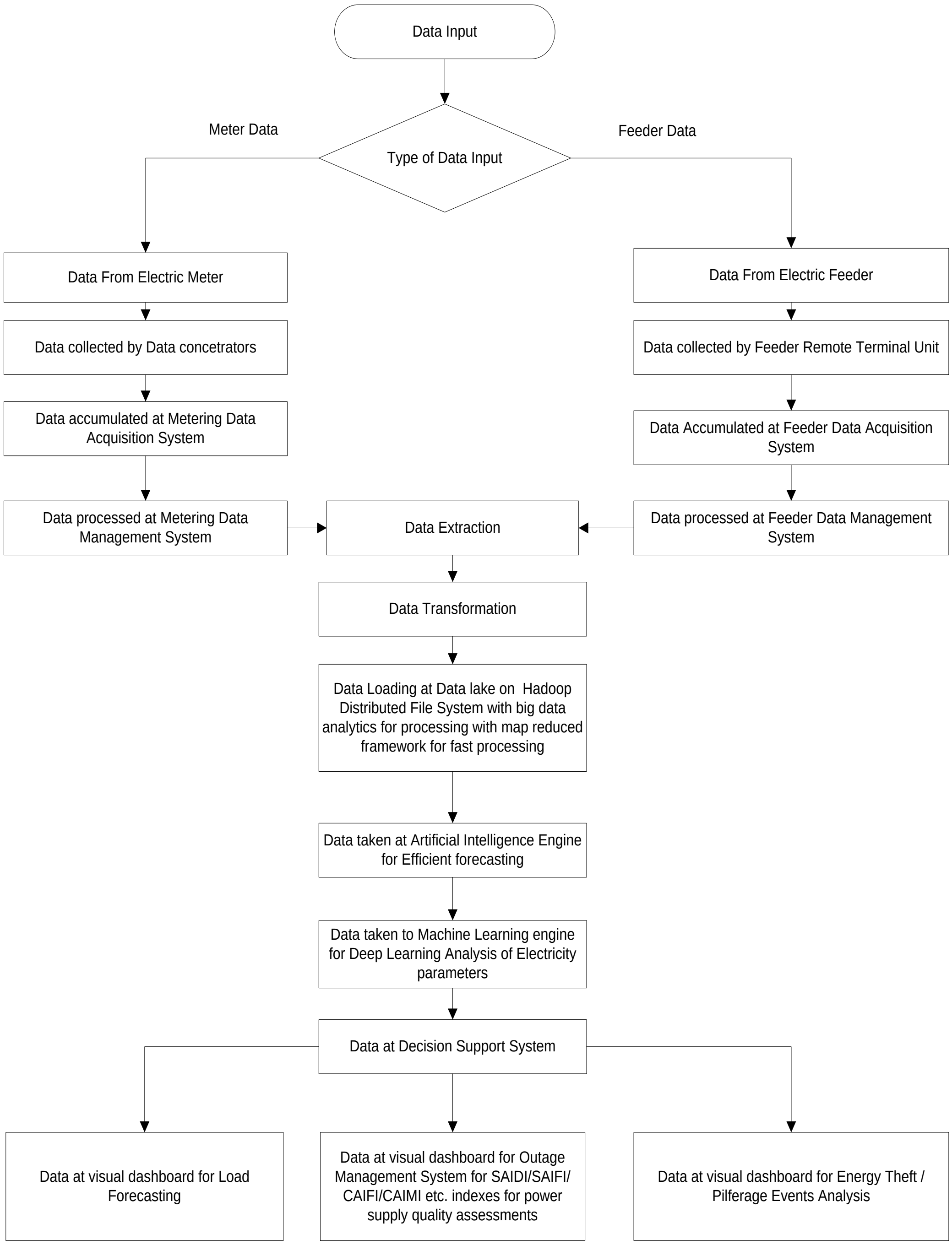


Figure 3.18: Data Flow Diagram of the Proposed Framework

3.5.3 Implementation

The design of the proposed framework to enhance the decision support system is divided into a total of six parts namely, the components, modules, management system, methods, data management, and alarms as shown in Figure 3.17. The network communication, data storage, visual dashboard and data analysis are the main components of the proposed framework. The framework consists of four modules for proper autonomous functioning of the framework. The user module takes care of the users for the operational aspect whereas the device module takes care of the device related operations. These operations are socket mapping, creation, joining, and binding of the devices with the consumer's database via the D2C mapping module. The visualization module will show the dishoard in the form of data visualization in various reports. The management system consists of a distribution management system, outage management system, and demand & response management system. The proposed framework stores the data in the HDFS environment. Therefore, it uses data extractions, transformation, and loading methods. Also, real-time data streaming and data analytics methods are used to analyse the real-time data. The data is handled by the data management part of the framework for the data input, output to the framework along with the backup and archival with the defined data age policy for retention of the data. In the alarms part, the grid events, meter events based on the feeder and meter data acquired at metering data acquisition system are generated and prompted accordingly. The utility billing-engine and framework health auto identification are also embedded in the framework as depicted in the Figure 3.18.

IoTs are used in this research work to capture the consumption details from the user through the proposed IoT device. The device has the capability to communicate with the central place, through the IoT device. The suggested VENVMQTT Model, also known as a Virtual Edge Computing Architecture Model for the Real-Time Data Server in the IoT Context, improves edge computing processing. In order to process and generate data, a number of smart metering devices have recently been connected via the Internet. According per our suggested strategy, an embedded RS232 port was inserted into the IoT device to transform its functionality into smart functionality. The data produced by the cloud server requires strong and dependable data storage as well as protection against illegal data access. Also, processing the data requires a huge variety of processing power in order to produce useful information. The various business processes include technologies to boost productivity and effectiveness with lower IoT device operating costs. The data handled by edge computing technology results from the data processing. The improvement in response speed, cost-saving bandwidth, and battery life brought about by technological progress have a big impact on workplace security and privacy. This proposed model provided a Virtual Environment Based HTTP Server Model known as (VEnvMQTT) for effective data processing in the edge computing architecture of the IoT environment. The suggested VEnvMQTT idea is made up of actuators and data from IoT servers. The recommended VEnvMQTT model uses edge computing technologies to examine the sensor data at a speedy rate. The simulation data analysis shows that the proposed VEnvMQTTmodel achieves a reduced latency of 24.566ms, or around 20% less than the existing MQTT model.

Initially, at the simulation scenario, the data is accumulated at the test bench server, the huge data generated by the IoT devices at a very short interval to get real-time statistics about the power consumption, the Cloud computing is used to store this huge data over the cloud. Cloud computing is sued to get the instant infrastructure to carry out the project work. The local server is able to serve the services very fast. The Software as Service (SaaS) model is best suited for the instant compute infrastructure requirement from where the services of the software are acquired irrespective of the place where the data resides with reliable infrastructure with security. The data is generated frequently by each edge computing device as well as the IoT devices used. The size of a record of a single IoT is 2KB. During the simulation scenario, the iterations of the single IoT device for string the record of a month is calculated and an analysis is carried out in the graphical form as Yearly Proposed Prototype Data Storage Estimation based on Electricity Power Consumers data extracted from internet ceicdata.com[190] for the year 2021 as below:

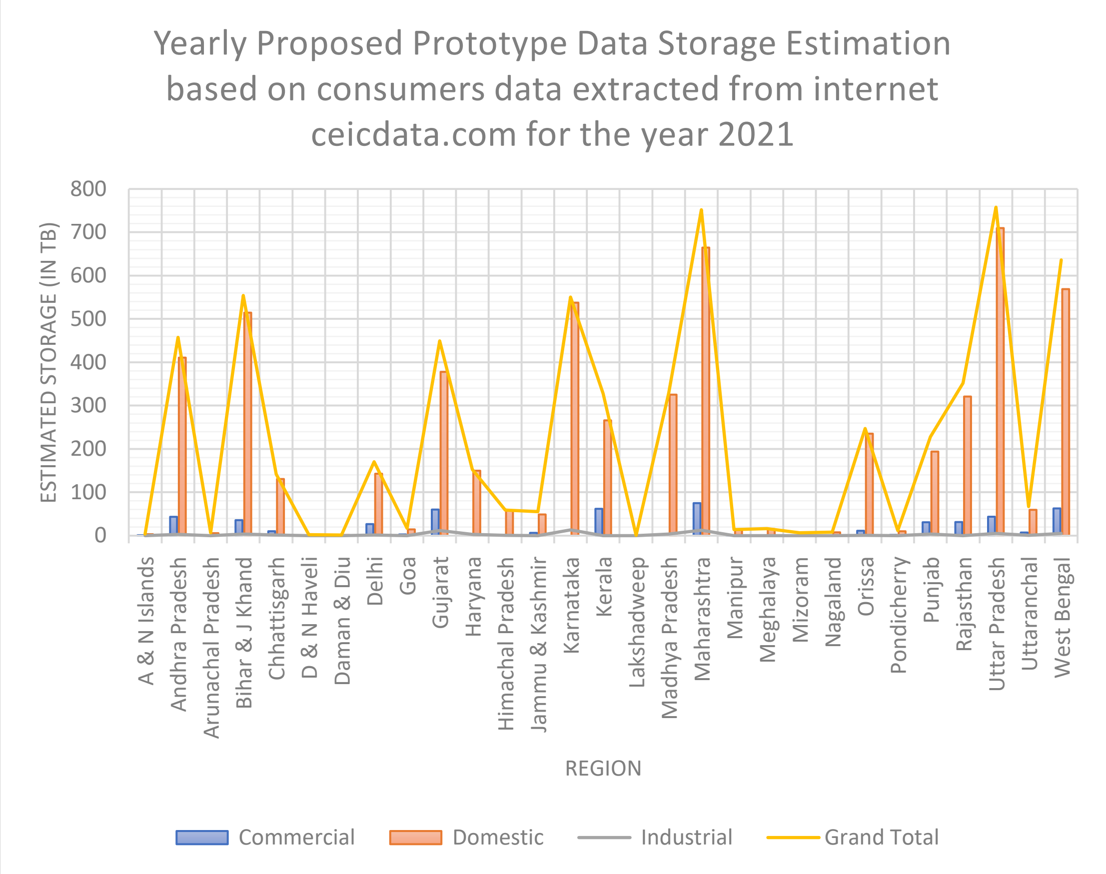


Figure 3.19: Yearly Proposed Prototype Data Storage Estimation based on consumers data extracted from internet ceicdata.com [190] for the year 2021

The above figure clearly mentions that there are a few regions, where the consumer count is very less and has no any growth of the data every year, but there exists some states where the consumer count in the domestic as well as in the non-domestic area is very high. The storage consumption is also proportionally high ranging from 500 to 1000 TB of data storage. For real-time decision making and showing the processed information on the visual dashboards, the processing of this big data is done with the help of the map-reduce framework. The iterations of the metering data is processed in the batch of the distribution transformer wise consumers. The information is processed from this huge collected data at metering data acquisition system.

3.6 Methodology To compare the performance of developed model with the existing model

3.6.1 Design Goal

This section is elaborating the comparison of the developed model with the existing model. The key impacting parameters are accumulated and then analyzed with the help of the graphical presentation.

3.6.2 Simulation Environment

The performance of the proposed multi-tier Fog computational model and the conventional VEnvMQTT-based IoT model is evaluated using various types of latencies. These matrices' mathematical structure. The performance of the planned service latencies for the various clients is computed in Table 5.1 using the measured simulation parameters taken into account.

Table 3.1: Simulation Environment

Description	VEnvMQTT based IoT	Multi Tier Architecture
Actuators (Virtual)	100	100
Sensor (Virtual)	100	100
IoT Devices	100	100
Brokers(Roof Main)	3	1
Brokers(Remote)	5	10
Time (Simulation)	2000	2000

The table 3.2 compares the packet transmission count for various client counts and delivers an analysis.

3.6.3 Comparison of Packet counts

Table 3.2: Comparison of Packet counts

Number of Clients	Traditional MQTT	Proposed VEnvMQTT
1000	1767	1456
2500	6348	5987
5000	12398	10934
7500	14936	11387
10000	18369	16298

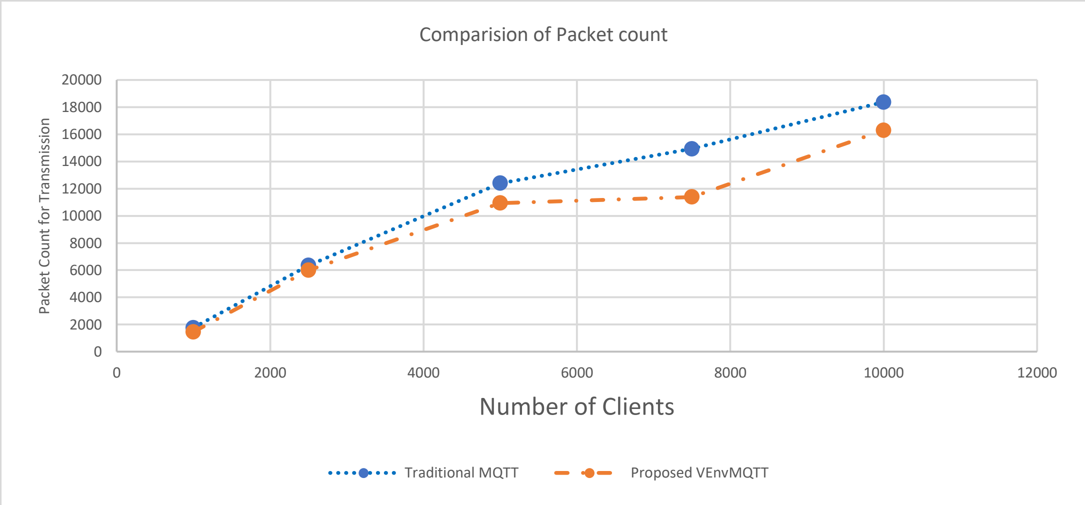


Figure 3.20: Comparison of Packet Count

According to the analysis, the suggested VEnvMQTT model achieves the lowest service latency when compared to the conventional MQTT model. The comparative study of the packet count is shown in figure 3.20. The suggested VEnvMQTT model is compared to the traditional MQTT model in Table 3.3 for comparison.

3.6.4 Comparison of Service Latency

Table 3.3: Comparison of Service latency

Number of Clients	Traditional MQTT	Proposed VEnvMQTT
1000	13.67	8.73
2500	17.45	9.83
5000	19.83	11.84
7500	21.85	13.67
10000	28.74	16.83

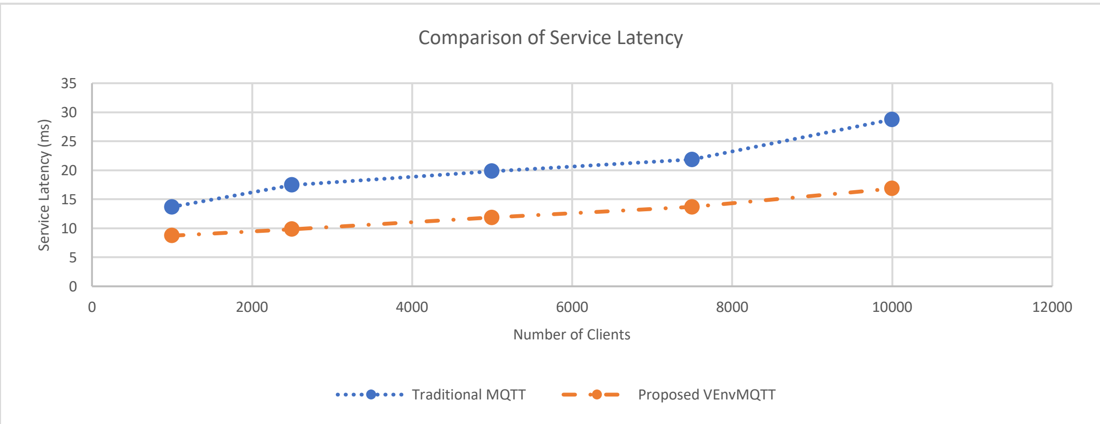


Figure 3.21: Comparison of Service Latency

3.6.5 Comparison of Transmission Latency

Table 3.4:Comparison of Transmission Latency

Number of Clients	Traditional MQTT	Proposed VEnvMQTT
1000	9.84	4.34
2500	18.94	7.83
5000	23.72	10.83
7500	29.74	12.85
10000	33.64	14.78

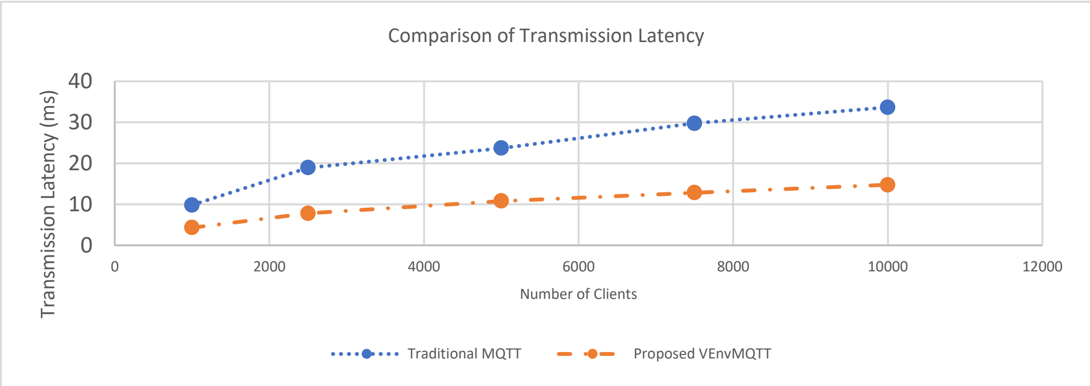


Figure 3.22: Comparison of Transmission Latency

3.6.6 Comparison of Processing Latency

Table 3.5: Comparison of Processing Latency

Number of Clients	Traditional MQTT	Proposed VEnvMQTT
1000	4.667	2.876
2500	4.893	2.969
5000	5.672	3.045
7500	6.782	3.567
10000	7.346	3.856

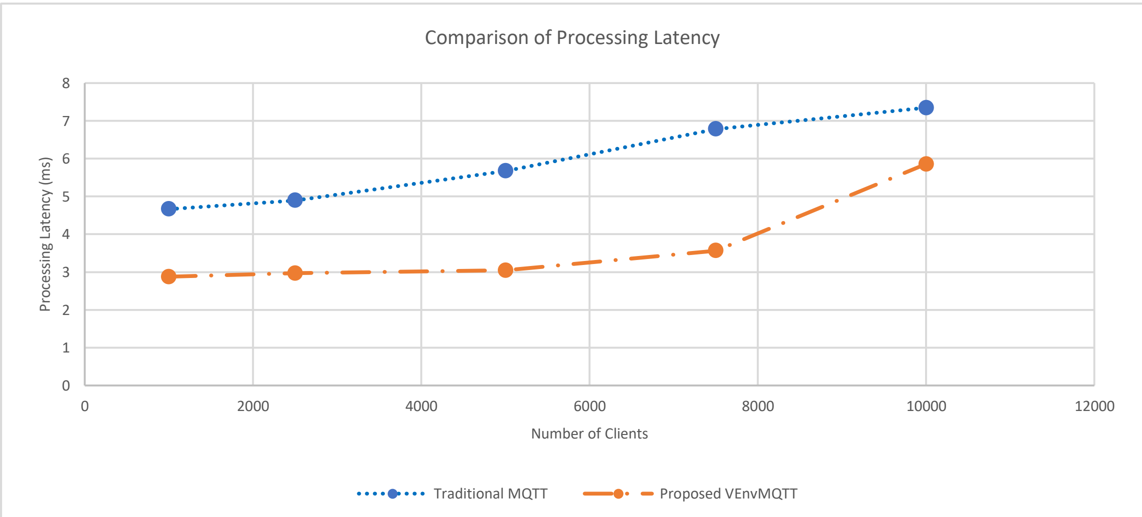


Figure 3.23: Comparison of Processing Latency

The transmission and processing latency for the various client counts ranges from 1000 to 10000 in tables 3 and 4. According to the comparison investigation, the suggested VEnvMQTT model has less latency than the conventional MQTT. The comparison between the proposed VEnvMQTT and the conventional MQTT is shown in Figure 3.20-3.22.

According to the simulation research, processing in an environment with edge computing grows as queue wait times increase. The suggested VEnvMQTT model outperforms the conventional MQTT model in terms of processing rate, which is 20% greater. Performance is attained with the edge computing paradigm using cloud analytics for the IoT platform. The transmission latency is 35% less than that of traditional MQTT. Analysis has revealed that the suggested VEnvMQTT model outperforms the conventional MQTT model in terms of quality of service.

3.7 Security Analysis

The security analysis is and important aspect in the electricity consumption specially when advanced metering infrastructure, smart grid, SCADA etc. are operational in the utilities. A thorough security analysis is crucial.

The following are some parameters considered while performing the security analysis:

3.7.1 Threat Modeling

It identifies the potential threats to the security and privacy of the system or data involved in the proposed research work of the electricity consumption. It clearly defines the threat model, including potential adversaries and attack vectors.

3.7.2 Vulnerability Assessment:

It conducts a systematic assessment of vulnerabilities in the system. It identifies the weaknesses in hardware, software, network configurations, or other components.

3.7.3 Risk Assessment

It evaluates the risks associated with identified vulnerabilities. It prioritizes risks based on their potential impact and likelihood.

3.7.4 Data Encryption

It assesses the use of encryption mechanisms for sensitive data of the electricity consumption, AMI, SCADA, Outage management system and distribution management system. It ensures that data in transit and at rest are appropriately encrypted.

3.7.5 Access Control and Authorization

It evaluates the effectiveness of access control mechanisms. It ensures that only authorized individuals or systems have access to sensitive information.

3.7.6 Authentication Mechanisms

It assesses the strength and reliability of authentication methods. It considers the multi-factor authentication for enhanced security.

3.7.7 Audit Logging

It implements the comprehensive audit logging to track system activities. It analyzes the logs to detect and respond to security incidents.

3.7.8 Incident Response Plan

It develops and documents an incident response plan. It specifies procedures to be followed in the event of a security breach or privacy incident.

3.7.9 Compliance with Regulations

It ensures that your research complies with relevant data protection regulations and standards.

It clearly articulates how your work aligns with GDPR, HIPAA, or other applicable frameworks.

3.7.10 Privacy-Preserving Techniques

It incorporates the privacy-preserving techniques such as anonymization or differential privacy in the electricity consumption. It evaluates their effectiveness in safeguarding user privacy.

3.7.11 Secure Development Practices

It considers the security from the early stages of development. It follows secure coding practices to mitigate the risk of vulnerabilities.

3.7.12 User Awareness and Training

It assesses the level of user awareness regarding security and privacy practices. It implements the training programs if necessary to enhance user awareness.

3.7.13 Reduction of Attack Surface

It minimizes the attack surface by disabling unnecessary services or features. It employs the principle of least privilege.

3.7.14 External Security Audits

It considers the engaging external security experts or organizations for security audits. It obtains independent assessments to validate the security of the system.

3.7.15 Continuous Monitoring and Improvement

It implements the continuous monitoring of security measures. It regularly updates and improves security protocols based on evolving threats.

The above parameters in the proposed research work in aspect of the security analysis, it equipped to identify, mitigate, and communicate the security and privacy measures implemented in the proposed research work. This not only strengthens the integrity of research work but also ensures responsible and ethical handling of sensitive information in the smart grid, electricity network in the electricity consumption.

3.8 Summary and Conclusion

This section explains every model and framework created to accomplish the goals of the research project. In this section of the thesis, the architecture, components, work flow, flowcharts, methods, and algorithms are thoroughly detailed. In the future, R/F-based IoT may be developed to establish a mesh technology, and NAN might help with the aid of fog computing concepts to transfer the information in real-time to the primary controller of the power distribution companies. The frameworks are intended to identify electricity theft on an as-needed basis. The above-discussed IoT-based converter enhances electricity metre reading techniques. When the performance of smart metres based on IoT is analysed, it is revealed that this technology is improved on data acquisition, PLC/WSN/wireless communication, energy quality monitoring, real-time pricing, outage management, automatic metre reading and billing, and privacy.

In this study, we provide a system based on machine learning (ML) for identifying the prudent deployment and implementation approaches from the many past artworks of various big data solutions. A group of smart homes will receive further application of the framework in the area of electricity usage. With an improvement in manageability, scalability, and performance in the algorithms of computer clusters for big data analytics, the segmentation of data based on sampling can offer significant advantages. Also reviewed is extensive research on sampling and partitioning methods for huge data sets. The new sampling-based partition model is vital for computing clusters with classification portioning algorithms that boost scalability because the calibre of the selected samples directly influences the findings' approximation. Key KPIs for electricity usage with sampling-based approximation in the analytics were briefly reviewed in addition to the framework. In support of the big data analytical approximation on computing clusters, significant technological issues with the smart home's electricity consumption are emphasised.

CHAPTER 4

Results and Discussion

4.1 Introduction

THIS chapter contains details about the results obtained and discussions based upon the findings and implementation of the models and framework. The findings from this study project are presented in this section. This section contains data provided in tabular form that was gathered via a thorough analysis of the technology behind smart grids and the Internet of things as well as the analysis done using graphs, patterns, and trends in visual formats

4.2 Metering / Billing/ Collection Techniques in Power Consumption

A study of electricity literature survey carried out and a picture of the core functions of the revenue management system i.e., metering, billing and collection activities are presented in the figure 4.1. A flow of the information in the trading of the electricity power consumption is presented. Starting from the premises of the end consumer, the units of electricity power consumption is recorded with multiple methods like manual, automatically through the AMR/RMR and even with smart meters and conveyed to the central billing engine through a graphical user interface and API. The meter readings are accumulated at the central storage device, the bill generation mechanism generates the invoices and dispatches to the consumers via different modes like post, courier, spot billing with instant bill to the consumers door etc. Further, the consumer pays their bills through manual human visits to the cash counters as well as online through website or with mobile based application. The meter reading techniques, ICT technology, algorithms and communications used in these systems is picturized in the figure 4.2 below. The methods of the communication (WIMAX, Power Line Carrier, WLAN, Zig-bee) along with their properties i.e. Coverage of Range, General usage, Bandwidth, Technology maturity, Peak single user data rate, Frequency range, Data Rate, Costing and Range are shown in the table 6.1 below. There are heterogenous methods of these activities are in practice even in a single utility as per the scenarios of their development. Wireless Technologies for Collection of Data in electricity meter reading is tabulated in the table 6.2 with their advantages and disadvantages.

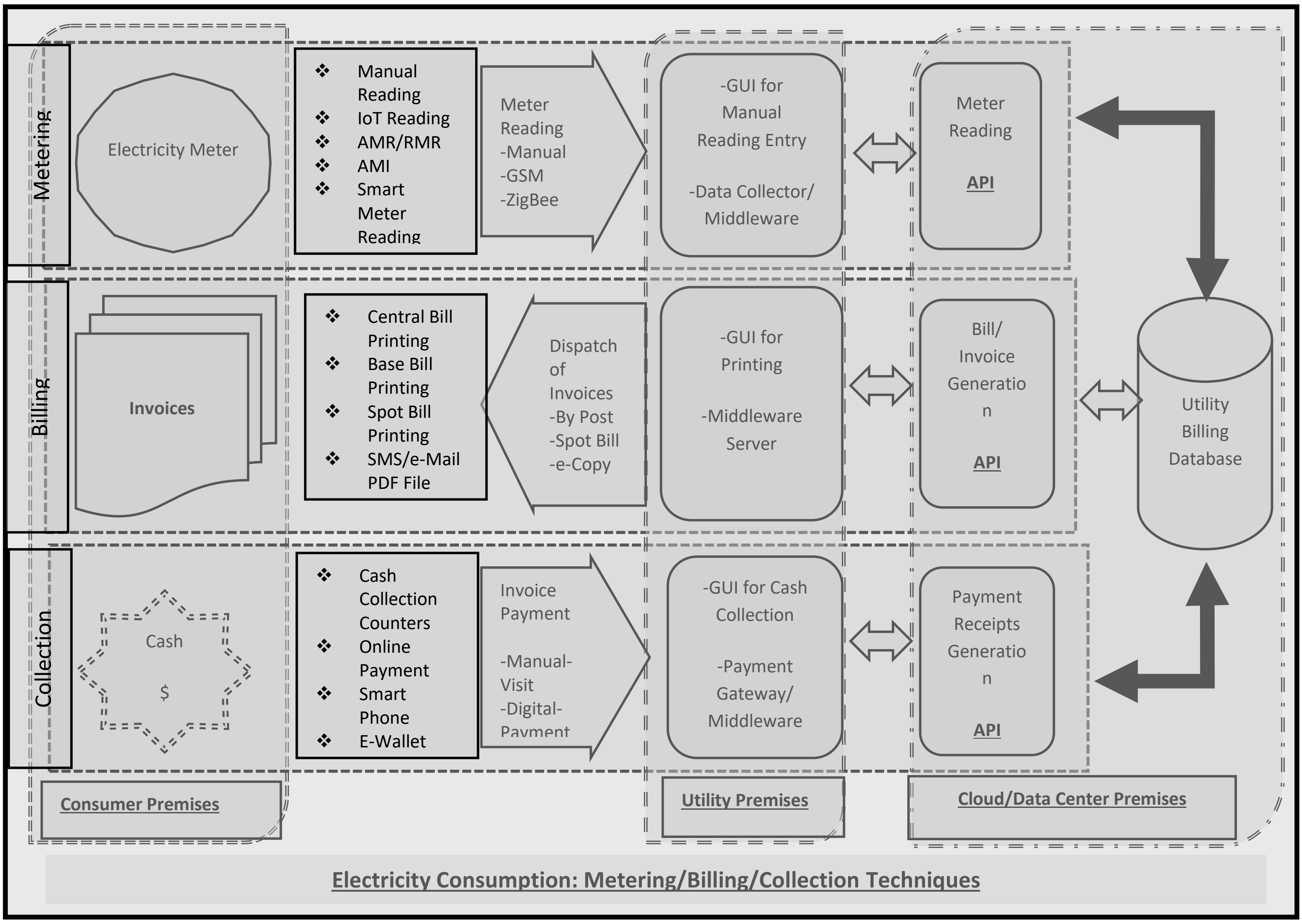
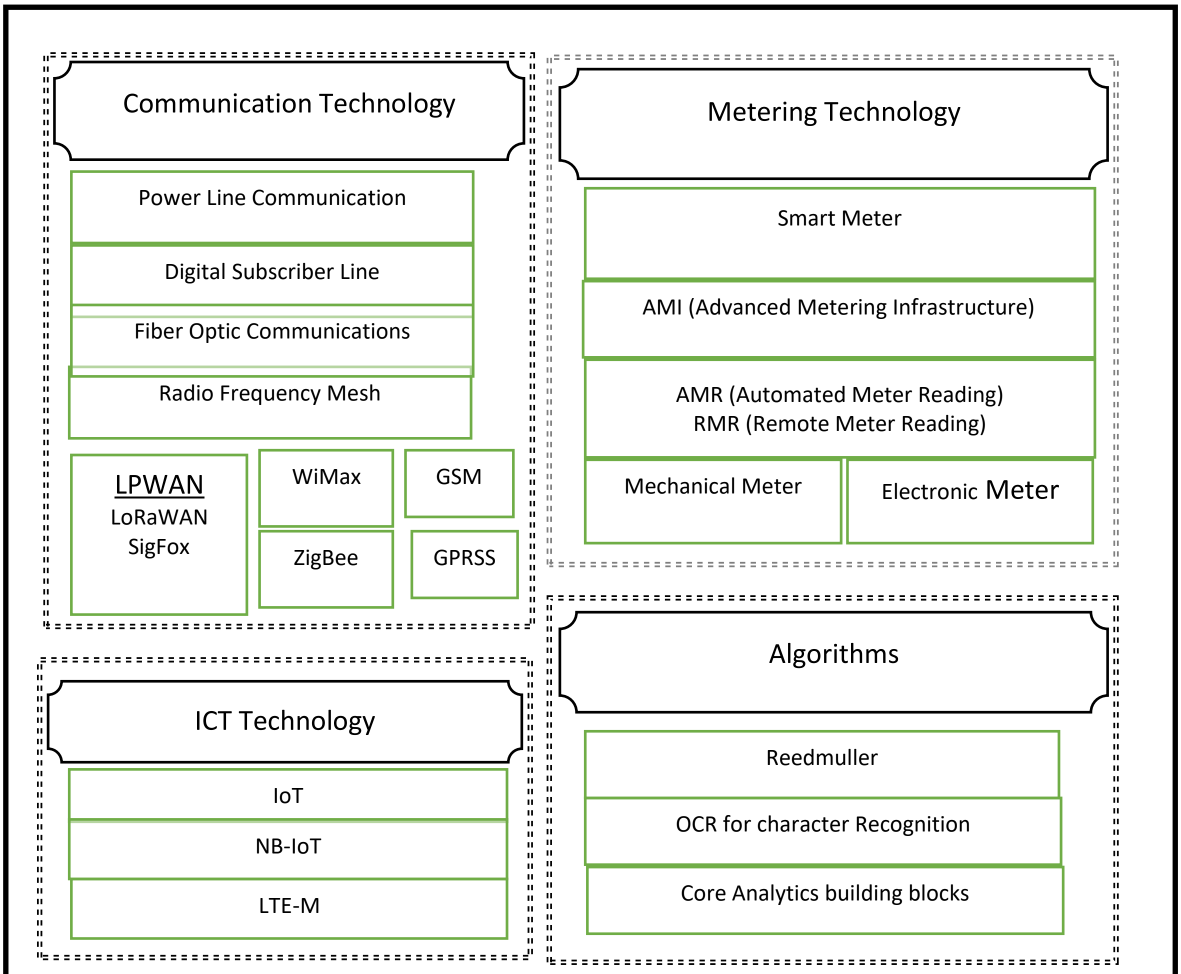


Figure 4.1The Electricity Power Consumption: Metering / Billing/ Collection Techniques



Electricity Meter Reading Techniques/ Algorithms/ Communications sources ([65-93])

Figure 4.2 the Electricity Meter Reading Techniques/ Algorithms/ Communications

Table 4.1 Methods of Communication: - sources [96-97]

	WIMAX	Power Line Carrier	WLAN	Zig-bee
Coverage of Range	longer distances capable with lower bitrates	Over a medium voltage network more than 15 KM can be	Up to 250 m for outdoor cases where as for indoor it is up to 100 m	Upto 50 m can be achieved

	approx 3-4 miles	achieved		
General usage	Wireless transport, point-to-point for data, voice & video etc.	also called as PLC, Broadband over Power Lines;	Wireless communication used in WAN & widely in indoor wireless LAN.	A secure communication in between Wi-Fi & Bluetooth, Long battery life due to Low data rate.
Bandwidth (Channel)	20 MHz or 28 MHz (European Country) or 25 MHz (United States)	Medium band 600Hz Wide band 1200Hz	20MHZ or 40MHz for 802. 20MHz for 802.11 a/g	Nominal 22MHz bandwidth
Technology maturity	More than 500 deployments across globe so Mature	Mature in Europe than North America as per popularity	Interoperable technology. Wi-Fi is a mature	these ratified in 2004
Peak single user data rate	Typical 4Mb/s to 16Mb/s	Speeds up to 10 Mb/s have been achieved; Low-frequency (approx. 100-200 KHz) carriers: about	Internal 10 MHz typical 5 MHz - 15 MHz Max.802.11b: up to 11Mb/s; 802.11 a/g/h/j: up to 54Mb/s;	depending on frequency band it varies 20Kb/s to 250Kb/s,

		hundred bits per second; Higher data rates shows shorter ranges.	802.11n:>100Mb/s ;	
Frequency range	450MHz, 700MHz; 2.3GHz, 2.5GHz, 3.5GHz licensed bands.	1.7MHz to 80MHz. Most providers rely on the 1-30 MHz spectrum bandwidth for BPL transmission;	Direct Sequence Spread Spectrum (DSSS), OFDM Unlicensed: 2.4GHz and 5GHz;	Direct Sequence Spread Spectrum coding; 868MHz, 915MHz, 2.4 GHz (unlicensed);
Data Rate	70Mb/second	576Kb/second	2.4Gb/second	250Kb/second
Costing	Moderate	Implementation cost is high & lacking of vendors	widely used & deployed in the consumer market makes it low costing	low power product for low bandwidth applications. Costing also low
Range	50 Kilometer	15 Kilometer	92 meter	70 m to 100 m

Table 4.2 Wireless Technologies for Collecting Data in electricity meter reading

Technology	Advantages	Disadvantages
Radio: Meter is equipped with a radio module	Low cost	Labour intensive
M-BUS: Meter is equipped	Fast reading, high	Cable infrastructure

with an M-BUS module	reliability, short reading intervals, cost effective	resulting in high investment cost
Zigbee: equipped with a Zigbee module for transmitting data over long distance, passes data via intermediate devices to cover long distance	Low cost, Low electricity power consumption, wireless, Collision avoidance, Large network capacity	Short range, low complexity, and low data speed

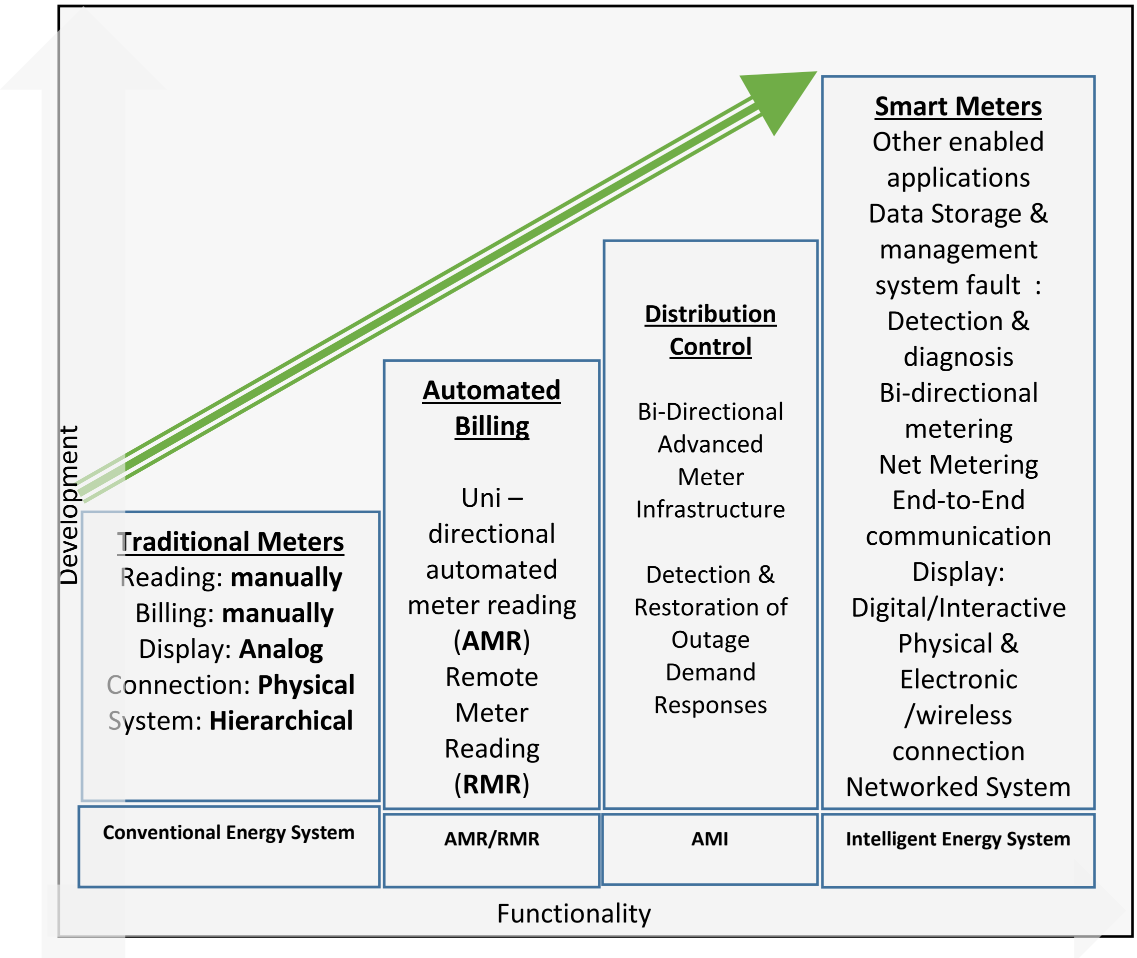


Figure 4.3 Development and functionality of the different techniques

Development and functionality of the different techniques of electricity meter reading machines is presented in figure 4.3 starting from the manual mechanical meter to intelligent electronic metering devices. The communication methods in the different techniques of electricity meter reading machines can be seen in figure 4.3.

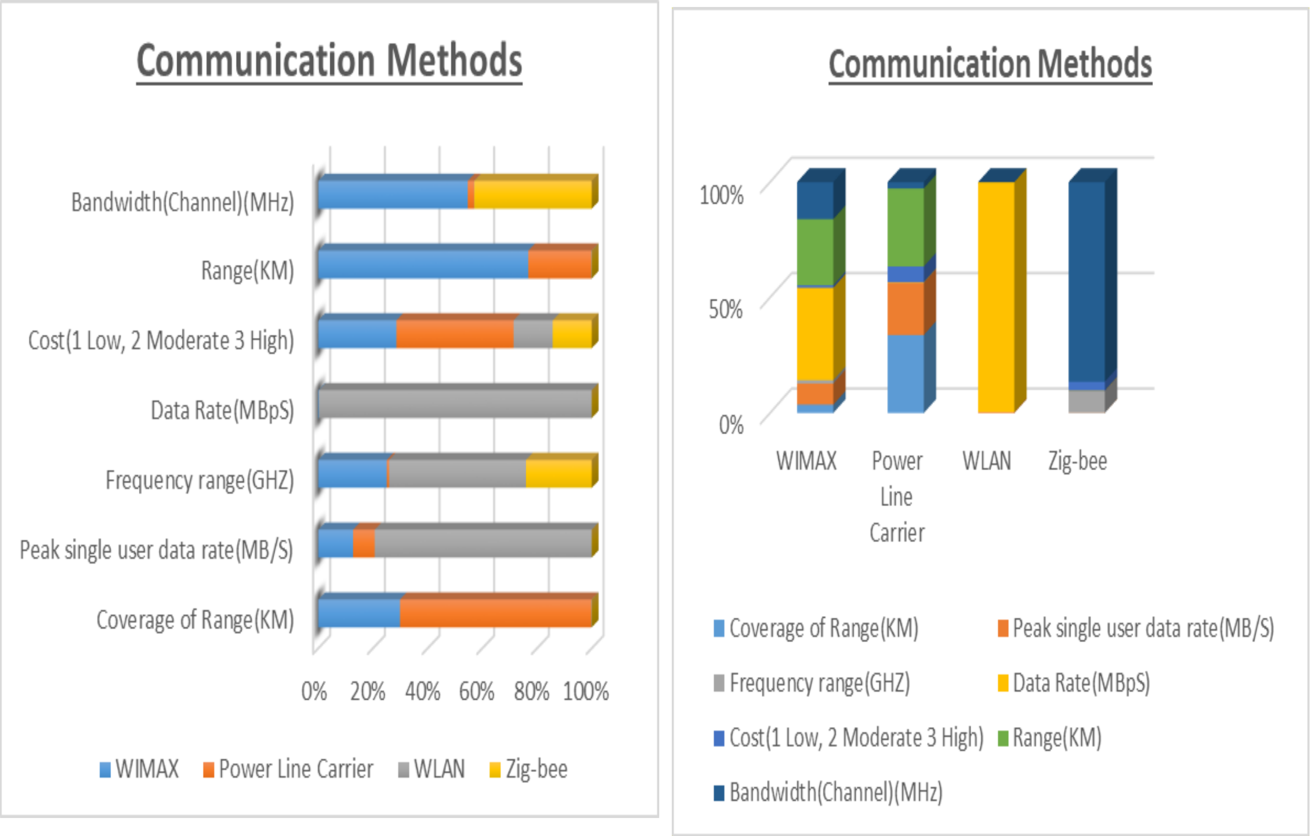


Figure 4.4 Communication methods in electricity power consumption

4.3 Scheduling in Electricity Power Consumption

A framework has been designed for power consumption scheduling. The various electricity appliances use for light, television, fan, dishwasher, refrigerator, and heating-cooling are studied before and after the scheduling of the use of the devices. The IoT device fitted on the device plugs, plays a vital role in the information collection at real-time. After the scheduling, and before the scheduling are presented in the graphical presentation in the following figure 4.5 and figure 4.6.

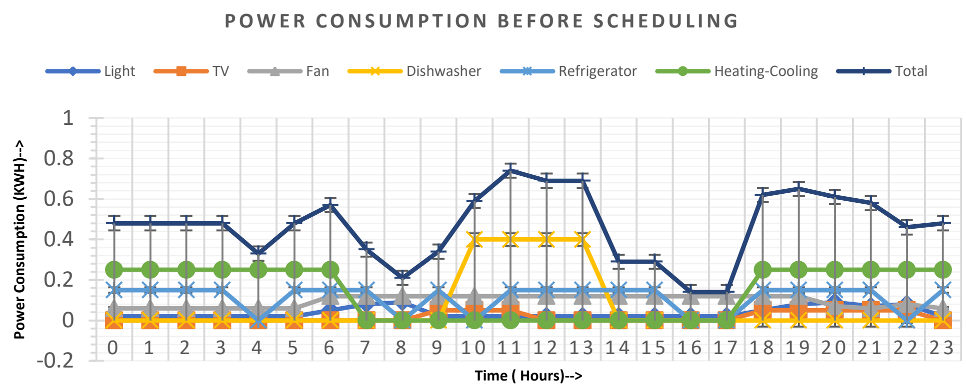


Figure 4.5 Power Consumption Before Scheduling

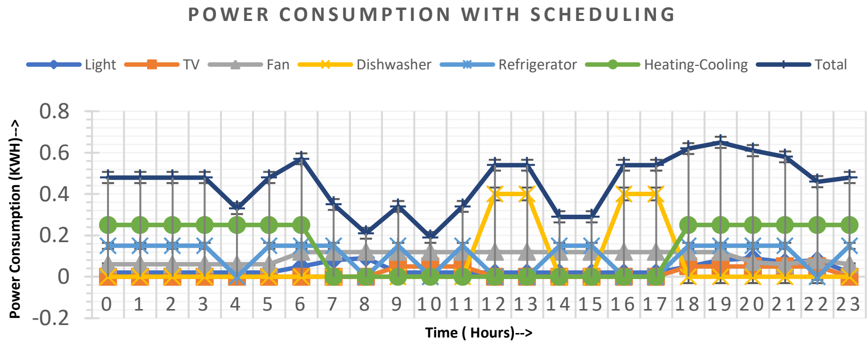


Figure 4.6 Power Consumption With Scheduling

4.4 Electricity Theft Detection

The framework is most effective for detecting the difference between real power consumption readings and invoiced readings, which unmistakably shows the loss of power in the identified sector. Four IoT devices were installed at various electricity customers' locations for the simulation of the IoT-based framework. An IoT device was put in front of the premises' power metre to track the actual amount of electricity used there. Prior to the four premises, where the combined readings computations are made, the main IoT is attached. For practical reasons, the fourth property metre was turned off from 4:00 AM to 9:00 PM. The framework later analysed the data as shown in the image, which clearly shows that for that particular section, actual power consumption is higher than invoiced power consumption. Additionally, it is evident that the IoT graph power consumption is nil from 4:00 AM to 9:00 PM, touching the ground, which makes it easy to see that the premises have been stealing electricity during that time. Therefore, the suggested framework can intelligently identify electricity theft in figure 4.7

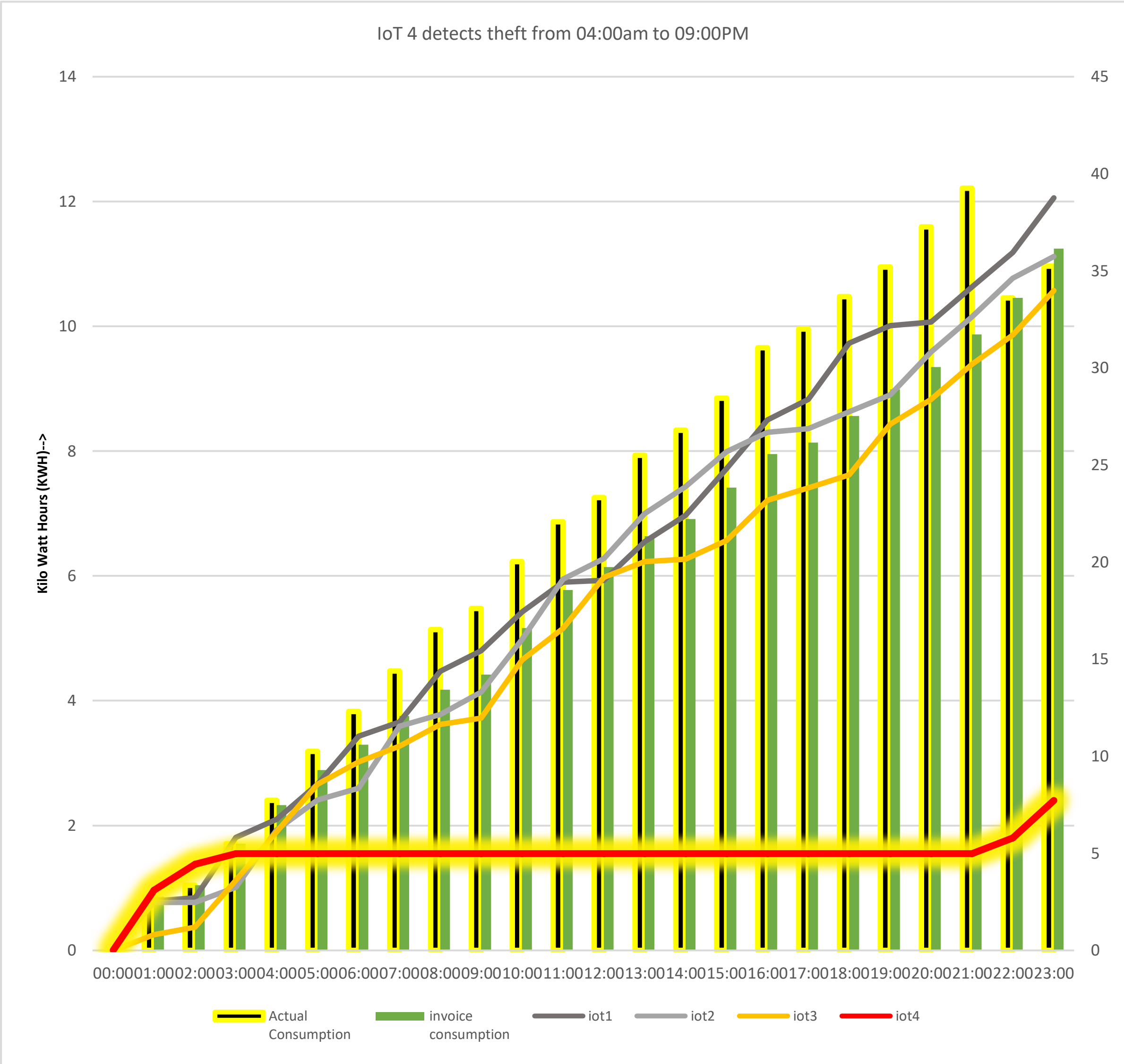


Figure 4.7 Graph showing the detection of power theft by IoT4

4.5 The different cases in metering reading system presented with the functionality of the system.

The following graph represent the graphical representation of the above tabular data in the pictorial form. The upper line shows the IoT based device performance, the middle one with the existing different AMR/RMR/AMI performance whereas the third one shows the performance in case of the Human Meter Readers physical visit (Visit may be restricted as at present due to pandemic

COVID19, the social distancing requirement all over the world for a particular duration) to the premises of the consumers.

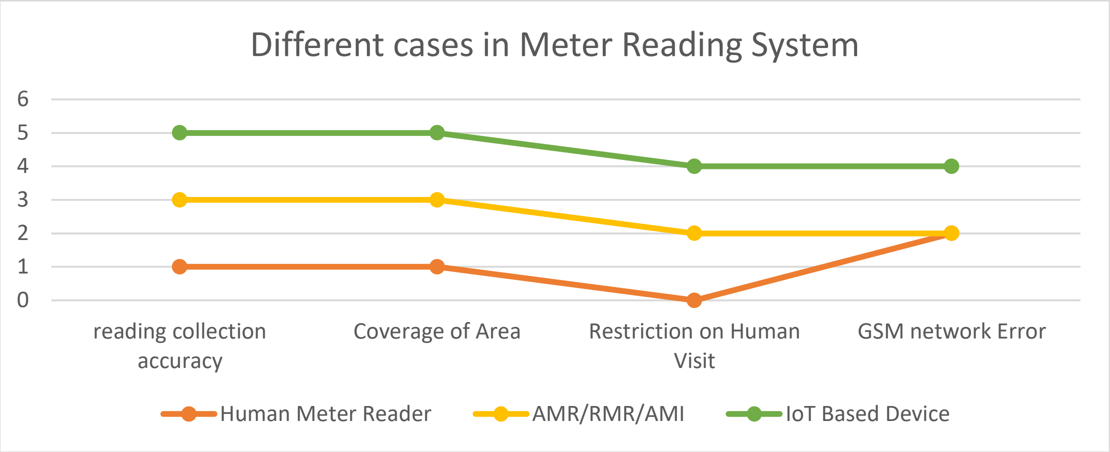


Figure 4.8 Cases in metering reading system with functionality

4.6 Electricity Power Consumption Monitoring

A Power consumption monitoring agent can be seen in the figure 4.9 showing the power consumption of the specific room through the sub meters installed in the rooms in premises of the consumers. An Artificial Intelligence Based Smart electricity power Consumption monitoring Agent shows the main meter along with their sub meters with a visual dashboard with power consumption trends.

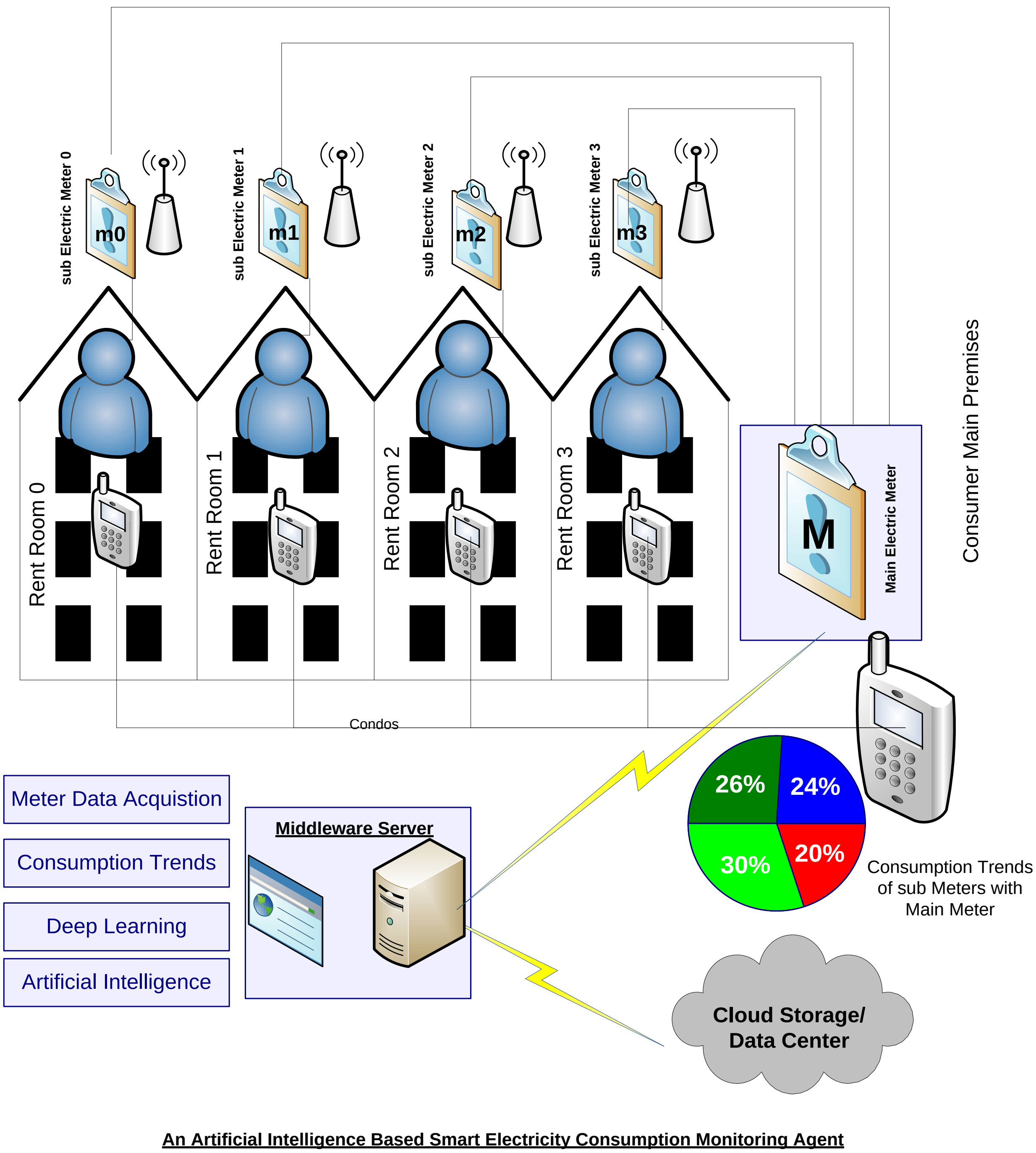


Figure 4.9 An Artificial Intelligence Based Smart electricity power Consumption monitoring Agent

4.7 Electricity Power Consumption Analysis

The electricity power consumption of the simulated data of the five meters installed as sub meters in the premises for monitoring of the electricity power consumption are shown in the figure 4.10 given below. The consolidated patterns are shown in the figure 4.11 and the prediction of the electricity is presented in the figure 4.12.

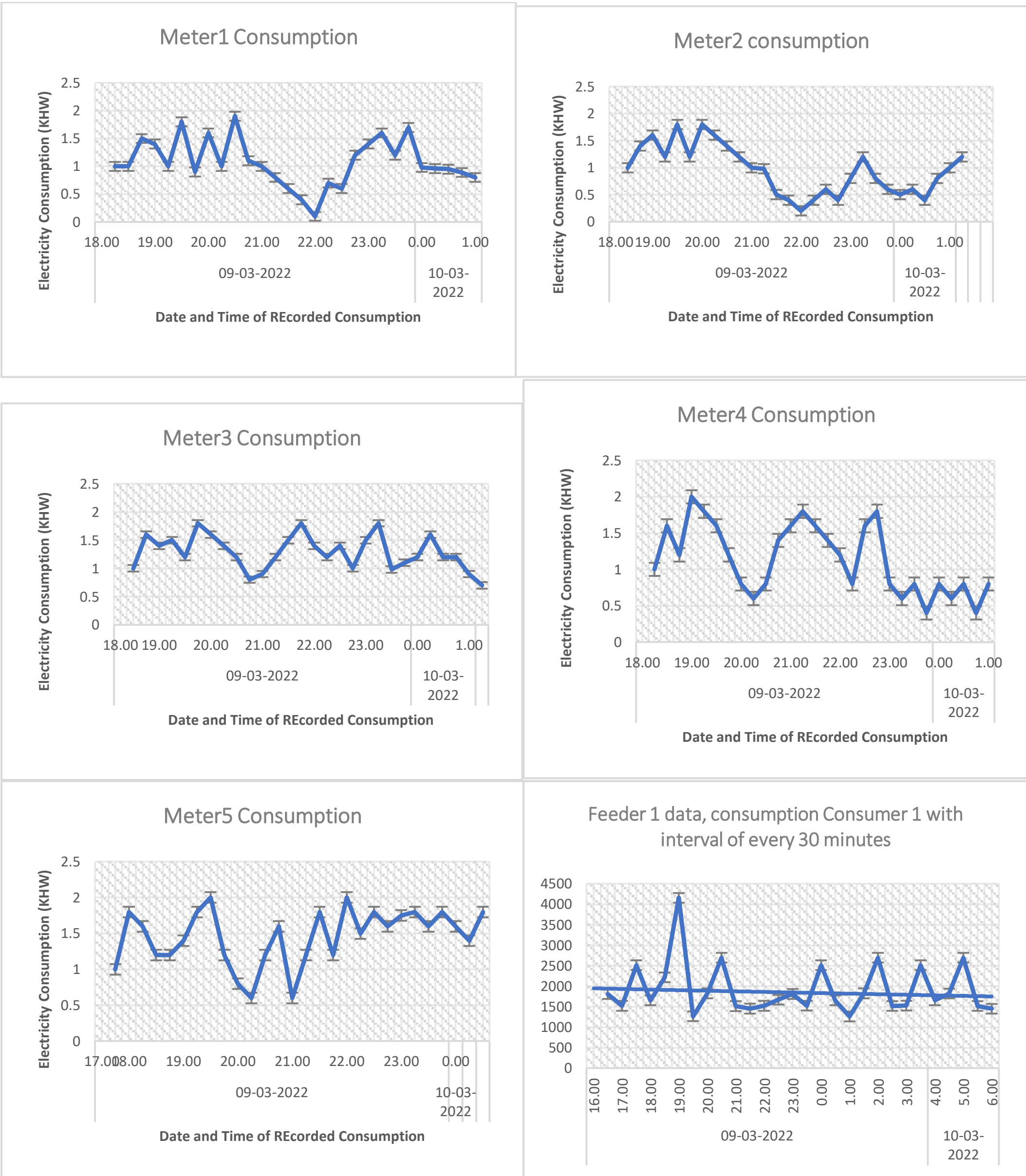


Figure 4.10 Electricity Power Consumption patterns of meters

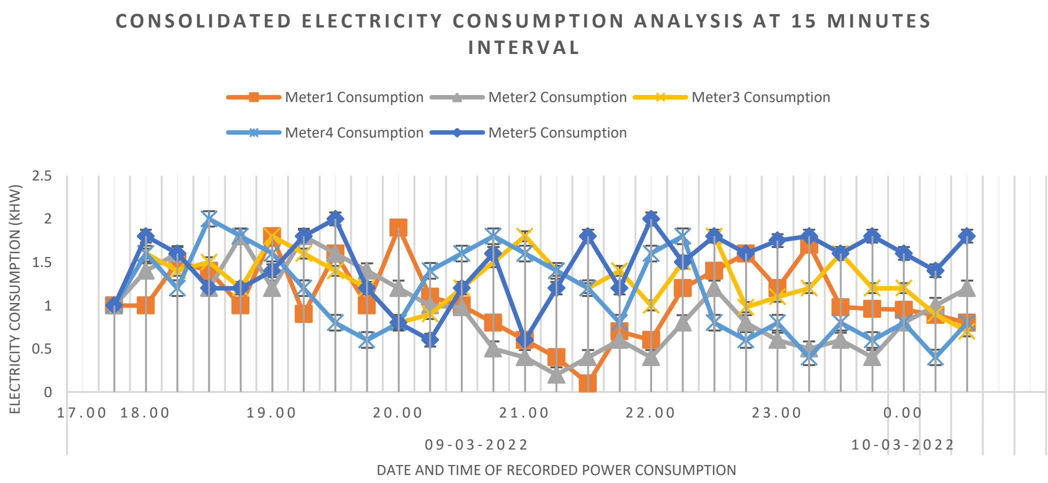


Figure 4.11 Consolidated Electricity Power Consumption Analysis at 15 Minutes interval

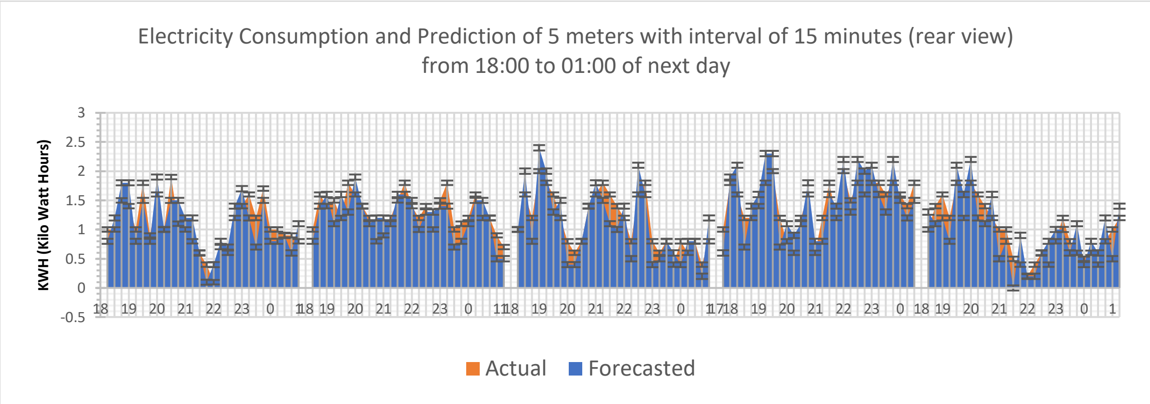


Figure 4.12 Prediction of the 5 meters with interval of 15 minutes

4.8 Missed call messaging system analysis.

Hourly (0–24) Missed Calls Trends over the Past Two Months : Figure 4.13 displays daily hourly trends from 00 to 2359 hours. The amount of missed calls in the time period from morning 5:00 to 10:00 produces a sharp slope in the months of July and August 2020. The busiest missed call period lasts until 21:00. The slope is then shut down until 2:00 a.m. According to the trends and patterns depicted in the image, there were extremely few missed calls between 0:00 and 4:00 the following morning. For simple analysis, the four quadrants Q1, Q2, Q3, and Q4 of a given hour are likewise divided into four portions. This chart can be used to perform the microanalysis.

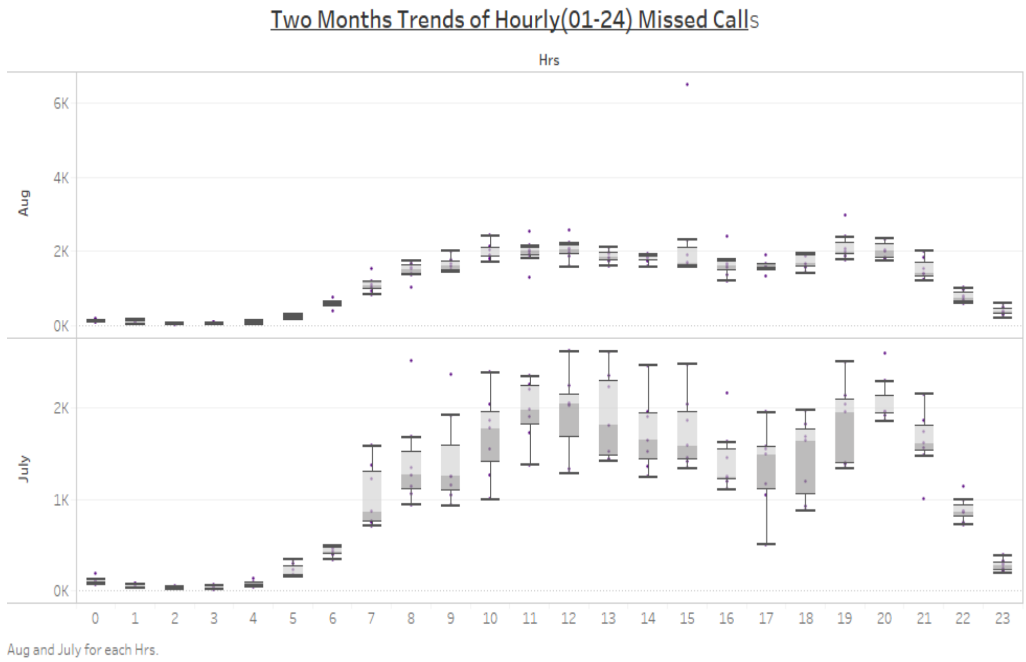


Figure 4.13 Two Months Trends of Hourly (0-24) Missed Calls

Weekly hourly trends in missed calls over the past two months:- Figure 4.14 displays patterns of weekly day-by-day and hour-by-hour missed call analysis data for the two months of July 2020 and August 2020. The similar type of pattern is discovered. On Sundays, which are holidays, the pattern is reversed; nevertheless, on the other weekdays, the pattern appears to have a constant slope across the graph. The graph displayed a sudden fluctuation throughout the graph, and when it was microscopically analysed, it was discovered that a specific mobile phone continued to send missed calls. The system was treated severely, and the maximum daily missed call limit was implemented to prevent such unnecessary interruptions.

A DDOS (Dedicated Denial of Service) assault can be launched against the system if a small number of numbers continue to call in this pattern. Therefore, if such events are recurring in nature, the database is additionally configured at middleware to handle such requests and make them permanently blocked.

Figure 4.15 displays a straightforward cured graph for the most recent two months of data, July 2020 and August 2020. This figure can be used to analyse the two-month missed call trends on an hourly basis. The bell-shaped curve displays the daily, weekly, and monthly patterns based on the daily hours of 00:00 to 23:59.

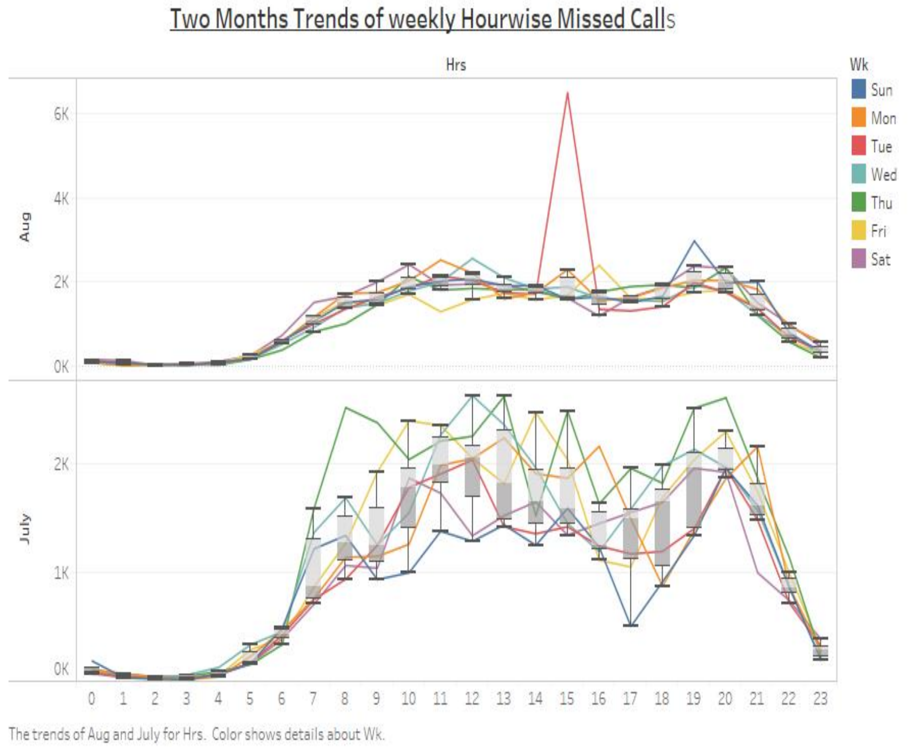
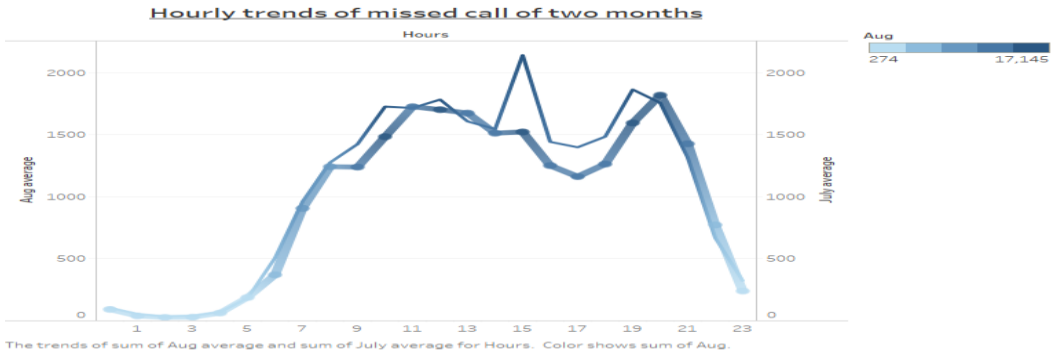


Figure 4.14 Two Months Trends of Weekly hour wise Missed Calls

The framework is most effective for detecting the difference between real power consumption readings and invoiced readings, which unmistakably shows the loss of power in the identified sector.

Four IoT devices were installed at various electricity customers' locations for the simulation of the IoT-based framework. An IoT device was put in front of the premises' power metre to track the actual amount of electricity used there. Prior to the four premises, where the combined readings computations are made, the main IoT is attached.

For practical reasons, the fourth property metre was turned off from 4:00 AM to 9:00 PM. The framework later analysed the data as shown in the image, which clearly shows that for that particular section, actual power consumption is higher than invoiced power consumption. Additionally, it is evident that the IoT graph power consumption is nil from 4:00 AM to 9:00 PM, touching the ground, which makes it easy to see that the premises have been stealing electricity during that time.



Hourly consolidated Trends of two months Missed Calls

Figure 4.15 Hourly consolidated trends of Missed Calls

FTER a systematic study of the technologies behind the smart grids and the IoT applications in the field of the electricity power consumption and analysis, the following key points revealed in context of the electricity power consumption for minimizing the aggregate technical and commercial losses.

4.9 Gathering Data

All the parameters generated by the smart meters related to electricity power consumption as well as for the power quality are stored in the device itself for a specified time duration. The data is transferred to the central storage device in the form of the XML file. The XML file further extracted with the valuable data in the specified format and then accumulated at the metering data acquisition system. All the decision related to the power quality in the electricity power consumption, outage management system, revenue management system etc. are dependent on the real-time data of electricity power consumption. The consumer wise, category wise, area wise, segment wise etc. can be analyzed by the different analytical engines only after accurate and complete power consumption parameters accumulation.

4.10 Develop and Discoveries

The methods for the data collection were improved i.e collection of the various parameters required for bill generation from the electric meters. The smart meters as well as the legacy electric meters (DLMS complied) have the capacity to store the various parameters in their own device. The communication media helps to transmit such information at central data acquisition place as demonstrated in the above models.

IoT Device designed to convert the functionality of the legacy electronic meter embedded with RS232 port is attached and data is collected at periodical basis. The data stored in a storage device over open-source platform i.e. Linux. The data is stored is structured; a processing method is applied on it to generate the information for visual dashboards.

Based on the above model design and implementation, the following section shows the data in the form of the graphs.

The electricity power consumption of 5 meters is shown in the figure 4.16 below. The prediction is carried out by analyzing the past power consumption trends. The gap in the prediction and the actual is also shown with the trends of the errors.

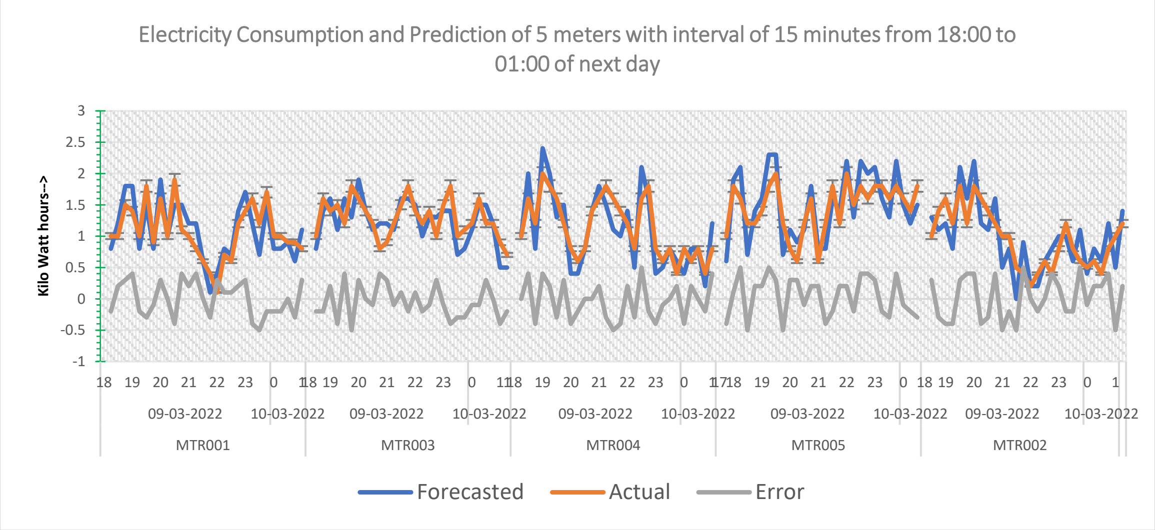


Figure 4.16 Electricity Power Consumption and Prediction of 5 Meters with interval of 15 Minutes from 18:00 to 01:00 of next day.

4.11 Data Sets of Electricity Power Consumption

The electricity power consumption is analyzed with the different key indicators. Like season-wise, peak-hour wise. The power consumption is directly proportional to the seasonal variables like weather, temperature, humidity, rainfall, winds movement etc.

The summer season has the impact of the air conditioner whereas the winter season has the usage of the heater and geyser. The power consumption is also higher during the daytime as compared to the night. An analysis of the power consumption with different time frames, season wise and peak hour wise carried out. At the industrial area, commercial area, bank buildings, offices, the consumption heat graph shows the dense graph at the official time 08:00 AM to 08:00 PM. Also at the Saturday, Sunday and any holiday, the graph shows the light graph as compare to the other time schedules.

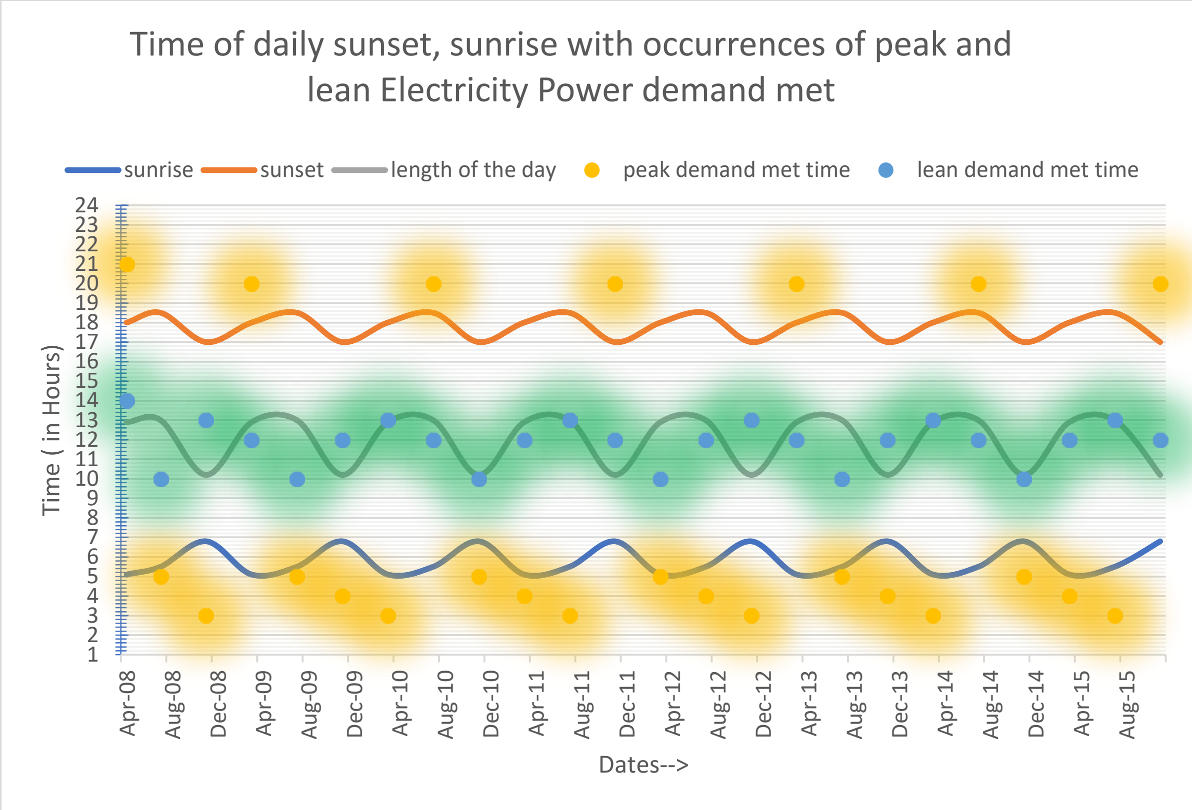


Figure 4.17: Time of daily sunset, sunrise with occurrences of peak and lean Electricity Power Consumption demand met (data source [193])

The Figure 4.16 shows the power consumption data of the time of daily sunset, sunrise with occurrence of the peak and lean demand met, the data retrieved from the posoco.in web portal. The peak demand met is at the specific time in the night, off time.

The dataset has been enhanced on different time frames i.e. season wise / peak hour wise. The summer season has the impact of the air conditioner whereas the winter season has the usage of the heater and geyser. The consumption is also more during the daytime as compared to the night. An analysis of the power consumption with different time frames, season wise and peak hour wise carried out and shown in the graphs given in the section. The Figure 4.16 shows the power consumption data of the time of daily sunset, sunrise with occurrence of the peak and lean demand met, the data retrieved from the posoco.in web portal. The peak Electricity Power Consumption demand met is at the specific time in the night, off time. The season wise and Monthly Electricity Power Consumption demand met pattern from eight years from the recent decade (i.e. 2008-2016) with considering the Winter season for the months December to January, Spring season for the months February to March, Summer season from month April to June, Monsoon season July to Mid-September and last but not least Autumn season from month September end to November.

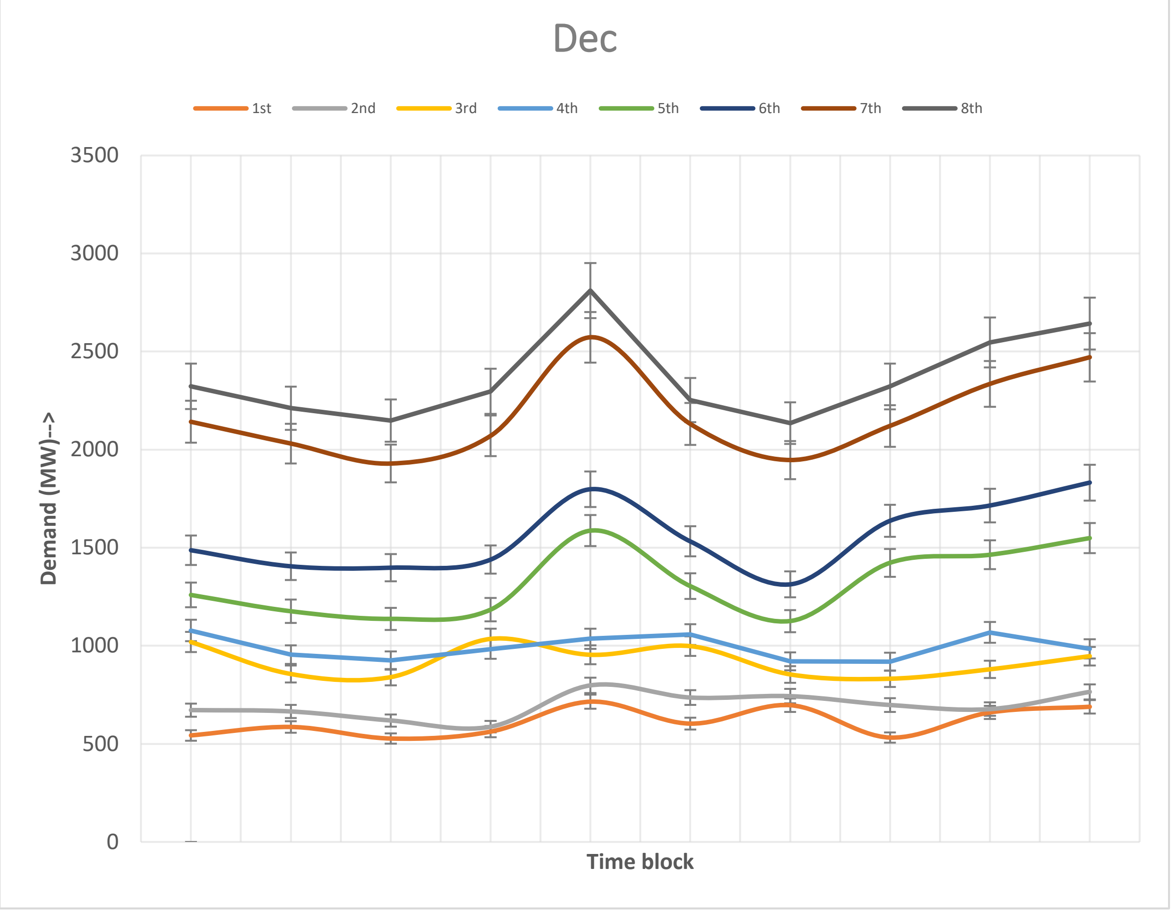


Figure 4.18 The above graph analyses the demand in megawatt with time block for a month of the winter (December) of recent decade (with eight years). In each year, the graph pattern is similar with the trend.

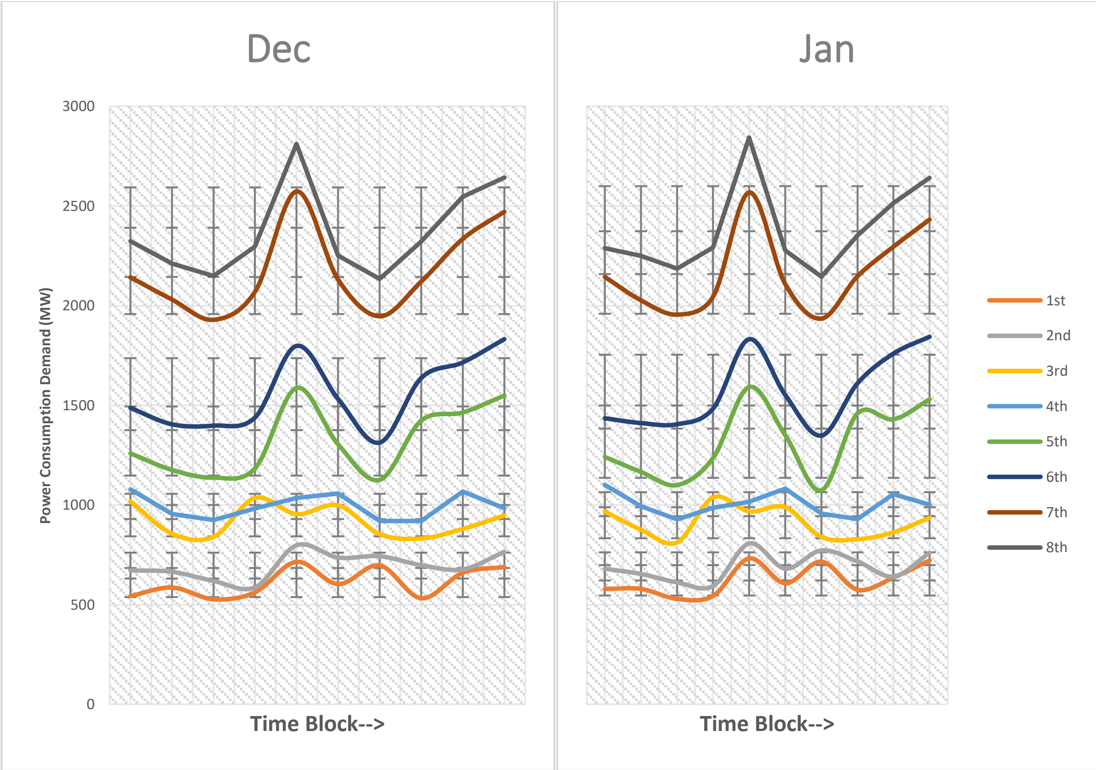


Figure 4.19 Winter Season Electricity Power Consumption demand analysis of recent decade (with eight years).

Figure 4.20 Spring Season Electricity Power Consumption demand analysis of recent decade (with eight years).

Figure 4.21 Summer Season Electricity Power Consumption demand analysis of recent decade (with eight years).

Figure 4.22 Monsoon Season Electricity Power Consumption demand analysis of recent decade (with eight years).

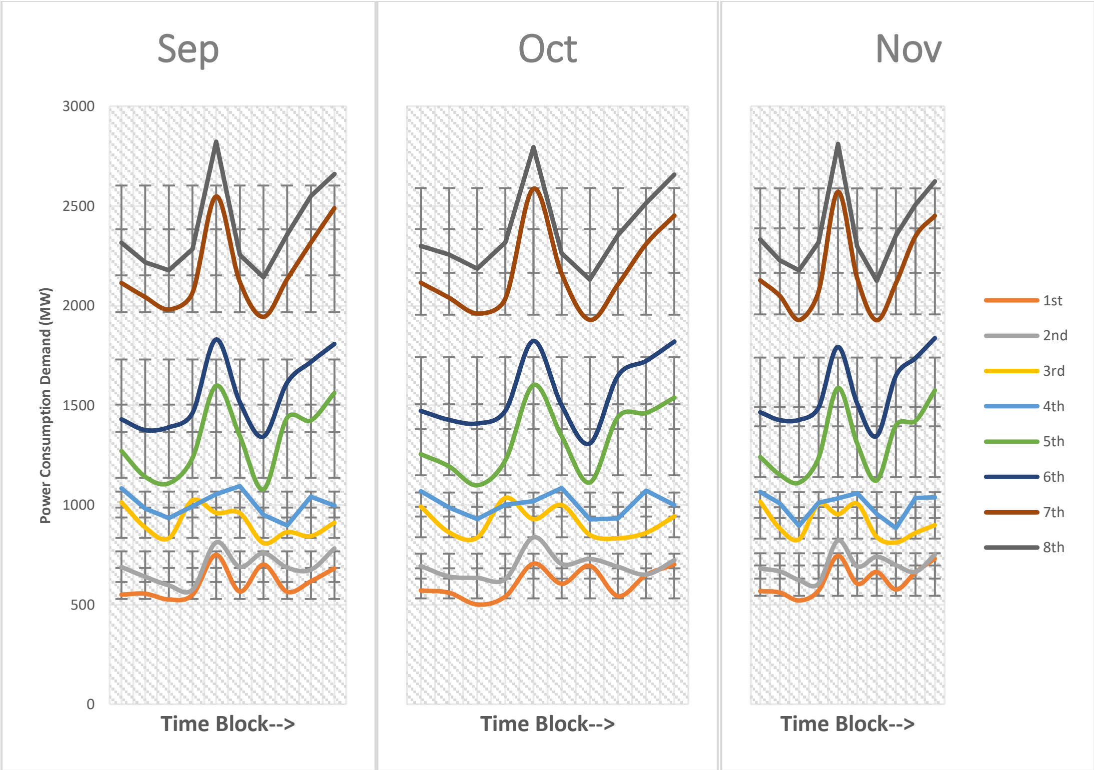


Figure 4.23 Autumn Season Electricity Power Consumption demand analysis of recent decade (with eight years).

The above graph analyses the demand in megawatt with time block for all season's month wise of recent decade (with eight years). In each year, the graph pattern is similar with the trend. Source reference [193].

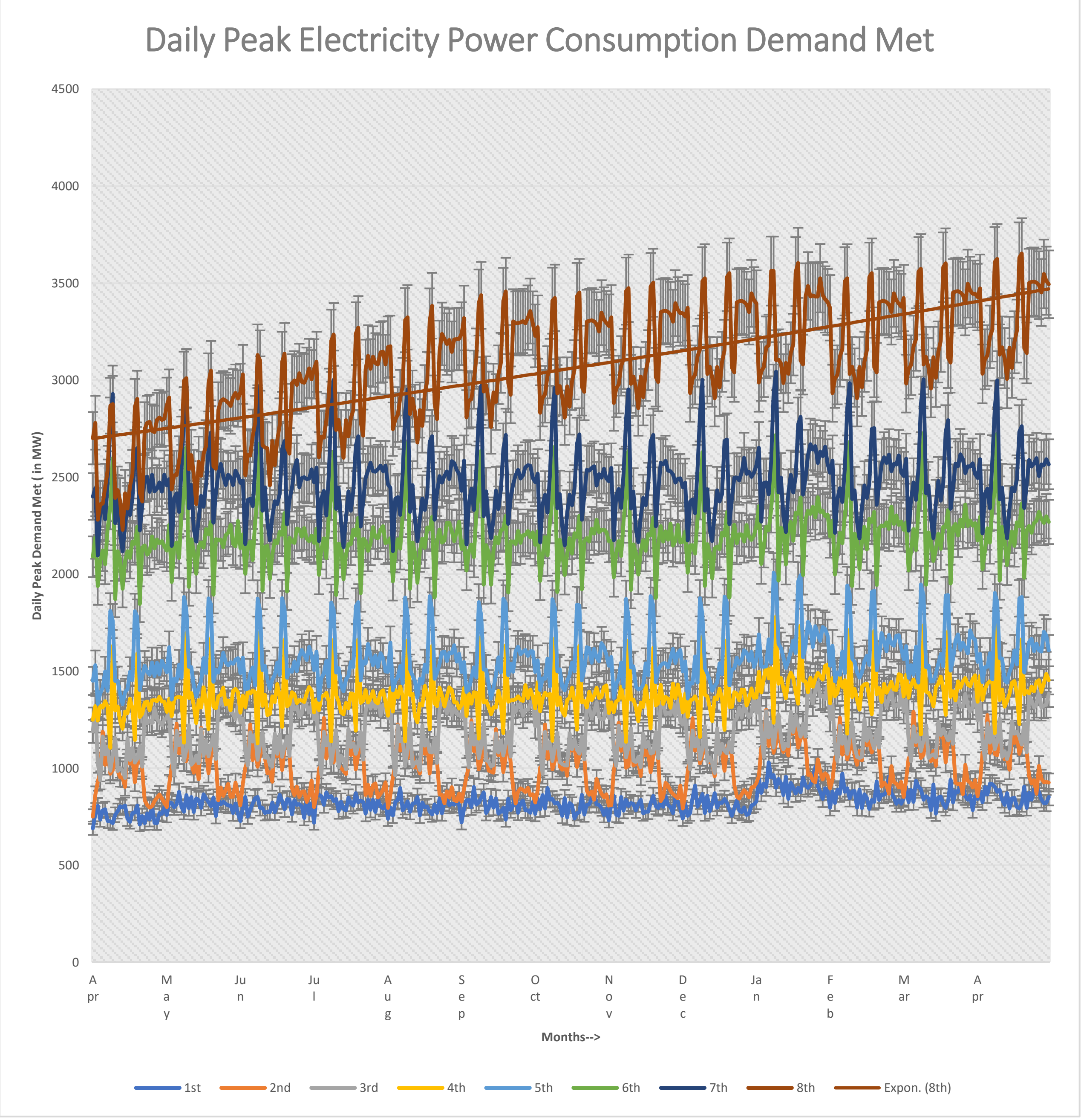


Figure 4.24 Daily Peak Electricity Power Consumption Demand Met, month wise in eight years of recent decade.

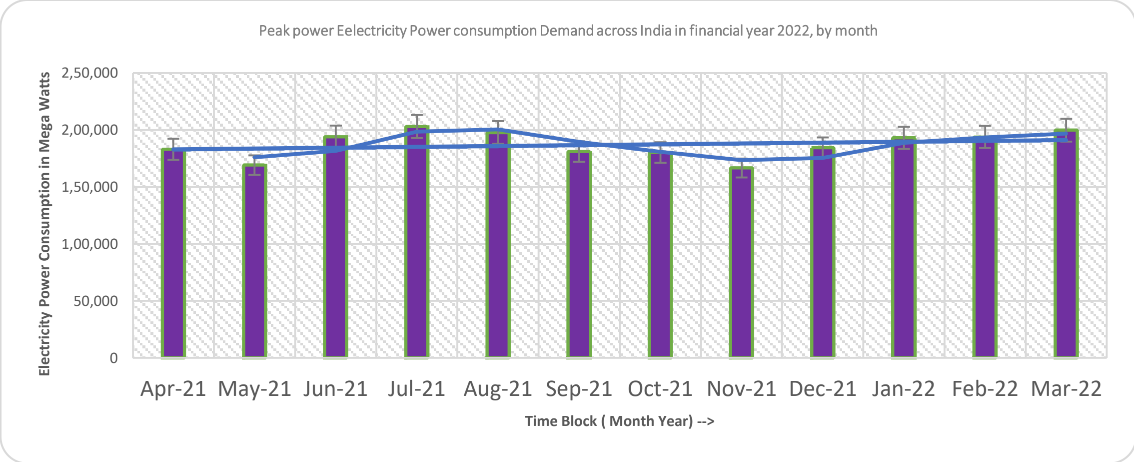


Figure 4.25 Peak Power Electricity Power consumption Demand across India in financial year 2022, month wise, data source [192].

Peak Power Electricity Power consumption Demand across India in financial year 2022, month wise, data source [192].

Target Audience:- The proposed framework is for the power distribution companies specially for the developing countries like India. The states like Biahr, Jharkhand, the geographical diversity and developing phases of the electrification etc are the main concerned. The quality in the supply of the electricity power with minimal transmission and distribution losses is the main theme of the framework and such states will be benefited with the proposed research work. A detailed analysis for use of emerging technologies like Artificial intelligence / machine learning, robotics, big data analytics is carried out. The data generated by the proposed devices with simulation is envisaged with actual targeted consumers from the financial year 2022 with all Indian power utilities with commercial, industrial and domestic types of the electricity power consumers.

Table 4.3 Comparison of the proposed proto-type model with existing traditional legacy and conventional electronic devices Source [194-197]

Type	**Traditional Legacy Devices**	**Conventional Meter (Electronic devices)**	**Proposed Proto Type (Advanced Devices)**
Type (Communication)	None (Physically Readings Are Taken)	GSM	Wi-Fi / ZigBee / PLC
Collection of Data	Manual	SMS	Cloud, Web Chart and SMS
Displaying Data	Units(KWH)	Units(KWH), Billing data, Recharge, Power Data	Units(KWH), Fault Detection, Billing Data, Recharge, Power Data Low

			Balance/Power Cut Warnings
Detection of Fault/ Prevention	No	No	Yes (Voltage, Current, Frequency)
Methods of Energy Control	No Control	No Control	Relay Control
Measurement	Single	Bi-Directional	Uni-Directional, Bi-Directional
Technology for Sensing	Magnetic Coupling	CT and PT Integrated to Current Sensors	IC, CT & PT If Required
Mode(Payment Method)	Post-paid	Prepaid	Prepaid
Interface(User Interface)	Gear Based Display	LCD	LCD / LED, Web And Android App, IHMD
Background Interface	No Interface	No Interface	Website and graph plots

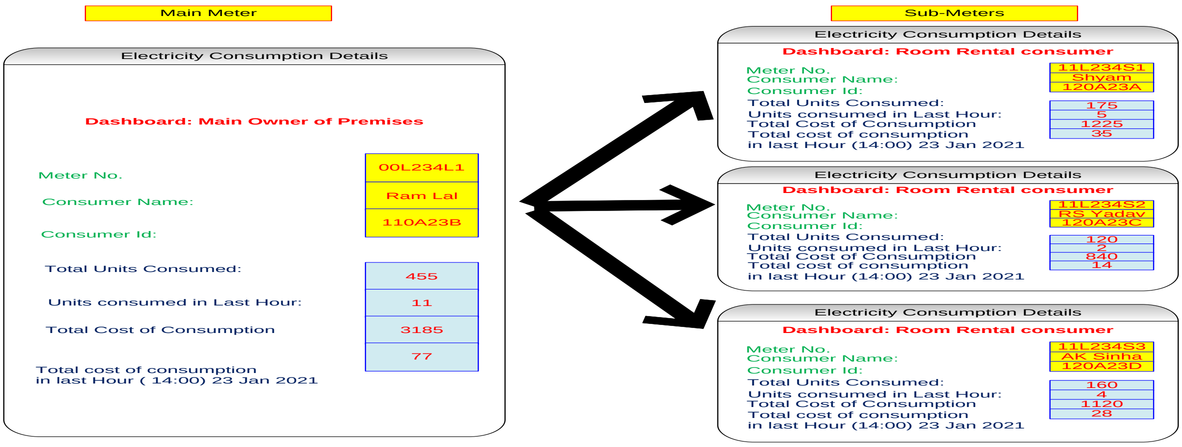


Figure 4.26 Customized mobile application for electricity power consumption with dashboard of main meter along with submeters with detailed analysis.

4.12 Privacy and Security

The privacy and security in the electricity consumption work can be achieved with the help of the following points.

4.12.1 Data Protection and Privacy Policies

It clearly articulates the data protection and privacy policies governing the handling of sensitive information. It ensures that these policies align with legal and ethical standards.

4.12.2 Data Minimization

It implements the data minimization principles by collecting only the necessary data for this research work.It avoids the unnecessary or excessive data collection that could pose privacy risks.

4.12.3 Informed Consent

It clearly describes the data collection processes and obtains informed consent from participants. It ensures that participants understand the purpose of data collection and how their information will be used.

4.12.4 Anonymization and Pseudonymization

It implements the effective anonymization or pseudonymization techniques to protect the identities of individuals. It assesses the efficacy of these techniques in preserving privacy.

4.12.5 Security of Personal Identifiable Information (PII)

It evaluates how personal identifiable information (PII) is handled and secured. It implements encryption and other security measures to safeguard PII.

4.12.6 User Control and Transparency

It provides users with control over their data and transparency regarding how their information is processed. It implements the user-friendly interfaces for managing privacy preferences.

4.12.7 Legal Compliance

It ensures the compliance with privacy laws and regulations applicable to your research context. It clearly documents how your research adheres to GDPR, HIPAA, or other relevant frameworks.

4.12.8 Third-Party Security

It involves third-party services or tools, assess their security measures. It ensures that third-party entities comply with your data protection and privacy standards.

4.12.9 Securing Communication Channels

It encrypts the communication channels to protect the confidentiality of data in transit. It utilizes secure protocols such as HTTPS for web-based interactions.

4.12.10Data Storage Security

It assesses the security of data storage facilities and databases. It implements access controls and encryption to protect data at rest.

4.12.11Privacy Impact Assessments (PIA)

It conducts the privacy impact assessments to identify and mitigate potential privacy risks. It documents the findings of the assessment and the steps taken to address identified risks.

4.12.12De-Identification Techniques

It explores and implements advanced de-identification techniques to further protect privacy. It assesses the effectiveness of de-identification methods in preventing re-identification.

4.12.13Security Awareness Training

It provides security awareness training to individuals involved in data handling. It ensures that personnel are educated on the importance of privacy and security measures.

4.12.14Incident Response for Privacy Breaches

It develops a comprehensive incident response plan specifically tailored to address privacy breaches. It defines procedures for notifying affected parties and regulatory authorities in the event of a breach.

4.12.15Continuous Privacy and Security Audits

It conducts regular audits to ensure ongoing compliance with privacy and security measures. It monitors for emerging threats and adjust security protocols accordingly.

With the help of the above parameters, it builds a robust framework for assessing and enhancing both the privacy and security aspects of the electricity consumption research work as proposed in this work. This comprehensive approach is essential for ensuring the responsible and ethical conduct of research with privacy and security implications.

4.13 Summary and Conclusion

The findings and results revealed in achieving the objectives set in the research work has been elaborated in the above section. The simulation of the electricity power consumption data through electricity meter reading has been analyzed in the above section. The use of amalgamation of the emerging techniques enhances the core functioning of the revenue management system and provides the prompt decision making.

CHAPTER 5

Summary and conclusions

THE conclusion part of the research work should be properly discussed based upon the results obtained rather than the hypothesis or assumptions. This section should also contain the future perspectives and applicability related to the dissertation work.

5.1 Summary

5.1.1 Theoretical Implications

In revenue management, the measurement of the electricity power consumption plays a main role. There are many parameters effecting the electricity power consumption monitoring and controlling point of view. The theoretical implications found in the metering are assessment of the electricity power consumption accurately and instantly. There are many power distribution utilities lacks in the full assessment of the power consumption in long run as well as in the short run. The smart prepaid metering systems/ IoT based systems can enhance the electricity trading with methods, techniques and processes for fast and accurate assessment of the electricity. The pre-pad systems can eliminate the long bad-debts factors from such trading.

5.1.2 Practical Implications

In the operations of the electricity power supply, the IoT devices enhances the smart grid operations for the qualitative supply. Power outage management can be more effective with real-time information assimilation through IoT devices with actuators and sensors. The data accumulated through various intelligent electronic devices at central place, needs to be processed with high speed for instant result analysis and prompt decision making. The practical implications of data and information accumulation and processing with high speed are the main practical implications.

5.1.3 Limitations

Table 5.1 limitations in the electricity power consumption system

Particulars	Descriptions
Traditional/Legacy Heterogeneous Non-Communicable	Currently there are more than 50% devices where the techniques of the meter reading is manual mode. However, the RS232 ports are available in the traditional electronic metering devices. The electric devices are built on different make and model with the different techniques which makes the

Devices:	electric meter reading a complex process. In most of the utilities, the human meter readers are still visiting the consumer premises for noting down the meter reading to compute the electricity power consumption.
Poor Meter Reading	Due to the above constrains in the techniques of the devise used for the electricity power consumption, the meter reading is not carried out accurately, due to manual human intervention in reading and noting down the reading and the keying in the system.
Occasionally Non delivery/ Loss of Physical Invoice Bill	As the generated invoices are sent to the consumers by the postal way or the representative of the utility, the invoices are sometimes not delivered may be due to door lock or the any other reason and resulting the over debts and finally the consumer converts to non-paying
Complex/Lengthy Process	Now the process for meter reading/invoice generation and revenue collection is very complex and time-consuming process, it needs to be rectified. An efficient IoT framework may be developed for the meter reading and for processing the bigdata concepts may be implemented for the fast processing of the huge data.
Wrong Bill Generation on Door Lock Readings	In the current scenario, there are cases, where the door of the consumers is locked, the human representative, either enter the readings by guess or leaves the blank, which further may result in the average billing and may generate any disputes from customer side.
Old Methods of Meter Readings	In the existing systems, most of the places, the existing old methods of the meter reading are still running. These manual readings are prone to manual errors and resulting the disputed invoices generations and converting the paying consumers as non-paying consumers. There exist some places the AMR/RMR and AMI for the meter readings, but the smart meter devices are lacing in the infrastructure of the meter reading techniques.
Lack of Multiple Methods of Revenue Collections	There exists some utilities where the revenue collections are done on the traditional ways. The cash collection counters need to be minimized. The online modes or other modes like customized mobile application, UPI or the door-to-door collection vans to get the revenue from the rural area is a visible challenge in the revenue collection techniques of the existing power distribution utilities.
Lack of Hundred Percentage Billing and Collection Efficiency	The existing meters are on the Traditional/Legacy technology. These devices need to be replaced with the latest technology. The non-communicating meters are left over the manual meter readings, and human can skip this target of hundred percentage of meter reading which gives less bill generations and automatically the revenue collection system is affected very adversely
Lack of IT/OT	In the present system, the IT and OT systems are not fully integrated and

Systems Integration	resulting the less efficient infrastructure of the power distribution companies.
Use of Traditional Legacy Outdated Systems:	There exists at some utilities, where the system are very old and requires to be replaced with the new one

5.1.4 Recommendations

The electricity meter reading system are analyzed, after detailed analysis of the current scenario limitations, the recommendations for the electricity meter readings are tabulated in table below.

Table 5.2 Recommendation for the legacy electricity power consumption system

Particulars	Descriptions
Upgradation of Old Legacy Infrastructure	As most of the electricity metering techniques are traditional. These old legacy electric meter readings are manual readings and prone to typing errors, may result in the dispute of invoices generated based on such readings. So it is strongly recommended to upgrade the existing infrastructure. The upgradation may be done by replacing the old devices with new one or with the integration of the IoT devices to change the functionality of the existing infrastructure.
Move to Prepaid Mode	Keeping the present situation of the electricity meter reading over the traditional technology, the invoice generation and dispatching of the invoices, the collection of revenue, are the challenging tasks. There are flaws in the process in context with the behavior of the consumers. To overcome such issues, the mode of the bill generation should be changed to the prepaid mode instead of the postpaid mode. This option should be from both aspects in trading i.e. customers of the electricity usages at one end and Power distribution company at the other end.
Use of Smart Meters:	In all the cases, whereas the power distribution is in the postpaid mode or the prepaid mode of the revenue collection against the electricity power consumption, the smart meters must be installed in the incoming time. The utilities must make their policies to install only the smart meters in the future to strengthen their infrastructure for the IT as well as OT point of view.
Use of IoT Over Legacy Meters	In the existing meters, if possible then the IoT over such systems may be installed. By installing such IoT devices, the metering data can be accumulated with the functionality in the IoT devices attached. If the relay

	is also embedded to such IoT devices, then the automatically power disconnection as well as reconnection can be achieved by such tasks
Use of Artificial Intelligence	In the existing system, the analysis part is very poor. To strengthen the smart infrastructure, the AI may be incorporated to the existing IT system. The existing MDAS system can be equipped with the ML, AI technology to give the best suggestions and optimizing the power distribution systems.
Use of Big Data Analytics	The exist data captured through various means on the real-time, can be utilities by the big data analytics and can result in the optimum suggestions over the past accumulated data as well as the real-time actuation of the data.
Strengthening of the IT/OT Infrastructure:	The existing IT and OT infrastructure needs to be strengthened, in incoming time, the SCADA at all city level, needs such infrastructure, so it may enhance the existing infrastructure keeping the future aspects of the utilities.
Restriction of Human Being due to Covid Pandemic	If the existing infrastructure is moved to the fully prepaid with smart meter infrastructure, then the physical movements of the human being to the premises of the closures will be restricted. The lock-down etc., imposed by the pandemic situations, will not affect over the power distribution, the essential services for human beings. Also, the missed call framework designed in the [20] is useful for the utilities in the distribution of the duplicate invoices over the missed call. The no-power complaints or fuse call complaints can also be served with the help of the framework. This framework can enhance the functionality of the power distribution companies. Especially in the COVID Pandemic lock-down duration. The long outstanding dues can also be mitigated by implementation of the above framework. By this the real-time outstanding dues as well as the no-power supply related complaints can be achieved.
Efficient Consumer grievance system:	by use of the smart infrastructure, the power break down information can be utilized by the power distribution companies received by the event triggered by the smart meters, the now power complaints can be addressed by the fuse call resolving team on the real-time basis.
Efficient Assets Break-down Management System:	Preventive actions can be initiated by use of the efficient assets break-down management system. The plant maintenance system can perform the maintenance in preventive mode for better break-down management in the electricity power consumption.

5.2 Conclusions

This thesis represented the various IoT techniques used in the Metering Billing and collection processes in the Revenue Management System in the Electricity power consumption of a power distribution company. We analyzed and suggested the recommendations for the electricity meter reading system with limitations in the traditional legacy systems. Research Work analyzed the existing techniques used in the electricity power consumption along with Revenue Management System (RMS) consisting of the Core activities i.e. Electricity Meter Reading, Bill Generation and Revenue collection against the electricity power consumption. In the power distribution companies, especially in the developing countries like India where the Aggregate Technical and Commercial (AT & C) Loss is a burning concept and maximum of the power distribution companies are running with a huge AT & C Loss. The thesis also covered the analysis and development of the frameworks useful in the reduction of the AT & C Loss and supply of the electricity with quality. Special prototypes designed to collect the electricity meter readings via IoT techniques and frameworks for decision support systems for Meter Data Acquisition System are supporting the distribution companies for seamless acquisition of the meter readings. Micro analysis carried out for the electricity power consumption with two broad aspects i.e. the information technology aspect and the other one is operational technology aspect. In the information technology, the revenue management system i.e. meter reading, invoice generation and the revenue collection along with energy accounting and auditing is focused with Geographical information system, assets management, inventory management etc. where as in the operational technology aspect the smart grid, smart meters, meter data acquisitions, head end systems etc. are studied and analyzed.

IoT data is assessed in a virtual environment in order to increase overall data processing with the edge computing environment. Performance of the proposed VEnVMQTT model is assessed in comparison to the established MQTT model. The simulation is run with different delay counts, including service, transmission, and processing latency. According to the simulation analysis, the suggested VEnvMQTT model has a lower latency than the current standard MQTT model. The simulation results showed that when compared to the traditional MQTT model, the suggested VEnvMQTT model delivers a 20% reduction in latency.

5.3 Future Perspectives

There are numerous topics in the electricity power consumption to carry out the systematic analysis of the flow of the electricity as well as the information in the trading of the electricity. The aggregate technical and commercial losses in the power distribution companies can be minimized to the standards by adopting the new emerging technologies like artificial intelligence and machine learning. The load shedding, load prediction and scheduling of the load at micro level, can be good topics related to the subject for further work. Distribution management system, Supervisory Control and Data Acquisition, real-time data acquisition, use of robotics in the surveillance of the power transmission lines can be the related domain to this thesis.

Apart from the above, the more future perspective aspects can be enumerated in the following section.

a. Integration with Industry Trends

It explores how this research work aligns with current and anticipated trends in the industry. It discusses potential collaborations with industry partners to integrate the findings into practical applications.

b. Adaptation to Technological Evolution

It anticipates how your research can adapt to and leverage upcoming technological advancements. It considers the integration of technologies such as artificial intelligence, blockchain, or quantum computing.

c. Long-Term Impact on Policy and Regulation

It assesses the potential long-term impact of this research work on policy-making and regulatory frameworks. It discusses how your findings might contribute to the development of new policies or the modification of existing ones.

d. Global Outreach and International Collaboration

It explores the possibilities for global outreach and collaboration with researchers and institutions worldwide. It discusses how this research could contribute to addressing global challenges and benefit diverse populations.

e. Cross-disciplinary Fertilization

It identifies the opportunities for cross-disciplinary fertilization with fields beyond this research work's immediate focus. It discusses potential collaborations with researchers from diverse disciplines to bring new perspectives to research.

f. Innovative Educational Programs

It proposes the integration of this research work's findings into innovative educational programs. It considers how this research work could enhance curricula, training modules, or professional development courses.

g. Open Data Initiatives

It advocates for open data initiatives related to this research work. It discusses how making this data openly accessible can foster collaboration and contribute to the advancement of knowledge.

h. Community Empowerment and Participation

It explores ways to empower and involve communities in the research process. It discusses strategies for participatory research that engages community members in shaping and implementing future projects.

i. Quantifying Societal Impact

It develops metrics and methodologies to quantify the societal impact of this research work. It discusses how impact assessments could provide valuable insights for policymakers and stakeholders.

j. Resilience to Changing Environmental Conditions

It considers how this research work can contribute to building resilience in the face of changing environmental conditions It discusses the strategies for adapting your findings to address challenges posed by climate change or other environmental shifts.

k. Robustness in the Face of Cybersecurity Challenges

It anticipates the potential cybersecurity challenges and discusses how this research work can contribute to creating robust and secure systems. It explores the strategies for addressing emerging threats in the cybersecurity landscape.

l. Health and Well-being Implications

It explores potential implications of this research work on public health and well-being. It discusses how the findings could contribute to health interventions, disease prevention, or healthcare improvement.

m. Economic and Market Implications

It evaluates the potential economic and market implications of this research work. It discusses how this research work might influence business strategies, entrepreneurship, or the development of new markets.

n. Continued Stakeholder Engagement

It emphasizes the importance of continued engagement with stakeholders, including end-users, policymakers, and industry representatives. It discusses mechanisms for sustaining fruitful collaborations and maintaining relevance.

o. Robotic Process Automation (RPA) and Autonomous Systems

It considers the integration of Robotic Process Automation (RPA) and autonomous systems in this research work. It explore how automation can enhance efficiency and decision-making processes.

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Appendices

Appendix -I Review paper in SCI/Scopus indexed Computers, Materials & Continua (Technologies Behind the Smart Grid and Internet of Things: A System Survey)

Computers, Materials & Continua

Tech Science Press

DOI: 10.32604/cmc.2023.035638

Review

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Technologies Behind the Smart Grid and Internet of Things: A System Survey

Kuldeep Sharma[1], Arun Malik[1], Isha Batra[1], A. S. M. Sanwar Hosen[2], Md Abdul Latif Sarker[3] and Dong Seog Han[4,*]

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Abstract: Electric smart grids enable a bidirectional flow of electricity and information among power system assets. For proper monitoring and controlling of power quality, reliability, scalability and flexibility, there is a need for an environmentally friendly system that is transparent, sustainable, cost-saving, energy-efficient, agile and secure. This paper provides an overview of the emerging technologies behind smart grids and the internet of things. The dependent variables are identified by analyzing the electricity consumption patterns for optimal utilization and planning preventive maintenance of their legacy assets like power distribution transformers with real-time parameters to ensure an uninterrupted and reliable power supply. In addition, the paper sorts out challenges in the traditional or legacy electricity grid, power generation, transmission, distribution, and revenue management challenges such as reducing aggregate technical and commercial loss by reforming the existing manual or semi-automatic techniques to fully smart or automatic systems. This article represents a concise review of research works in creating components of the smart grid like smart metering infrastructure for postpaid as well as in prepaid mode, internal structure comparison of advanced metering methods in present scenarios, and communication systems.

Keywords: Electricity consumption; bidirectional; advanced meter infrastructure; energy; internet of things; smart grid; smart meter

1 Introduction

The existing technologies in the electricity supply contain information technology (IT) and operational technology (OT) broader aspects. In the OT part, the supply operational infrastructure like supervisory control and data acquisition (SCADA), real-time data acquisition system (RTDAS), and distribution management system are covering the demand side, whereas revenue management system (RMS) mainly, meter reading or billing and collection, geographical information system (GIS), assets management, plant management, etc. are the IT aspects. The combination of the concepts of

Appendix -II Research paper in Scopus indexed international journal of intelligent system and applications in engineering (Architecture Model VeEnvMQTT)

International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING

IJISAE

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Virtual Edge Computing Architecture Model for the Real-Time Data Server in the IoT Environment

Kuldeep Sharma[1], Arun Malik[2]

Submitted: 24/08/2022 Accepted : 21/11/2022

*Abstract:*Recently, a number of smart devices are connected through the Internet to achieve data processing and generation. The data generated from the cloud server demand robust and reliable data storage and protection for unauthorized data access. Additionally, the processed data demands for avast range of processing power to tangible effective information for processing. The different business process comprises of technologies to increase efficiency and performance with the reduced cost of operation in the IoT devices. The data processing leads to the data handledwith the edge computing technology. The technological procession deal with the response time improved cost-saving bandwidth and battery life those significantly impacts on safety and privacy in the organization. This paper presented a Virtual Environment Based HTTP server model termed as (VEnvMQTT) for effective data processing in the edge computing architecture of the IoT environment. The proposed VEnvMQTT model comprises of the actuators and IoT server data. The proposed VEnvMQTT model evaluates the data collected from the sensor at an effective level of processing time with edge computing technology. The analysis of the simulation results expressed thatthe proposed VEnvMQTTmodel achieves a reduced latency of 24.566ms which is ~20% minimal to the existing MQTT model.

Keywords:*Virtual server, Edge computing, MQTT, Internet of Things (IoT), Quality of Sevices*

1. Introduction

Internet of Things is the system of physical gadgets such as vehicles, home appliances, and different devices connected to the Internet. These devices are equipped with software, hardware, network, sensors, and actuators, which allow these "things" to connect and exchange data [1]. This interconnection opens the door for more straightforward coordination of the real world 'things' into computer-based frameworks. This binding improves proficiency changes, commercial advantages, and reduced human efforts. A survey conducted in 2017 states that there were 8.4 billion IoT gadgets during that year, and it also appraises that "there will be around 30 billion gadgets by 2020" [2]. The worldwide market estimation of "IoT is anticipated to be $7.1 trillion by 2020" [3]. "IoT" was coined by Kevin Ashton in 1999. However, the author favors the expression called "Web of Things" (WoT) [4]. At that point, "Radio Frequency Identification" (RFID) as a primary part in building IoT would enable computers to deal individual things.

With the explosion of information, devices, and networking, the present Cloud architecture on its own cannot handle the flood of data. The Cloud offers extensive computation, storage, and even connectivity for users who can access the Cloud efficiently and economically. These centralized resources can create notable delays and lack in the performance for devices located far away from a centralized Cloud viz., data center. Edge computing, otherwise called merely "Edge," does processing near the data source, and should not transmit to the remote Cloud or other unified frameworks for handling. The time it takes to send data to the source is reduced, which enhances the speed and execution of data transmission [5]. Fog computing is a standard that characterizes how edge processing should function. It also encourages the task of figuring, stockpiling, and system administration benefits between end-to-end devices, where data values are identified in the Cloud. Furthermore, Fog off-loading the Cloud for edge processing [6] can resort to many applications. There is a range of critical abilities which Edge can provide for Industrial IoT (IIoT) applications taking into account the prerequisites of the current issues, as enunciated by the accompanying instances found in regular mechanical tasks [7]. With Edge, PC, and capacity frameworks dwell at the edge also, as close as conceivable to the segment, gadget, and application or human that creates the data being handled. The objective is to minimize latency because the data need not be sent from the edge of the system to a central organizing framework, and back to the edge [8]. The IoT-associated gadget is an obvious use for edge processing. With remote sensors introduced on a machine, partly or entirely, they produce large measures of data. The data that is sent over an extended network is to be dissected, logged, and followed. This takes substantially more time than if the information is handled at the edge, near the data [9].

IoT demands a fresh kind of infrastructure which requires more capital. Present Cloud computing models are not planned for the variety, volume, and velocity of information which these IoT devices produce. For example, current unconnected devices are present in the volume of billions, and they are producing more

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Appendix -III Conference Paper presented in the international conference ICAICR 2020 , CCIS 1394 (Missed Call Messaging Framework)

An Efficient IoT Based Framework for Missed Call Messaging Services for Electricity Consumers

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Abstract. This paper is introducing the missed call messaging services to the consumers of the electricity. Nowadays, there are consumers who could not get their monthly bills in the form of physical papers, specially the consumers residing at the remote area/ far distinct from the utility offices. The consumers at remote area can pay their dues monthly very easily, but once the backlog is increased, the consumer becomes defaulters due to non-availability of huge amount in the form of backlog with heavy amount as delay payment charge/ penalty. So they are ready to pay the bills monthly, but due to non-awareness of their dues amount, they are not able to pay the bills. So for mitigating this issue, the missed call messaging service is proposed for the electricity consumers specially those who are not aware of the internet/ website/ smart phones etc. services. The consumers are not to bother about remembering their large number consumer id, the mobile number registered at utility office, is sufficient enough, they will be getting the messages about their pending dues at utility office after the consumer make a missed call on a specific number for getting the balance details. The missed call for No_Power_Supply complaint on the other number will lodge the no power supply complaint and a unique complaint number will be messaged to the consumer on their mobile phones (can be delivered on basic mobile phone as text message). The architecture is based on the open source solutions.

Keywords: Arduino/ESP32 SIM800L/REST API · IVR · VOIP · cURL · Energy · IoT

1 Introduction

Now a days, the urban area is so much advanced, the consumers are aware of the electricity website, android mobile applications etc. They are able to get the various information about their electricity bills due amount along with their due date and ultimately paying their bills online via any of the plenty of the services available within the prescribed period and even getting the benefits of paying the bills online before due dates with

K. Sharma—Research work carried out at Department of Computer Science and Engineering at Lovely Professional University, Punjab.

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Appendix -IV Conference Paper presented in 2021 International Conference on Computing Sciences (ICCS) (Theft Detecting Framework)

2021 International Conference on Computing Sciences (ICCS)

An Efficient IoT Based Electricity Theft Detecting Framework For Electricity Consumption

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***Abstract* — The framework is designed for the electricity power trading companies for detecting any electricity theft by unauthorized means. The framework is based on the (Internet of Things) IoT techniques. The Data for all consumers tagged to specific geographical area is required to be analyzed by the framework. The framework in first part is analyzing the data of the past consumption of the specific area, this area may be Distribution Transformer level or Feeder Level or any portion of the electricity supply which is suspected of such electricity theft. In the second part, the IoT devices are added to the metering units of the specific sources. From this source, all the electricity supplied to the specific region will be accumulated on real-time basis. Rest IoT devices will be added to different parts of the Electricity Supply Line. Based on the analysis of real-time data accumulated via these IoT devices through Global System for Mobile (GSM) technology at the server located at either Data Center or Cloud Storage as the case may be. The framework will pinpoint the specific area where the theft of electricity is affected. Another vigilance IoT device is used to capture the images of the scenes for monitoring the naked wire for prevention from the electricity theft. The Real-Time reporting of this devices is generating alert to the power distribution company representatives to take necessary steps to reduce the losses occurred due to energy theft. The advanced infrastructure, now a days, is more prone to electricity theft, the Advanced Metering Infrastructure (AMI), is fully machine to machine (M2M) functioning, if such system is compromised, the theft may occur, to stop such electricity theft, since last two decades, various researchers are proposing their expert algorithms to minimize the same. The current paper proposes the additions in the existing literature of electricity theft detection and prevention.**

Keywords— IoT, Energy, Electricity Theft Detection, Power Trading

I. Introduction

The Power distribution infrastructure is upgrading day by day and moving towards the smart grid infrastructure. The advance metering infrastructure of two-way communication of the electrical devices is making it smarter. Power Theft, its detection and prevention is the most prevalent issues in all the power distribution companies of developing countries like India. It not only causes the financial losses but also the irregular electricity supply with quality. This theft is of two types, one is Power-Tapping, and another is Meter-Fraud. The metering data is collected by such infrastructure over a central place. This huge data can be processed by the big data techniques to analyze and take appropriate decisions. But still there exists some places of the electricity distribution where the electricity theft is a challenging task. This electricity theft is increasing the Aggregate Technical and Commercial Loss in their annual accounts. To reduce the Aggregate Technical and Commercial Loss (AT & C Loss) is the prime target to the power distribution companies.

In the modern era, each and every activity is based on the electricity, but still there exist some flaws in the processes adopted in the system resulting theft and leakage which causes the heavy energy losses to electricity supply utilities and the society [8]. The framework, proposed in this work, is IoT based and shows how, the readings accumulated at the metering data acquisition system can be analyzed for the decision support system to detect and prevent the power theft scenarios.

In this paper we propose a framework for electricity power trading companies for detection of the electricity theft. The further sections of this paper are review of literature in section II, Section III point outs the research gap, section IV focuses on the research methodology, section V explains the components of the framework, section VI elaborates the findings and discussion, and section VII shows the result and discussion.

II. Review Of Literature

In the current era, the electricity consumption is increasing exponentially, keeping this in view, the distributions companies are strengthening their Information Technology (IT) and Operational Technology (OT) infrastructure for achieving their main objectives, the first is to provide the qualitative electricity supply to their valued consumers and reducing the aggregate technical and commercial loss. The loss incurred due to technical reasons cannot be omitted, whereas the commercial loss incurred due to theft of the electricity can be minimized by applying the latest technologies. But even in the lack of advance equipment the supply side, the proposed framework can identify the theft of the electricity after using the framework. This framework can be helpful to the power distribution companies to minimize the theft cases and enhance the revenue collection against the electricity consumption on the real-time.

The following are the related work carried out in the context of electricity consumption and power theft related IoT devices.

1. In 2004, Bernard Cole et al. in their research paper proposed the work of attaching the lined their smart unit of meter to a satellite for accumulation of the existing data from the meters by a cubical box of 8inch side [1]. In this model, the data handshaking of the consumption was at the interval of the 15 minutes. This model was also useful for the load profiling and forecasting to avoid any blackouts [1]. A hall effect current sensor was used by author of [6] to tackle the problem of the power theft. The traditional method of the electricity theft adopted to 11 Kilo Volt (11KV) distribution Low

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Appendix -V Conference Paper Presentation Certificate in Fourth International Conference on Advance Informatics on computing Research

Fourth International Conference on
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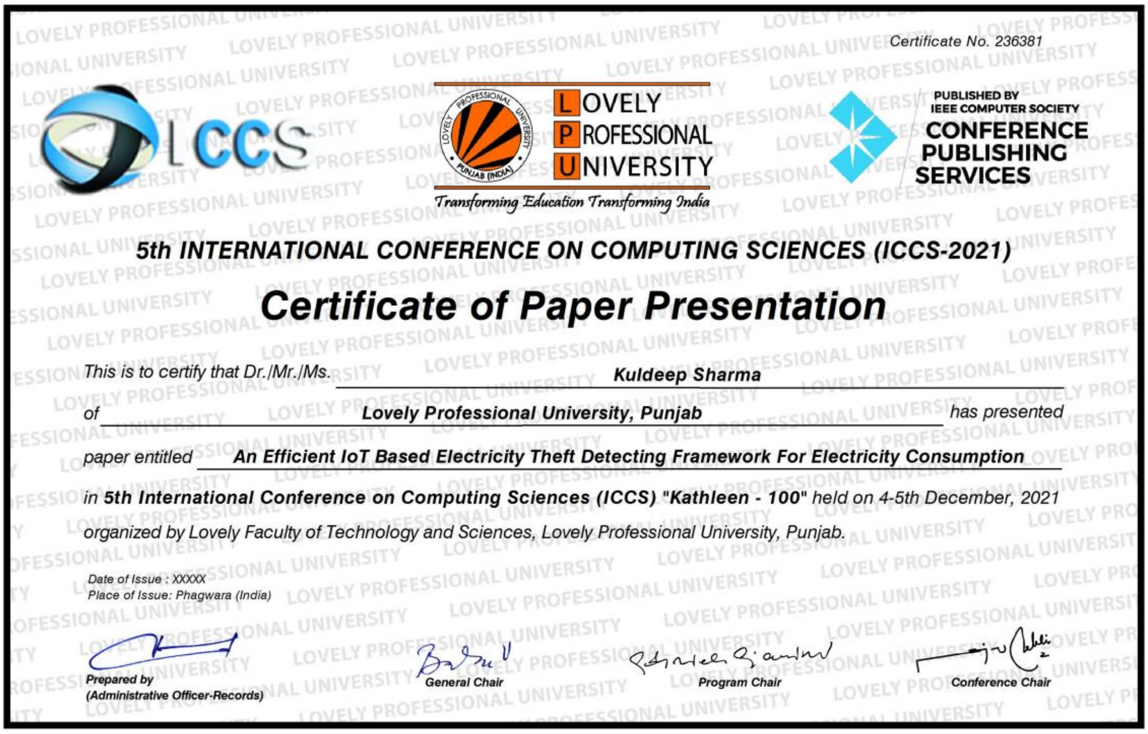
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Appendix -VII Conference Paper Presentation Certificate in international conference on "emerging Trends on Technology in Computational and Socialist Era"

Narayan Academy of Managerial Excellence (Faculty of Information Technology)

GNSU GOPAL NARAYAN SINGH UNIVERSITY

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held at Gopal Narayan Singh University, Jamuhar, Bihar, India on 10th and 11th September 2021.
He also Presented a Paper titles
An Efficient Artificial Intelligence Based Framework As Virtual Assistant For Electricity Consumers.

Dr. (Prof) M. L Verma
Vice Chancellor, GNSU
Jamuhar, Rohtas, Bihar

Govind Narayan Singh
Secretary, GNSU
Jamuhar, Rohtas, Bihar

Dr. Ipseeta Nanda
Convenor

Appendix -VIII Conference Paper Presentation Certificate in 2nd international conference on Global issues in Multidisciplinary Academic Research

2nd International Conference
On
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This is to certify that Prof. / Dr. / Mr. / Ms.

Kuldeep Sharma

has participated in the International Conference on Global Issues In Multidisciplinary Academic Research organized by Indian Academicians and Researchers Association in association with Rajabhat Maha Sarakham University, Thailand on 5th June 2022

He / She has presented the paper titled

AN EFFICIENT AI BASED FRAMEWORK FOR MONITORING AND SUGGESTING FOOD CONSUMPTION

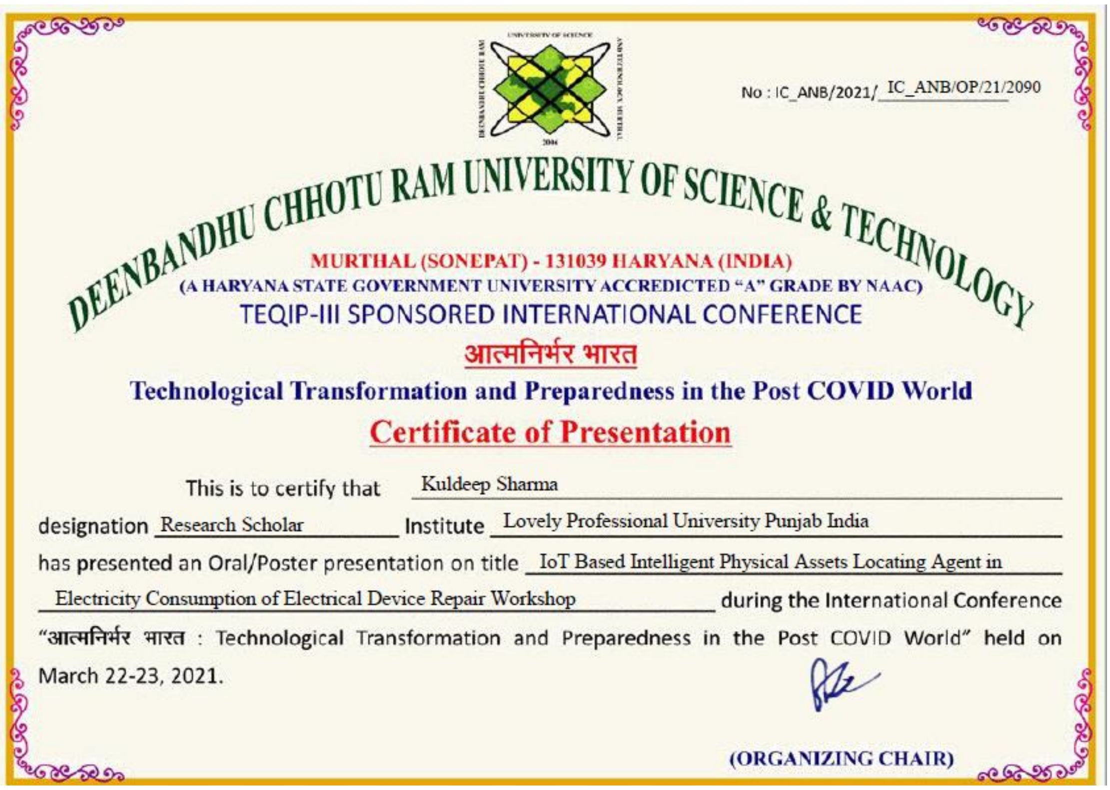
www.iaraconference.com

Assoc. Prof. Dr. Sanya Kenaphoom
Conference Convenor
Director, RDI, RMU
Thailand

Ms. Nattida Klangpracha
Conference Convenor
Director, IRIE, RMU
Thailand

Dr. Tazyn Rahman
Conference Convenor
Director, IARA Research Solutions Pvt Ltd, India

Appendix -IX Conference Paper Presentation Certificate in TEQIP-III sponsored international conference Aatmnirbhar Bharat technological transformation and preparedness in the Post COVID World



No : IC_ANB/2021/ IC_ANB/OP/21/2090

DEENBANDHU CHHOTU RAM UNIVERSITY OF SCIENCE & TECHNOLOGY

MURTHAL (SONEPAT) - 131039 HARYANA (INDIA)

(A HARYANA STATE GOVERNMENT UNIVERSITY ACCREDICTED "A" GRADE BY NAAC)

TEQIP-III SPONSORED INTERNATIONAL CONFERENCE

आत्मनिर्भर भारत

Technological Transformation and Preparedness in the Post COVID World

Certificate of Presentation

This is to certify that Kuldeep Sharma designation Research Scholar Institute Lovely Professional University Punjab India has presented an Oral/Poster presentation on title IoT Based Intelligent Physical Assets Locating Agent in Electricity Consumption of Electrical Device Repair Workshop during the International Conference "आत्मनिर्भर भारत : Technological Transformation and Preparedness in the Post COVID World" held on March 22-23, 2021.

(ORGANIZING CHAIR)

Appendix -X Patent Filing (An IoT Based Device to Convert functioning of Legacy electronic Meter into Smart Meter)

सत्यमेव जयते

INTELLECTUAL PROPERTY **INDIA**
PATENTS | DESIGNS | TRADE MARKS
GEOGRAPHICAL INDICATIONS

Controller General of Patents,
Designs & Trade Marks

G.A.R.6
[See Rule 22(1)]
RECEIPT

Docket No 105546 **Date/Time 2021/10/05 10:30:06**

Dharam Buddhi Lovely
professional university
JalandharDelhi GT road
Phawgara Email: dip@lpu.co.in

Sr. No.	Ref. No./Application No.	App. Number	Amount Paid	C.B.R. No.	Form Name	Fee Payment	Remarks
1	202111045082	TEMP/E-1/51085/2021-DEL	1600	35078	FORM 1	Full	AN IOT-BASED DEVICE TO CONVERT FUNCTIONING OF LEGACY ELECTRONIC METER INTO SMART METER
2	E-106/939 /2021/DEL	202111045082	0	-1	FORM28	Full	

TransactionID	Payment Mode	Challan Identification Number	Amount Paid	Head of A/C No
N-0000863229	Online Bank Transfer	0510210001632	1600.00	1475001020000001

Total Amount : ₹ 1600

Amount in Words: Rupees One Thousand Six Hundred Only

Received from Dharam Buddhi the sum of ₹ 1600 on account of Payment of fee for above mentioned Application/Forms.

* This is a computer generated receipt, hecnce no signature required.

Appendix -XI Granted Patent (An AI Based Smart Electricity power Consumption Monitoring Agent)

क्रम सं/SL No :011164972

पेटेंट कार्यालय,भारत सरकार | The Patent Office, Government Of India

पेटेंट प्रमाण पत्र | Patent Certificate

(पेटेंट नियमावली का नियम 74) | (Rule 74 of The Patents Rules)

पेटेंट सं. / Patent No.	:	441011
आवेदन सं. / Application No.	:	202111051671
फाइल करने की तारीख / Date of Filing	:	11/11/2021
पेटेंटी / Patentee	:	Lovely Professional University

प्रमाणित किया जाता है कि पेटेंटी को, उपरोक्त आवेदन में यथाप्रकटित *AN AI BASED SMART ELECTRICITY CONSUMPTION MONITORINGAGENT* नामक आविष्कार के लिए, पेटेंट अधिनियम, 1970 के उपबंधों के अनुसार आज तारीख नवम्बर 2021 के ग्यारहवें दिन से बीस वर्ष की अवधि के लिए पेटेंट अनुदत्त किया गया है।

It is hereby certified that a patent has been granted to the patentee for an invention entitled *AN AI BASED SMART ELECTRICITY CONSUMPTION MONITORINGAGENT* as disclosed in the above mentioned application for the term of 20 years from the 11th day of November 2021 in accordance with the provisions of the Patents Act,1970.

अनुदान की तारीख : 28/07/2023
Date of Grant :

पेटेंट नियंत्रक
Controller of Patents

टिप्पणी - इस पेटेंट के नवीकरण के लिए फीस, यदि इसे बनाए रखा जाना है, नवम्बर 2023 के ग्यारहवें दिन को और उसके पश्चात प्रत्येक वर्ष में उसी दिन देय होगी।

Note. - The fees for renewal of this patent, if it is to be maintained, will fall / has fallen due on 11th day of November 2023 and on the same day in every year thereafter.

Controller General of Patents, Designs & Trade Marks
Plot No. 32, Sector 14, Dwarka, New Delhi-110075
Tel No. (091)(011) 28034304-06 Fax No. 011 28034301,02
E-mail: delhi-patent@nic.in
Web Site: www.ipindia.gov.in

सत्यमेव जयते

INTELLECTUAL PROPERTY INDIA
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G.A.R.6
[See Rule 22(1)]
RECEIPT

Docket No 118907 **Date/Time 2021/11/11 14:08:43**

To
Dr. Monica Gulati

UserId: Registrar

Lovely Professional University Jalandhar
Delhi GT road

CBR Detail:

Sr. No.	Ref. No./Application No.	App. Number	Amount Paid	C.B.R. No.	Form Name	Remarks
1	E-12/2534/2021/DEL	202111051670	2500	39867	FORM 9	
2	E-12/2535/2021/DEL	202111051675	2500	39867	FORM 9	----
3	E-12/2537/2021/DEL	202111051669	2500	39867	FORM 9	----
4	E-12/2540/2021/DEL	202111051671	2500	39867	FORM 9	----
5	E-12/2533/2021/DEL	202111051674	2500	39867	FORM 9	----
6	E-12/2532/2021/DEL	202111051672	2500	39867	FORM 9	----
7	E-12/2536/2021/DEL	202111051676	2500	39867	FORM 9	----
8	E-12/2539/2021/DEL	202111051677	2500	39867	FORM 9	----
9	E-12/2538/2021/DEL	202111051673	2500	39867	FORM 9	----
10	E-2/1568/2021/DEL	202011020313	0	-----	FORM 2	----
11	202111051671	TEMP/E-1/58201/2021-DEL	1600	39867	FORM 1	AN AI BASED SMART ELECTRICITY CONSUMPTION MONITORING AGENT
12	202111051670	TEMP/E-1/58619/2021-DEL	1600	39867	FORM 1	A SMART DETACHABLE AND FOLDABLE DINING TABLE

Patent Search

Patent Search   Patent E-register   Application Status   Help

Invention Title	AN AI BASED SMART ELECTRICITY CONSUMPTION MONITORINGAGENT
Publication Number	48/2021
Publication Date	26/11/2021
Publication Type	INA
Application Number	202111051671
Application Filing Date	11/11/2021
Priority Number	
Priority Country	
Priority Date	
Field Of Invention	COMMUNICATION
Classification (IPC)	H04L0029080000, G16Z0099000000, G08B0025010000, G07C0005080000, G08B0013220000
Inventor	

Name	Address	Country	Nationality
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Arun Malik	Lovely Professional University, Delhi Jalandhar GT road Phagwara- 144411.	India	India
Dwaraka Niranjana. P	Lovely Professional University, Delhi Jalandhar GT road Phagwara- 144411.	India	India
Jyotirmoy Pathak	Lovely Professional University, Delhi Jalandhar GT road Phagwara- 144411.	India	India
Isha	Lovely Professional University, Delhi Jalandhar GT road Phagwara- 144411.	India	India
Atul Khosla	Lovely Professional University, Delhi Jalandhar GT road Phagwara- 144411.	India	India

Appendix -XII Patent Filing (System and Method for Missed call messaging services for Electricity Consumers)

Indian Patent Advanced Search System

Patent Search

Patent Search Patent E-register Application Status Help

Invention Title	SYSTEM AND METHOD FOR MISSED CALL MESSAGING SERVICES FOR ELECTRICITY CONSUMERS
Publication Number	21/2022
Publication Date	27/05/2022
Publication Type	INA
Application Number	202211028422
Application Filing Date	17/05/2022
Priority Number	
Priority Country	
Priority Date	
Field Of Invention	COMPUTER SCIENCE
Classification (IPC)	G06Q0020100000, G06Q0030040000, H04W0004120000, H04N0021262000, G06N0020000000
Inventor	

Name	Address	Country	Nationality
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Arun Malik	Lovely Professional University, Phagwara, Punjab, India -144411	India	India
Isha	Lovely Professional University, Phagwara, Punjab, India -144411	India	India

List of Publications

List of Conferences