STABILITY COMPUTATION USING SMALL SIGNAL ANALYSIS AND MITIGATION OF INTERAREA OSCILLATIONS SUCH AS FREQUENCY AND TIE-LINE POWER DISTURBANCES IN LARGE POWER POOLS

DISSERTATION-II

Submitted in partial fulfillment of the requirement for the award of the degree of

MASTER OF TECHNOLOGY

IN

ELECTRICAL ENGINEERING

By

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May 2017

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I **GABRIEL KAPAPULA**, student of M.tech (Electrical Engineering) under school of Electronics and Electrical Engineering of Lovely Professional University, Punjab, hereby declare that all the information furnished in this dissertation report is an authentic record of my own work carried out under the supervision of **MR.MUKUL CHANKAYA**, Assistant Professor, School of Electronics and Electrical Engineering. The matter presented in this dissertation has not been submitted to Lovely Professional University or to any other university or institute for award of any degree.

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ACKNOWLEDGEMENT

I would like to thank **LOVELY PROFESSIONAL UNIVERSITY** for giving me the opportunity to use their resource and work in such a challenging environment. I am grateful to the individuals who contributed their valuable time towards my thesis.

I wish to express my sincere and heart full gratitude to my guide "**Mr. MUKUL CHANKAYA**" Assistant professor, who has always guided me prudently in working on this thesis in sync with global trends in a scientific approach.

I would also like to extend my gratitude to my friends and family who always encouraged and supported me in this thesis work.

Last but not the least; I would like to thank all the staff members of department of **Electrical and Electronics engineering** who have been very patient and co-operative with me.

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CERTIFICATE

This is to certify that **GABRIEL KAPAPULA** bearing Registration no. **11511936** has completed objective formulation of thesis title "**STABILITY COMPUTATION USING SMALL SIGNAL ANALYSIS AND MITIGATION OF INTERAREA OSCILLATIONS SUCH AS FREQUENCY AND TIE-LINE POWER DISTURBANCES IN LARGE POWER POOLS"** under my guidance & supervision. To the best of my knowledge, the present work is the result of his original investigation & study. No part of the thesis has ever been submitted for any other degree at any University.

The thesis is fit for submission and the partial fulfillment of the conditions for the award of **MASTER OF TECHNOLOGY (ELECTRICAL ENGINEERING).**

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I, **GABRIEL KAPAPULA** student of **MASTER OF TECHNOLOGY (Electrical Engineering)** under the department of **ELECTRICAL AND ELECTRONICS ENGINEERING** of Lovely Professional University, Punjab, hereby declare that all the information furnished in this thesis report, is based on my own intensive research and is genuine.

This thesis does, to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university without proper citation.

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ABSTRACT

This exploration work manages reasonable methodologies for calculation and examination of oscillatory security of expansive interconnected power frameworks inside power framework operation by utilizing the little flag strength strategy. Next to voltage soundness and transient dependability, oscillatory strength must be evaluated, as well. It can be appeared, that parallel eigenvalue calculation utilizing a parallel variation of Arnoldi technique can lessen the time essential for eigenvalue calculation of vast power frameworks. Besides, it is demonstrated that strategies for Computational Intelligence can alleviate the quick appraisal of oscillatory solidness.

Inaddition, oscillatory solidness evaluation itself is bothered as a result of two noteworthy reasons. Right off the bat, oscillatory solidness can't be appraised on the premise of nearby data. It ordinarily requires a full and reasonable element model of the entire interconnected power framework. Along these lines, the trading of data between utilities is of great significance in the sense that if on one region there is a problem; power can still be gotten from the other region. Then again, this is progressively ruined by a hefty portion of the free power makers carrying on prohibitively to shroud their information. Also, the current true standard techniques and apparatuses for little flag solidness are not ready to perform security examination in the guaranteed reaction time required for online utilize.

Exchange work examination approach or transfer function method which is the cutting edge strategy will be broadly connected in this work with a specific end goal to evaluate the damping of overwhelming modes. It can likewise be for all intents and purposes utilized as a part of framework arranging, especially for plan and tuning of control frameworks. At the TSO side, clear genuine power edges over cross-outskirts and comparing soundness saves must be displayed rapidly and in a way, which is near human thinking, as opposed to eigenvalues. Aside from that, feebly damped modes must be followed under possibility conditions for genuine and arranged load stream circumstance. For exhibit purposes, models have been composed utilizing MATLAB/SIMULINK and with the assistance of the FUZZY LOGIC streamlining procedure.

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LIST OF ABBREVIATIONS

AESOPS	-	analysis of essentially spontaneous oscillations in power systems
SMA	-	selective modal analysis
EEAC	-	extended equal area criterion
EMS	-	energy management system
OLTC	-	on load tap changer
TCSC	-	thyristor controlled series compensator
PSS	-	power system stabilizer
PSO	-	particle swarm optimization
FACTS	-	flexible alternating current transmission system
SSSR	-	small signal stability rank
LFEO	-	low frequency electromechanical oscillations
PMU	-	phasor measurement unit
RFESS	-	redox flow energy storage system
SSSC	-	static synchronous series compensator
LFC	-	load frequency control
GA	-	genetic algorithm
BFOA	-	bacteria foraging optimization algorithm
TSO	-	transmission system operators
MATLAB	-	matrix laboratory
AC – DC	-	alternating current – direct current
MSPG	-	multi-source power generation

TCPS	-	thyristor controller phase shifter
POD	-	power oscillation damping
HVDC	-	high voltage direct current
CPU	-	computer programmable unit
ACE	-	area control error
AGC	-	automatic generation control
EDC	-	economic dispatch control
ANN	-	artificial neural network
IEEE	-	institute of electrical & electronics engineers
PID	-	proportional integral derivative
TDF	-	two degree of freedom
IMC	-	internal model control

CHAPTER 1
INTRODUCTION

Control frameworks are consistently developing with ever bigger limit. Once in the past isolated frameworks were interconnected to each other. Present day control frameworks have developed into frameworks of huge size, extending over a huge number of kilometers. With developing era limit, diverse ranges in a power framework are included with considerably bigger inactivity. Besides the dismantling of era, transportation as well as distribution is not common with respect to the practical application when it comes to the issue to do with maintaining an inter-related power systems, covering an extensive region with coordination with various divisions and generating stations. On approximated increased congestion of the power transportation corridors, the transmission operator might be forced to put up serious measures as reduce on the thermal limit capacities as a result of this overloading on the power transmission corridors.

The end result of this heavily loaded of the power transportation corridor is that little flag soundness, particularly between zone motions, turn into an expanding significance. Between range wavering is a typical issue in huge power frameworks around the world. Numerous electric frameworks worldwide are encountering expanded stacking on bits of their transmission frameworks, which can, and now and then do, prompt inadequately reduced filtered recurrence in lower ranges between territory motions. Many power utilities worldwide have this challenge of a congested inter-related power transportation corridor have usually addressed this issue with all the serious it deserves. Between range motions can seriously limit framework ability thereby demanding the shortening of the transfer of power between different operators as a way of streamlining operations. Such measures if properly implemented would likewise prompt far reaching framework aggravations if falling blackouts of transmission lines happen because of oscillatory power swings.

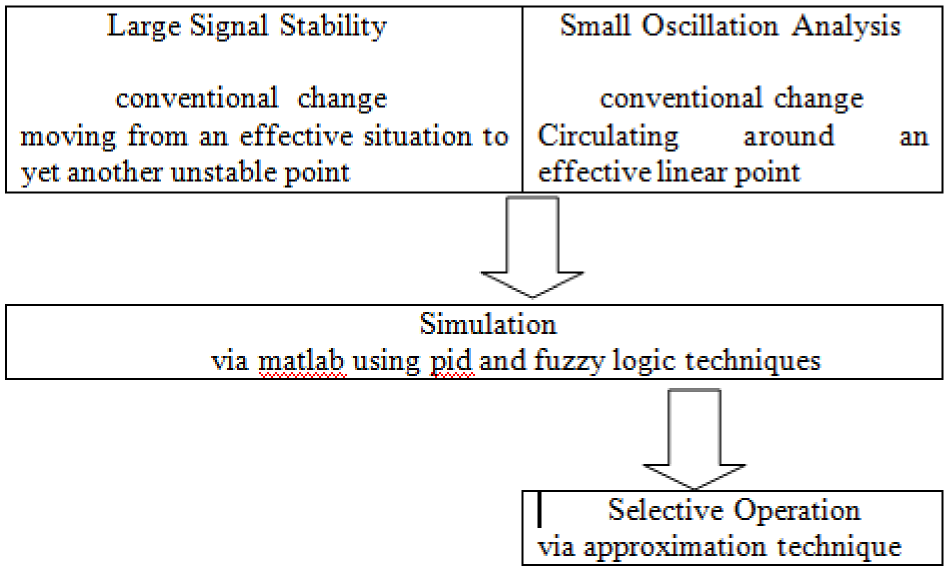

Figure 1: Analysis of Electromechanical Phenomena

In addition between territories motions in mass power frameworks can be related with the flow of energy exchanges and may include gatherings of synchronous machines that waver in respect to each other. These framework wide motions emerge from measured system topologies, heterogeneous machine elements, unfavorably between acting controllers, and vast between region control exchanges. With expanded framework burdens and arrangement of renewables in re-bit regions, long-separate power exchanges will in the end out-pace the expansion of new transmission offices. This incites extreme anxiety and execution confinements on the transmission arrange and may even bring about flimsiness and blackouts [1].

1.1 MOTIVATION

Worldwide investigation of the power framework markets demonstrates that LFC is a standout amongst the most productive subordinate administrations of the interconnected power frameworks. LFC is imperative theme of research and numerous analysts concentrated these issues with different blends of controllers and power framework models. All the controller techniques exhibited in writing for LFC consider have their own points of interest and burdens.

Utilization of the ideal control hypothesis to power system has demonstrated that an ideal LFC can enhance the dynamic security of a power framework. The LFC controller outline methods utilizing current ideal control hypothesis empower the power specialists to plan an ideal control framework concerning given execution model. As state input controllers require the exchange of data from all parts of the framework to a focal control office for preparing, which for extensive scale bury associated control framework could turn out to be restrictive. In the bigger frameworks every one of the states may not be accessible for estimation and require substantial number of sensors. Keeping in view the above, analysts persuaded to make use of all the more encouraging and commonsense type of ideal OFC for the investigation of LFC as this controller utilizes just a subset of the state vector for input purposes, this is less difficult, more reasonable and simple to actualize than the full state criticism controller.

Apart from progress made in charge innovation, the world has continued to make other advance in the last ten years, for instance, unbundling of the entire power system in terms also of its commercial operation profile, utilization to do with AC-DC tie lines, FACTS gadgets and so on. The vast majority of the specialists considered either warm or hydro creating units in a control territory. In a genuine circumstance, control region may have assortment of wellsprings of eras, for example, hydro, warm, gas, atomic, sun based, wind and so on. The control range having diverse wellsprings of energy era spoke to by a likeness warm or hydro unit elements just may not bring about reasonable plan of LFC control. Keeping in view the changing force situation, mix of multi-source generators in a control region with their comparing era commitment elements is more reasonable for the investigation of LFC. Furthermore, this spurred to incorporate the more sensible mix of multi-source control era (Thermal, hydro and gas) in a control region. An endeavor has been made to concentrate the LFC of different new power framework models with MSPG including FACTS gadgets (TCPS), AC-DC tie lines and rebuilt control framework condition. To show the execution of controller over an extensive variety of variety in parameters and load condition is likewise one of the key component of inspiration.

1.2 MODAL/LINEAR ANALYSIS

Eigenvalue or Modal investigation depicts the little flag conduct of the framework which include operation around a particular effective point and while at the same time not taking into consideration the distorted behavior such as those of many power electronics devices. Along these lines time space reproduction and modular examination in the recurrence area supplement one another when it comes to investigation the network electricity frameworks.

This approximation investigation explores the conventional conduct looking at the power network framework in general with different operating ranges and recurrences. In this respect, it is always considered that all the operating ranges in a power framework are stable. Also, the desire is to try and ensure that all the disturbing oscillations are effectively minimized in the quickest possible means. In order to have a clear perspective concerning the aftereffects to do with this approximation investigation are assumed to be frequency and effective filtering of disturbance operating range. A filtering part of say 10 % implies saying for 6 wavering amplitudes the adequacy of filtering may be say 52 % to do with its underlying worth. The actual threshold as to where to reach in terms of this filtering aspect is rather unknown. A filtering component of less than for example 6 % should be looked at with urgency. This process of filtering will be looked at as being effective when each particular operating range have an anticipated filtering proportion of not more than 7 %.

Also, little flag dependability investigation with the technique for eigenanaly-sister has demonstrated as the best examination instrument for power framework low-recurrence motions. This technique gives not just data identified with the system of destabilization additionally those territories which have potential flimsiness issues. In this strategy the framework is initially linearized around a working point. Straight estimate of the first framework, which is basically nonlinear, can be introduced by the accompanying state-space little flag conditions [26, 27, 28, 29]:

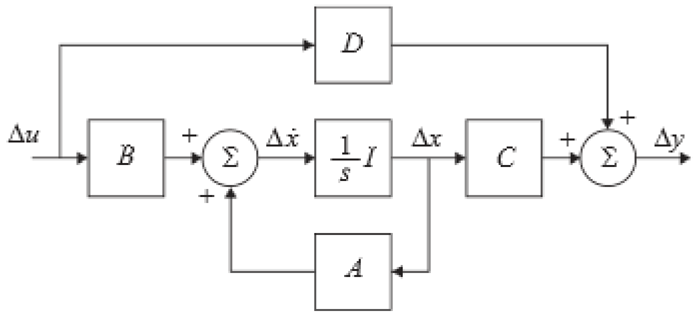

Figure 2: Diagram of the state-space representation

$$\Delta\dot{x} = A\Delta x + B\Delta u$$

$$\Delta y = C\Delta x + D\Delta u \qquad (1)$$

Where,

Δx corresponds to n-dimensional angle having state deviations,

Δy corresponds to m-dimensional angle having output deviations,

Δu corresponds to r-dimensional angle having input deviations,

A corresponds to state shape occupied by n×n,

B corresponds to input shape occupied by n×r,

C corresponds to input shape occupied by m×n,

D corresponds to feed forward shape occupied by n×r.

The mathematical model in equation (1) can be shown as Fig. 2.

The approximate quantities occupied by n×n of shape A will be n solutions $\lambda = \lambda 1, \lambda 2, ..., \lambda n$ of (2)

$$\det(A - I\lambda) = 0 \quad (2)$$

These eigenvalues might be genuine or complex numbers. The perplexing eigenvalues dependably happen in conjugate combine and are of the frame $\lambda = \sigma \pm j\omega$ which signify a swaying mode. From a swaying mode the damping proportion and oscillatory recurrence for that mode can be resolved. The damping proportion of the wavering is given by,

$$\zeta = \frac{-\sigma}{\sqrt{\sigma - \omega}} \quad (3)$$

and the damped recurrence distortions in Hertz is taken as

$$f = \frac{\omega}{2\pi} \quad (4)$$

The level of filtering proportion decides the rate of rot of wavering plentifulness. On the off chance that the genuine piece of the eigenvalue is sure then damping proportion will be negative, which implies the wavering will endure with time, while the negative genuine part demonstrates positive damping which implies the swaying will has the inclination of rotting.

For each eigenvalue λi of the n×n matrix A, there are right and left of eigenvectors which

satisfy the Eqs. (5) and (6), respectively.

$$A\varphi_i = \lambda_i \varphi_i \quad (5)$$

$$\psi_i A = \lambda_i \psi_i \quad (6)$$

Where,

λi corresponds to ith approximation quantity,

φi corresponds to right approximation shape (n-column) associated with λ,

iψ is the left eigenvector (n-row) associated with λi.

The sense of mode shape can be obtained when left and right eigenvectors are added:

$$P = [P_1\ P_2\ \dots\ P_n] \quad (7)$$

where Pi = [p1i, p2i, ..., pni]T = [φ1i ψ1i, φ2iψ2i, ..., φniψni], φki corresponds to kth section occupied by approximation shape of ith component while ki corresponds to kth passage of the left approximation shape of ith operating range. The component

pki = φki ψki is known as the segment figure which is numerically communicated as the increase of left and right eigen-vector.This is taken as an estimation to do with minimal correlation involving kth state function of the ith component.

The rotor point modes can be recognized from left and right eigenvectors in conjunction with the investment considers, and can be named as "mode shape." If a mode is found in which the generators can be gathered by the comparability of their rotor edge qualities in various regions, then that mode can be distinguished as a between region swaying mode.

1.3 DAMPING OF INTER-AREA OSCILLATIONS

The filtering involving oscillations between different regions is of great importance. These disturbances would be effectively reduced after additional vitality would get infused with the framework, when it comes to quick drop of speed along a slope at the same time as potentially additional vitality gets devoured involving the framework, and while at the same time when momentarily quickened. Concerning well established power systems the filtering vitality gets acquired to do with balance pertaining to power flow as well as a period of a timeframe, commonly in the scope of five to ten seconds. The damping vitality must have the right stage move in respect to the quickened/decelerated frameworks. Wrong stage edges can even energize control motions. Conventional examination and control of between zone motions depends on modular methodologies [17], [18]. Regularly, between region motions are distinguished from the spatial profiles of eigenvectors and interest components of ineffectively damped modes [19], [20], and they are damped by means of decentralized controllers, whose additions are deliberately tuned utilizing root locus [21], [22], shaft arrangement [23],adaptive [24], hearty [25], and ideal [26] control systems. Figure 3 demonstrates distinctive procedures to moist power motions

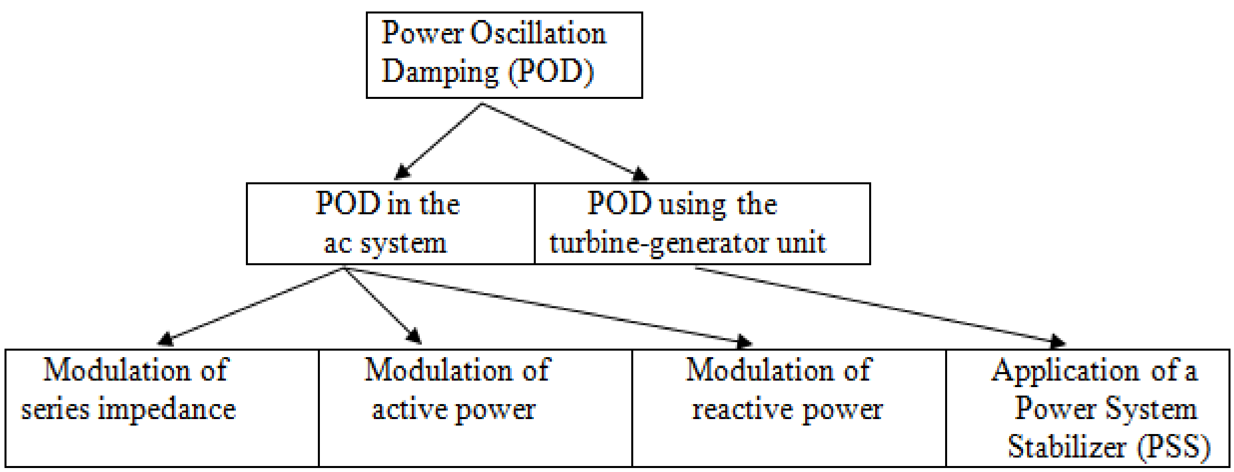

Figure 3: Strategies to Damp Power Oscillations

1.4 TECHNICAL ASPECTS OF GRID INTERCONNECTIONS

1.4.1 General background of Intertwined Power Networks

Power matrix intertwined systems historically have always played an important aspect when it comes to power networks globally. When we look at the current both at country or regional level, all the power utility companies all started many years as single entities, and in most cases as just an independent power generating plant in a rapidly expanding region or district. Thereafter due to economic expansion in these regions the provision of power distribution grew leading to these utility providers to extend their power system infrastructure so as to cater for this growth in the demand for power and hence there was a need to even begin sharing this power between different regions.

Gatherings of utilities started to shape control pools, permitting them to exchange power and share limit saves. The main intertwined electric network for example in United States took off along Connecticut Valley right about 1925. Due to advancement made in the transportation of power, it brought about at the same time independent operation of these power networks, once in a while crossing national fringes. The primary global power merging involving Europe took place right about 1906, where Switzerland manufactured power transportation connections to reach France as well as Italy.

For the last number of decades considerable designing accomplishments have been made when it comes to advancement involving extensive coupling exchanging alternating current control matrices, whereby these electric power systems which have been merged try to maintain same electrical constants such as frequency and polarities. Currently the United States is made of four major intertwined regional electric power networks which include one in the Eastern, another in the Western, yet again the Texas region and finally the Quebec power network. The power pool in the Eastern region is arguably without anyone else's input has been known as the biggest machine on the planet, comprising of thousands of generators, a large number covering a large distance of power transportation networks as well as a number of distribution tappings, and in excess of millions connected loads. In spite of this intricacy, the system works at optimal levels of constant frequency as a single unit. In the same case the intertwined Western region of Europe power pool connects with other regions such as the one involving the UK, Scandinavia, and through to Italy as well as Greece, grasping en route quite a bit also of other parts of Europe near countries like Eastern Europe Poland, Hungary, Slovakia, and the Czech Republic. Elsewhere also such as in South America, Africa and the Middle East there has been a rapid growth in terms of sharing of electric power between these different continents and regions.

While the world has seen a massive expansion and growth in the operation and actualization of using coupled AC systems, another yet important aspect of power system called High Voltage Direct Current (HVDC) is beginning to receive much attention because of its numerous advantage when it come to transportation of power over long distances. Apart from that another important advantages of HVDC is that it allows for the coupling of two electrical systems having different frequencies to synchronize together. Moreover, HVDC system comprises of different focal points, particularly to transmit a lot of control over long separations.

1.4.2 Basic advantages of grid interconnections

The merging together of electricity grid networks has several specific advantages, a large portion having to do with monetary segments. Specialized justifications for system merging together of power pools can be summarized below:

- Enhancement of dependability as well as minimizing the cost of generation: What happens here is that if one side of the interconnection system is probably down, power can still taken from those regions having extra reserves so that there is no interruption when it come to production in the industries.

- Decreased interest of producing limits: Independent frameworks should lessen creating limit necessity, while at the same time should defer as why other new limits are to be incorporated, on the off chance that they can share the creating assets of an interconnected framework.

- Improving load figure and expanding load differing qualities: Systems work most financially when the level of energy request is relentless after some time, instead of having high pinnacles. Poor load calculates (the proportion of normal to crest control request) imply that utilities must develop era ability to meet top prerequisites, however that this limit sits sit out of gear a great part of the time. Frameworks can enhance poor load figures by interconnecting to different frameworks with various sorts of burdens, or loads with various day by day or regular examples that supplement their utility goals.

- Saving in cost of production and development: Individual expenses to do with the threshold in power transportation for the most part decrease with expanding scale, to a limited degree. Sharing assets in an interconnected framework can permit the development of bigger offices having a reduction in individual expenses.

- Heterogeneity to do with an era blend and distribution protection: Merging of power pools will allow for the utilization of diverse advancements as well as powers to create more power by giving prominent security if one sort of era winds up plainly constrained. Indeed this similarity stands as a solid motivation for interrelated power networks supplying for example hydro power plants. On the other hand, much larger power networks with an assorted era blend likewise suggests greater differing qualities in the sorts of constrained blackouts that happen, enhancing dependability.

- Economic trade: Interconnection permits the dispatch of the slightest exorbitant creating units inside the interconnected zone, giving a general cost reserve funds that can be partitioned among the segment frameworks. Then again, it permits modest ways of trading between two regions with one region having excess but much more costly power supply.

- General surroundings and location of power plant: Over the last number of years there has been in improvement in technology when it comes the emissions generated by these plants. Merging of power pools also helps to identify as to which region could be most affected in terms of emissions and therefore would try to use and get power from those regions less affected. Besides that, setting up of power plants is always encouraged in those place where there is an abundance in the main raw material used for generation of power in that particular region.

- Linkage of support calendars: Intertwining of power pools allows for arranged blackouts which can be facilitated with the goal that general cost and unwavering quality for the interconnected system is improved.

A few expenses and advantages of interconnections are hard to measure, however as an unpleasant picture of legitimacy has shown that power pools for example operating in North America do continue to show signs of general reduction in the cost reserve funds while the power pools in Europe have brought about decreased limit necessities of 7-10 percent since the 1990's.

1.4.3 Physical difficulties and threats to power pools

In as much as there has been an increased and rapid expansion in the merging together of power pools so as to enable the pulling of reserves, it has also come with a number of complexities. Obviously most the cost when it comes to construction of AC power pools goes towards the erection of towers with their conductors as well as the building of substations, and as for HVDC system the major cost is mostly towards converter stations. Power pooling additionally involve different expenses, specialized difficulties as well as dangers. The coupling of AC power pools particularly, an individual unit which is coupled to another unit can be taken like they are in a marriage due to the fact the two units when coupled together would work like a single unit. In order for this to be accomplished would require specialized similarity as well as efficient support one with another and thereby allowing for the reduction in expenses of a multifaceted nature having a range in inalienable contrasts to that of the other frameworks included. For example as a way of an illustration, in the event of merging power pools together, regardless of the possibility that they are generally completely good, blame streams (the present that streams amid a short out) for the most part increment, which involve establishment of maximum rated circuit breakers in keeping up of the wellbeing as well as anything to do with unwavering power quality. To legitimately determine these and numerous other specialized changes required by interconnection requires broad arranging contemplates, PC displaying, and trade of information between the interconnected frameworks.

The troubles of joint arranging and operation of interconnected frameworks change generally. Likewise with relational unions, from the institutional and authoritative outlook, coupled frameworks may turn into a solitary element, which completely isolate themselves from the rest of other units.

Inside nations, there are regularly basic specialized guidelines helping operators decrease their unpredictability involving coupling independently frameworks. In various nations, then again, control frameworks may have advanced independently, with altogether different models and innovations, which includes an additional layer of specialized intricacy to interconnections. Institutional and authoritative elements of energy frameworks in various nations are likewise prone to contrast from multiple points of view, and these distinctions perpetually influence the specialized and operational measurements of an interconnection. Issues running from power exchanging understandings to unwavering quality benchmarks, while communicated in specialized terms regularly should be settled inside the domain of arrangement or in other spheres of life. And just has a certain expert in the field of intertwined power networks once commented, "numerous specialized, hierarchical, business and political issues have must be settled to get vast systems connected by universal interconnections to work".

The best advantages of interconnection are typically gotten from synchronous AC operation, yet this can likewise involve more noteworthy unwavering quality dangers. In any synchronous system, unsettling influences in one area are rapidly felt in different areas. In the wake of coupling of frameworks that once operated independently to their nearby regional partners, those systems however, presently remain powerless against any unsettling influences. From the real power outages which were experienced in both North America and Europe of 2003, did illustrate the fact that extensive scale unsettling influences can proliferate through interconnections and bring about falling blackouts, cutting down frameworks that had already been working ordinarily. Furthermore, long-remove interconnections with long transmission lines have conceivably more noteworthy steadiness issues than is the situation for shorter lines. At long last, numerous frameworks that have experienced power progression as of late have encountered extensive increments in transmission limit usage, lessening hold edges. Limiting the probability as not to allow a power pool to prompt issues that may lead things like voltage crumple, sudden as well as short flimsiness, and falling blackouts because of engendered unsettling influences requires cautious arranging and all around composed operation.

1.5 General classification of power system stability

Control framework soundness is basically a solitary issue; in any case, the different types of dangers that a power framework may experience can't be legitimately comprehended and adequately managed by regarding it accordingly. As a result of high dimensionality and multifaceted nature of soundness issues, it makes improving presumptions to dissect particular sorts of issues utilizing a proper level of detail of framework portrayal and suitable scientific procedures. Examination of steadiness, including distinguishing key components that add to shakiness and concocting strategies for enhancing stable operation, is enormously encouraged by arrangement of soundness into fitting classifications. Arrangement, in this manner, is basic for significant useful investigation and determination of energy framework strength issues.

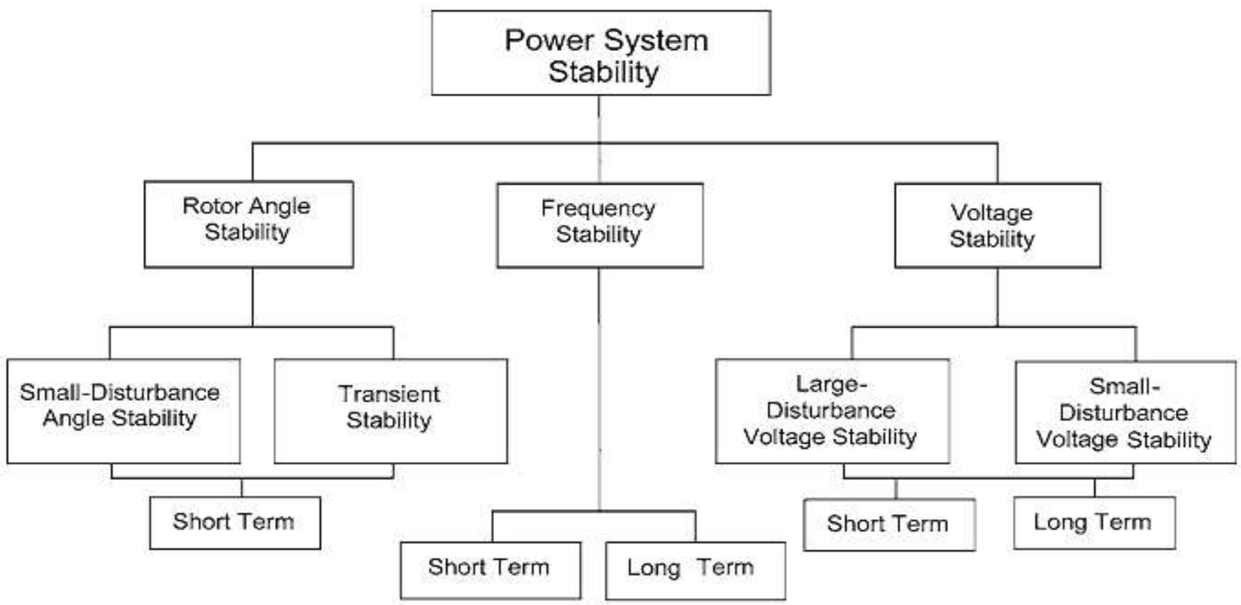

Figure 4: Classification of Power System Stability

CHAPTER 2
LITERATURE SURVEY

2.1.REVIEW AND ANALYSIS OF THE DIFFERENT PAPERS

Y. Xue, M. Shi and Y. Chai (1989) presented 'Fast Initial Estimation of Power System Eigen values'. Up to now, the AESOPS algorithm was still the only effective and reliable tool to calculate the eigen values of very large power systems. But it needs good initial guesses at each eigenvalue and the corresponding generator which participates in that mode most significantly.
The large power systems, where many eigenvalues can be very close to each other, the results of the AESOPS and all derivative methods become very sensitive to those guesses. Sometimes, the same eigenvalue may be found in many places, while a nearby one would not be identified at all. This project aims at solving the above problems. The basic idea is that the oscillation modes are the same for both a small disturbance and a severe short circuit at a generator bus.
And later on, another direct method called the Extended Equal Area Criterion which could precisely and very quickly identify the oscillation modes under large disturbances without any additional computational to the transient stability assessment was developed. For each mode identified above, using the concept of Partial Center of Angles equivalence used in the EEAC for transient stability analyses, we have an equivalent two-machine system, further an equivalent one-machine infinite-bus system. The eigenvalues of the system can be calculated analytically at a negligible computation price and used, together with the critical group identified, as a good initial guess for the AESOPS algorithm.

Delfino F. Fornari and S. Massucco (2002), displayed 'Power frequency regulation as well as the aspect of power sharing investigation in deregulated power networks'. The subject of load-recurrence control (LFC) from the perspective of the rebuilding procedure of the electrical business is tended to. LFC is dealt with as an auxiliary administration fundamental for keeping up the electrical framework unwavering quality at a satisfactory level. Reference is made to the rules recommended concerning the appointment and transportation of power flow. The aftereffects of recreations performed on a power framework in light of an IEEE Reliability Test System masterminded into a three-control-zone setup are accounted for the distinctive LFC plans. Assessment of incidental exchanges is performed and proposals on their bookkeeping are proposed.

Bevrani H.et al (2004), introduced 'Dynamic dispersed power recurrence regulation utilizing an iterative straight matrix inequalities philosophy'. Practically speaking LFC frameworks utilize straightforward relative basic mechanical tuning regulators. Notwithstanding, the fact that most of the mechanical tuning regulators their constants which typically can be modified in view of established or experimentation approaches, they are unequipped for getting great dynamical execution for an extensive variety of working procedures as well as different power variations situations involving a number of zones which are merged together and also their control framework. Looking at this issue critically, it can be observed that the decentralized Load Frequency Control amalgamation is detailed specifically for the purpose HN-regulation issue and while at the same time fathomed in order to utilize a repetitive direct framework imbalances calculation to plan of hearty electromechanical regulators and actuators involving several territory control frameworks. Interconnection between three area control systems case with an extensive variety involving different power variations would be presented as representing the projected method. These subsequent regulators as well as actuators would appear to limit the impact of unsettling influences and keep up the hearty execution.

Thomas J. Overbye (2004) announced 'Power System Simulation'. The basic role of an air conditioner electric power framework is to move electric power from the wellsprings of the electric power, the generators, to the customers of the electric power, the heaps, through the wires joining the two, the transmission and circulation framework. Control frameworks arrive in an assortment of sizes, extending in size from those with a solitary little generator and maybe a modest bunch of burdens to the colossal. For instance, aside from a couple of islands and some little disengaged frameworks, the whole electric lattice in North America is truly only one major electric circuit. The modest divider outlet is really a door to one of the biggest and most complex protests at any point assembled. This framework incorporates billions of individual electric burdens, a huge number of miles of wires, and a great many generators. The concentrate of this article is on the operation of these expansive, interconnected lattices.

This high level of interconnection has two essential advantages. The first is unwavering quality: with a great many generator interconnected through a huge number of transmission lines, the loss of even the biggest generator or transmission line normally has however an infinitesimal effect on the dependable operation of the framework. When one gadget fizzles others can compensate for the misfortune. The second advantage is monetary, giving the way to the advancement of energy markets. In spite of the fact that the framework was not manufactured unequivocally for mass power transmission (the development of electric power starting with one locale of the framework then onto the next) members can purchase and offer electric vitality with each other, exploiting differentials in the cost of electric administration.

In any case, this availability has some hindering reactions also. Since an interconnected framework is truly only one vast electric circuit, issues in one bit of the framework can quickly proliferate to the rest of the framework, conceivably bringing about a falling power outage.

Shayeghi H. and H. A. Shayanfar (2005), introduced 'Combined H2/H∞ which involved principles of LFC in a Dispersed kind of Power Electric Network'. This research work did try to look at a dispersed kind of strong electromechanical regulators for power recurrence regulator of a power framework in the deregulated condition is proposed. A summed up model for the LFC plan is created in light of the conceivable contracts in the new condition. The proposed strategy is tried on a three-region control framework with the conceivable contracted situations under vast load requests. The outcomes are appeared to keep up powerful execution within the sight of indicated vulnerabilities and framework nonlinearities for an extensive variety of range load requests and unsettling influences in correlation with the PI controller.

Koji Abe et al (2006), introduced 'Latest Power Recurrence Regulation Approach which could be used for Increased Production of Wind Energy'. This research work proposes a planning strategy for a heap 76 recurrence control utilizing aggravation onlooker when an increased flow of wind is released in one particular power network system. A situation where unsettling influence cancelation issue in the aggravation eyewitness is considered. The aggravation onlooker gauges unsettling influences from detectable amounts of states, and crosses out the impact of the unsettling influence. By this technique, the quick power varieties of the wind control eras can be stifled. For instance, it has been run reenactments for a three-region longitudinal framework to contrast the proposed technique and a traditional strategy (PI sort controller).

Shayeghi Hossein et al (2007) introduced 'Several Steps An Electromechanical Regulator Working With Fuzzy Technique Of Power Recurrence Regulator Applied In Deregulated Electricity Network'. This research work did look at arrangement of Fuzzy working together with electromechanical regulators in tackling the challenge of power recurrence regulation involving power system which have been resuscitated and working with a dispersed kind of reciprocal. The proposed technique is tried on a three-zone control framework with various contracted situations under different working conditions. Reenactment comes about demonstrate that the proposed system is exceptionally successful and ensures great strong execution against parametric instabilities, stack changes and aggravations even within the sight of GRC.

Liu Le et al (2008) displayed 'Figure-Regulating with Projected Recurrence Preference Parameter Level Approach'. With a specific end goal to actualize question of regulating while putting up preventive measure when it come to systematic production regulation, strategy for evaluating recurrence inclination coefficient by utilizing multi-target improvement innovation and here and now stack expectation is introduced. For commonsense usage, the technique is planned in view of discrete-time framework. The technique is analyzed by computerized reproduction with a three-region framework demonstrate. The outcomes demonstrated that the technique the viability of using this technique and its ability precise and accurate approximations when it comes to accessing of certain specific parameters in the implementation and execution actualization of a power pool and thereby adding to the enhancement and efficient application of regulators as well as prescient recurrence inclination parameters.

Wen Tan (2010) displayed 'Dynamic Control using Electromechanical Regulators for Power Recurrence Regulation in Transmission Networks. An approach which looks at bound together electromechanical regulating strategy to regulate power recurrence involving energy frameworks gets explained. This regulation technique depends upon more than one level aspect involving flexibility encompassing inside designs, outline strategy as well as a tuning guess system. Execution is based on meeting specific targets as well as subsequent tuning regulators identified with higher regulating constants having vigorous capabilities to regulate the higher order constants. This technique plays a big role in many transmission frameworks having unheated as well as heated as well as in many power plants. Recreation comes about demonstrate that it can in reality enhance the damping of the power frameworks. It is demonstrated that the strategy can likewise be utilized as a part of decentralized PID tuning for multi-region control frameworks.

Sundaram V. Shanmuga and T. Jayabarathi (2011) displayed 'Findings Involving Human Expert Knowledge in the Application of Electromechanical Regulators implemented in Multi Power Systems for Power Recurrence Regulation'. The target of power recurrence regulation is there so as not to go beyond a certain limit that tries to sway from its normal position and to ensure that unfaltering variable mistakes are avoided. This paper manages different controllers like relative fundamental mechanical actuators and valves, expert human knowledge as well as tuned electromechanical regulators to manage and regulate recurrence in multi power networks. Final execution and monitoring of the output results coming from such a system can observed and analyzed using computer softwares.

D. Mondal et al (2012) exhibited 'Examination on the Slow Developing Disturbances Effectiveness in Large Power Pools Involving Dynamic Regulators'. An endeavor has been made in this paper to examine the little flag soundness issue of a genuine multi-machine control framework with the utilization of Thyristor Controlled Series Compensator (TCSC). In spite of the fact that Power System Stabilizers (PSS) are obligatory prerequisites for damping of motions in the power framework, its execution gets influenced by changes in system designs, stack varieties and so on. With a specific end goal to accomplish obvious damping, establishment of TCSC has been recommended here notwithstanding traditional PSS. Nonetheless, the execution of any FACTS gadget exceedingly relies on its parameters and its arrangement at appropriate areas in the power system. In this paper, a delicate processing procedure, which has to do with the fair distribution and maximization of the available resources amongst a given population as well as in this case parameters of the TCSC controller with a specific end goal to relieve little flag motions is used. Moreover, in view of basic eigenvalue varieties another pointer being named as Small Signal Stability Rank (SSSR) has been proposed for appraisal of adequacy of the PSO based TCSC controller for three noteworthy possibilities. What's more, the issue of low recurrence (0.2-1.0Hz) motions is a long-standing issue in electric power frameworks. These motions may manage and grow up to bring about serious framework blackout if sufficient damping is not accessible.

V. S. Patel et al (2013) illustrated 'Battery Storage Capacity Analysis to do with Major Slow Recurrence Disturbances'. Currently most transmission frameworks with expansive size territories get intertwined so as to benefit one from another region in terms of sharing energy reserves in the case of diminished supply from any of the regions. Because of the fact that these transmission interconnection systems get overloaded and overstressed if on one side of the network a fault has happen on one of the units or probably due to maintenance schedules, they may reach certain extreme limits. Working attach lines nearer to maxi-mum limit builds the likelihood of between zone motions which would be experiencing lower values of frequency between these operating zones as well as the entire region. Apparently due an increased coupling level of these power pools it becomes quite a big problem as to identify where the territory having reached a steadiness examination on how to locate it.

R. Shankar et al (2016) exhibited 'Slow Recurrence Balanced Investigation involving more than one Transmission Network having Power Recurrence Regulator which is Supported by Dynamic Controllers as well as Battery Holding Capacity'. This paper manages the displaying and little flag strength investigation for the two regions interconnected power framework utilizing a heap recurrence controller. The eigenvalues and the cooperation consider investigation are utilized to look at the little flag solidness and commitment of various states in a specific eigenvalue of the framework, separately. A heap recurrence controller is intended to balance out the recurrence deviations which happen because of the little bother in the framework. In this paper, the proposed control plot comprises of a vital controller in a joint effort with the Redox Flow Energy Storage System (RFESS) and the Static Synchronous Series Compensator (SSSC). The dynamic reactions of the general framework have been enhanced by the proposed controller, which is additionally checked with the assistance of eigenvalue and support consider examination. This investigation demonstrates that general framework swaying has been diminished through a proposed controller.

CHAPTER 3

DETAILED ANALYSIS OF THE MAJOR COMPONENTS OF A POWER PLANT

These components which are also used for the load frequency control can be properly explained with the help of the following schematic diagram;

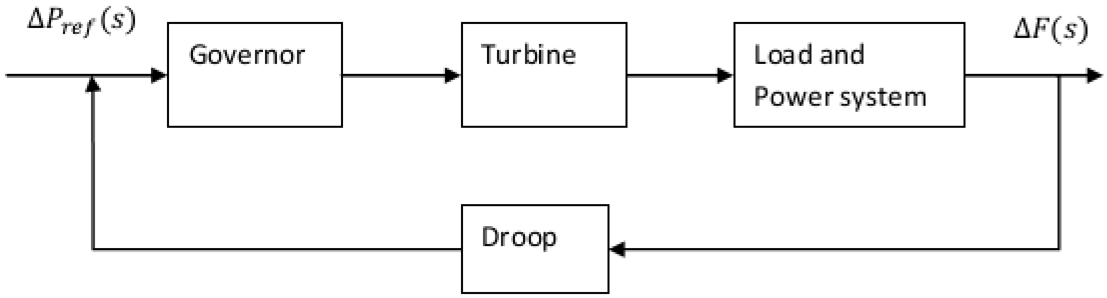

Figure 5: Schematic display showing dynamic power recurrence regulation

3.1 Mechanical Converters

Turbines can be considered both as mechanical as well as electrical equipments and of which their sole purpose is to initially work on the raw materials such as water and steam while they are still in their natural state. Thereafter once that raw energy material such as steam and water are fed to the turbine, their task would be to translate that raw material into useful mechanical energy for the onward relay to the generator. Therefore the design and development of these turbines should be done while taking all the necessary parameters into consideration. In power system in general, turbines are mainly of three types which include: non-reheat, reheat as well as the hydraulic types. All these turbines their modeling and representation is done using transfer functions. Talking about non-reheat type of turbines, their analysis is given using first-order expressions and whereby the time elapse (Tch) is considered as to when the actuator are enabled and the production of the force applied. On the other hand, representation and analysis of reheat type of turbines is done using the second order expression since sometime in here we do have the challenge overcoming the pressure being low for the proper function of the turbine.

And usually concerning hydraulic turbines, there is less resistance in the flow of the water immediately it enters the pen stocks to go to the turbine as this water would flow at a constant velocity. The representation of the turbine power output as a whole would depend on the tuning of the actuators installed. In this case we would want to look at non-reheat type of turbine for instance, which has both one gain constant as well as one time constant in terms of projection, their representation are given as follows;

$$\Delta P_T(s)/\Delta P_v(s)=K_T/1+sT_T \quad (8)$$

Where $\Delta P_v(s)$ = the in feed coming to the turbine

$\Delta P_T(s)$ = the load from the turbine

3.2. Electrical Converters

A generator is an electrical device whose main function is to convert the mechanical energy coming from the turbine for the onward translation into electrical energy. But in this aspect our main attention is on the rate at which the rotor runs or rotates than the conversion of electrical power. The rate at which the rotor rotates is in collaboration with the recurrence with the whole power network. The important thing is that due limited means when it comes storage of electrical power generated, it is of great need that we ensure that there is a leveling of some kind between the power produced and that one which must be given as load. Any sort of fluctuations with the output power may cause a situation whereby the power released by the turbine cannot level with the actual useful power generated and hence an error signal would be generated, and has to be given to the rotor in order to vary the rotor speed ($\Delta\omega$) at different intervals. And recurrence preference can be expressed as $\Delta f = 2\pi\Delta$. Furthermore, the output power could be taken or measured in terms of resistance. This resistive load is mainly kept constant during the variations in the speed of the rotor and while at same time its rate of movement would also depend on the amount of load coupled to the system. And with the corresponding low change in the mechanical power the same effect would also be transferred onto the load meaning that only smaller proportional of the load could be connected to the system.

Arithmetically can be tabulated as follows;

$$\Delta P_v(s)/\Delta P_g(s) = 1/\ 1+sT_g \quad (9)$$

Where

$\Delta P_v(s)$ = the load power obtained

$\Delta P_g(s)$ = the in feed coming from the turbine

T_g= the time settings parameters given to the generator+

3.3. Speed Regulators

The basic function of the governor system is simply the control and regulation of the speed. They are installed just before the turbine in order to detect any slight variation in the recurrence as a result of either an increase or decrease in the load at the output terminals of the generator. It would fill its function by constant monitoring any slight variations in the parameters such as the speed regulation (R) as well as its time constant (Tg). We know that the load which is connected to the keeps on varying depending on the task to be accomplished and this could therefore have a bearing on the overall speed on which the generator would run. In order to strike a balance the governors actuators are closed and opened at different intervals so as to control and maintain the flow of the feed and thereby helping to maintain this balance. The implementation of power recurrence regulation which is one of the applications of small signal stability desires to lessen disturbances in the recurrence amidst constant variations in true power measured across the load. As a result, the power threshold point could be used in the modification of the actuators in order to reduce all the disturbances introduced upon the system and thereby would help in the regulation of the power output unlike only being concerned with recurrence fluctuations.

And tabulating conceptually the expression can be shown as follows;

$$\Delta P_g(s) = \Delta P_{ref}(s) - 1/R\ \Delta F\ (s) \qquad (10)$$

Where,

$\Delta P_g(s)$ = the output of the governor

$\Delta P_{ref}(s)$ = is the reference signal

R = is the regulation constant or the droop

ΔF (s) = is the deviation in frequency corresponding to change in speed

3.4. Power Outpout

There are various types of electrical loads that would be connected to the power network system. Furthermore, these types of electrical load could be of three types i.e; resistive, inductive, and capacitive types. Mostly the resistive type of loads are never so much affected by the variations in the system frequency and the other hand, the inductive loads which include such electrical device arc welders and compressors would be affected with slight variation in the system frequency as a result of changes in the load connected and given by the following expression below;

$$\Delta P_e = \Delta P_L + D\Delta\omega \qquad (11)$$

Where,

ΔP_L = Load change of non-frequency response

$D\Delta\omega$ = Load change of frequency response

D = % change in load / % change in frequency

3.5. Inter-connections

Many isolated power pools could be coupled and merged together through transmission power lines referred to as tie-lines. The transfer of power between for example two power pools would take place via the inter-connections lines when they would have had a dissimilar in their recurrence. This exchange and transfer of power between the power pools could be taken as region i as well as region j (ΔPij) while the coupling force constant as (Tij). It can therefore be observed that when it comes to the fundamental in terms of the variance between power pools, an estimated difference in the power output could be generated as a result of these interconnections.

Another important reason why these power interconnectors were designed was for the sole purpose of transfer and at times the selling or transaction of power purchase between different power pools and hence leading to a reduction in the cost. This export of power between closer regions is mainly done at night during off-peak period when less clients are using the power. There many countries in world whose source of their power is mainly from hydro generation. Now in times like drought when the water level in the dams drastically go down, using these power interconnectors, power could be purchased from one region having excess to supply those regions affected by the drought. One other aspect that can be pointed out is that during those times when perhaps there is a fault on one of the units in a particular region, this could also have a bearing on the power system recurrence and therefore power could be gotten from those other regions having no fault so as try balance out the deviation in the recurrence as a result of the fault created on one particular unit.

Assuming we have two power pools and that there has to be the transfer of power between region 1 as well as region 2.

Arithmetically the expression can be given as follows;

$$P_{12} = |V_1||V_2| / X_{12} \sin(\delta 1 - \delta 2) \tag{12}$$

Where 1 represents control area 1 while 2 on the other hand there is also region 2.

X_{12} = represents series impedance for control region 1 as well as region 2

$|V_1||V_2|$ = voltage magnitudes for control area 1 as well as area 2

3.6. Corresponding working for electric converters

Considering where most of these electric converters are used, it would be seen that there would be a number of these electric converters working side by side to give power to various machines connected to the system. One such an example is the European power pool which trans-cross between these nations and has thousands of these electric converters enabling the exchange of power between them.

The main benefits for allowing coupled electric converters side by side could be tabulated as follows:

1. Performance of the electric transmission network gets enhanced at the time electric converters would be working in correspondence to each other, due to the fact that if one of them is defective, the other remaining ones would continue to give supply.

2. Allowing these electric converters to function side by side entails that even if there are many of them connected between them, one of them can safely be taken of service for the sole purpose of repair works and still power would continue to be supplied the remaining units.

3. When you allow one of these units to function single handedly, it may not attain or reach its full potential however, when several of them would function side by side or at the same time, there

would be a significant sharing of power and thereby enabling them to almost their maximum capacity.

And the following standards should be met before these electric converters could be connected together;:

1. Any two of these electric converters should have an equal root mean square line potential.

2. Any two of these electric converters should carry and possess similar phase order.

3. Any two of their phases should have similar angles.

4. Any two of these electric converters should have the same polarity.

5. The value of recurrence for the starting electric converter should be much higher as compared to that of the operating network.

Apart from that, when several number of these electric converters are to be run correspondingly for the production of electrical energy to cover a specific region, another electric converter could also be brought on board so as to relieve of the pressure. Similarly, in terms of consideration for analysis, other factors such as electric converter potential parameter (Meq), filtering parameter for power output (Deq) as well as properties to do with recurrence behavior (Beq) may also be looked at. The transfer of power via through these interconnectors and the sagging down characteristics of the recurrence, their modeling showing power pools could be merged together and then modified or extruded using corresponding motion for these electric converters. The speed for one generator in a single particular area may be given by the following expression that is $\omega = 2\pi f$.

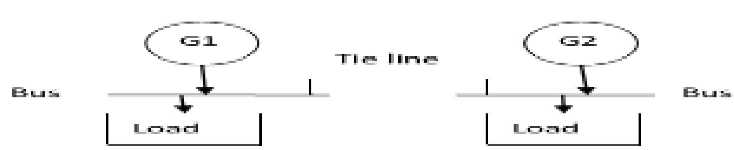

Figure 6: Block diagram for parallel operation of generators

CHAPTER 4

DESIGN AND DEVELOPMENT OF PROPOSED MODEL

4.1. Introduction

An augmented power framework can be isolated into various load recurrence control (LFC) regions, which are interconnected by tie lines. Such an operation is known as a power pool framework operation. These frameworks which are interconnected together as utilities would fundamentally work freely inside their own particular limits, however there are other legally binding assentions with regards to inward framework trades of energy by means of the tie lines and different understandings are identified with working strategies on the most proficient method to keep up framework recurrence. Besides, there are additionally strategies that need to do with the treatment of event of real blames and different crises. The rudimentary idea of a power pool operation when worked in the ordinary enduring state would accommodate the accompanying;

Maintaining of planned exchanges of tie-line control: The interconnected ranges share their hold energy to deal with the foreseen stack tops and unforeseen generator blackouts.

Absorption of possess load change by every zone: The interconnected ranges can endure bigger load changes with littler recurrence deviations than the confined power framework regions.

4.2 Three Area System

As far as control, the three area framework or system is like a two area sort of system. The indispensable control circle which is utilized as a part of the single range system and two region framework can likewise be identified with the three area system. Because of progress made in terms of power delivery some transformations can be noticed while unfaltering conditional recurrence (Δf) would require a different circle which cannot interact with the essential circle which tries to level the recurrence to the underlying quality, prior to when heap unsettling influence happens.

The vital regulator having the capability of bringing down the recurrence to its minimum value can be placed within the auxiliary circle. Three territory intertwined frameworks would in this case be comprised of three power pools which are merged together. A number of transmission interconnectors for power flow regulation would be arranged in form of streams and having the ability to make adjustments to the heap request because of the interconnection made between the control territories.

In this way the general dependability of the framework is kept up at an adjusted condition despite the consistent varieties in the heap and load changes.

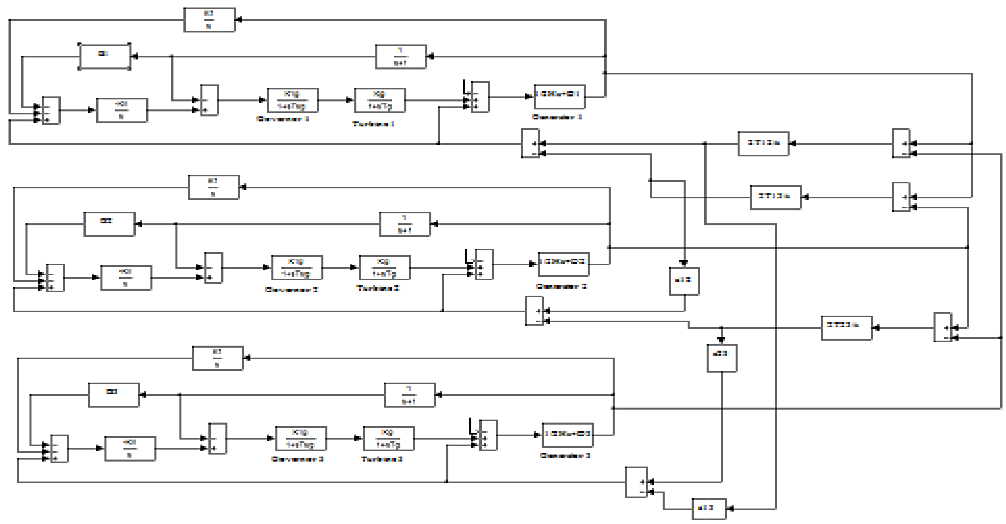

Figure 7: Pictorial design of a three regional power pool

Calculation to obtain variation in the recurrence of three region could be tabulated below;

$$\Delta f_1(s) = -\frac{R_1 K_p m_1 (s\,T_g + 1)(s\,T_t + 1)}{K_p (s + Ki_1 R_1) + R_1 s (s\,T_g + 1)(sT_p + 1)(s\,T_t + 1)}$$

$$\Delta f_2(s) = -\frac{R_2 K_p m_2 (s\,T_g + 1)(s\,T_t + 1)}{K_p (s + Ki_2 R_2) + R_2 s (s\,T_g + 1)(sT_p + 1)(s\,T_t + 1)}$$

$$\Delta f_3(s) = -\frac{R_3 K_p m_3 (s\,T_g + 1)(s\,T_t + 1)}{K_p (s + Ki_3 R_3) + R_3 s (s\,T_g + 1)(sT_p + 1)(s\,T_t + 1)}$$

On the other hand, power transfer amongst these power pools is as well given as follows;

$\Delta P_{12}(s) = 2\pi T^0/S[\Delta f_1(s) - \Delta f_2(s)]$

$\Delta P_{13}(s) = 2\pi T^0/S[\Delta f_1(s) - \Delta f_3(s)]$

$\Delta P_{23}(s) = 2\pi T^0/S[\Delta f_2(s) - \Delta f_3(s)]$

Furthermore, the three area control system state space equations for Eigen value calculation can be developed as follows;

$$\frac{d}{dt}(\Delta f_1) = \frac{1}{\tau_{ps1}}\left[-\Delta f1 + K_{ps1}\Delta P_{G1} - K_{ps1}\Delta P_{D1} - K_{ps1}\Delta P_{TL1}\right]$$

$$\frac{d}{dt}(\Delta f_2) = \frac{1}{\tau_{ps2}}\left[-\Delta f_2 + K_{ps2}\Delta P_{G2} - K_{ps2}\Delta P_{D2} - K_{ps2}\Delta P_{TL2}\right]$$

$$\frac{d}{dt}(\Delta f_3) = \frac{1}{\tau_{ps3}}\left[-\Delta f_3 + K_{ps3}\Delta P_{G3} - K_{ps3}\Delta P_{D3} - K_{ps3}\Delta P_{TL3}\right]$$

$$\frac{d}{dt}(\Delta X_{E1}) = \frac{1}{\tau_{sg1}}[-\Delta X_{E1} + \Delta P_{C1} - \Delta f_1/R_1]$$

$$\frac{d}{dt}(\Delta X_{E2}) = \frac{1}{\tau_{sg2}}[-\Delta X_{E2} + \Delta P_{C2} - \Delta f_2/R_2]$$

$$\frac{d}{dt}(\Delta X_{E3}) = \frac{1}{\tau_{sg3}}[-\Delta X_{E3} + \Delta P_{C3} - \Delta f_3/R_3]$$

$$\frac{d}{dt}(\Delta P_{G1}) = \frac{1}{\tau_{t1}}[-\Delta P_{G1} + \Delta X_{E1}]$$

$$\frac{d}{dt}(\Delta P_{G2}) = \frac{1}{\tau_{t2}}[-\Delta P_{G2} + \Delta X_{E2}]$$

$$\frac{d}{dt}(\Delta P_{G3}) = \frac{1}{\tau_{t3}}[-\Delta P_{G3} + \Delta X_{E3}]$$

$$\frac{d}{dt}(\Delta P_{TL1}) = 2\pi T_{12}^0[\Delta f_1 - \Delta f_2] + 2\pi T_{13}^0[\Delta f_1 - \Delta f_3]$$

$$\frac{d}{dt}(\Delta P_{TL2}) = 2\pi T_{12}^0[\Delta f_1 - \Delta f_2] - 2\pi T_{23}^0[\Delta f_2 - \Delta f_3]$$

$$\frac{d}{dt}(\Delta P_{TL3}) = 2\pi T_{13}^0[\Delta f_1 - \Delta f_3] + 2\pi T_{23}^0[\Delta f_2 - \Delta f_3]$$

$$
\begin{bmatrix} \Delta X_{E1} \\ \Delta X_{E2} \\ \Delta X_{E3} \\ \Delta P_{G1} \\ \Delta P_{G2} \\ \Delta P_{G3} \\ \Delta f_1 \\ \Delta f_2 \\ \Delta f_3 \\ \Delta P_{TL1} \\ \Delta P_{TL2} \\ \Delta P_{TL3} \end{bmatrix} = \begin{bmatrix} \dot{x_1} \\ \dot{x_2} \\ \dot{x_3} \\ \dot{x_4} \\ \dot{x_5} \\ \dot{x_6} \\ \dot{x_7} \\ \dot{x_8} \\ \dot{x_9} \\ \dot{x_{10}} \\ \dot{x_{11}} \\ \dot{x_{12}} \end{bmatrix} =
$$

$$
\begin{bmatrix}
-\frac{1}{\tau_{ps1}} & 0 & 0 & 0 & 0 & 0 & \frac{K_{ps1}}{\tau_{ps1}} & 0 & 0 & -\frac{K_{ps1}}{\tau_{ps1}} & 0 & 0 \\
0 & \frac{-1}{\tau_{ps2}} & 0 & 0 & 0 & 0 & 0 & \frac{K_{ps1}}{\tau_{ps1}} & 0 & 0 & -\frac{K_{ps1}}{\tau_{ps1}} & 0 \\
0 & 0 & \frac{-1}{\tau_{ps2}} & 0 & 0 & 0 & 0 & 0 & \frac{K_{ps1}}{\tau_{ps1}} & 0 & 0 & -\frac{K_{ps1}}{\tau_{ps1}} \\
-\frac{1}{R_1\tau_{gs1}} & 0 & 0 & \frac{-1}{\tau_{sg1}} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -\frac{1}{R_2\tau_{gs2}} & 0 & 0 & \frac{-1}{\tau_{sg1}} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & -\frac{1}{R_2\tau_{gs3}} & 0 & 0 & \frac{-1}{\tau_{sg3}} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \frac{1}{\tau_{t1}} & 0 & 0 & -\frac{1}{\tau_{t1}} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \frac{1}{\tau_{t2}} & 0 & 0 & -\frac{1}{\tau_{t2}} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & \frac{1}{\tau_{t3}} & 0 & 0 & -\frac{1}{\tau_{t3}} & 0 & 0 & 0 \\
2\pi(T_{12}^0 + T_{13}^0) & -2\pi T_{12}^0 & -2\pi T_{13}^0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
2\pi T_{12}^0 & -2\pi(T_{12}^0 + T_{23}^0) & 2\pi T_{23}^0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
2\pi T_{13}^0 & 2\pi T_{23}^0 & -2\pi(T_{13}^0 + T_{23}^0) & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
$$

$$[B] = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1/\tau_{sg1} & 0 & 0 \\ 0 & 1/\tau_{sg2} & 0 \\ 0 & 0 & 1/\tau_{sg3} \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \qquad [J] = \begin{bmatrix} -\frac{K_{ps1}}{\tau_{ps1}} & 0 & 0 \\ 0 & -\frac{K_{ps2}}{\tau_{ps2}} & 0 \\ 0 & 0 & -\frac{K_{ps3}}{\tau_{ps3}} \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

4.3 PID CONTROLLER

Electromechanical tuning and regulation remains one of the famous available regulation methods or philosophies in many of the production and processing plants of their acceptance globally has been well received for automation regulation as well as optimization applications. Among the reasons for their world-wide acceptance could be attributed somehow to the fact that they have been able to show higher rates fast execution and reliability encompassing broad area when it comes to practical applicability thereby enabling them to be operated by technical personnel and straight to the point.

Going by the suggestion of their name, PID philosophy comprises of three important parameters; proportional, integral and derivative which are tuned in order to obtain a favorable response. And the output U(t) of the controller can be defined as;

$$U(t) = K_p\, e(t) + K_i \int_0^t e(t) + K_d \frac{d}{dx}\, e(t)$$

Where,

K_p= proportional constant for regulator

K_i = fundamental constant for regulator

K_d= derivative constant for regulator

4.3.1 Proportional parts for the regulator

This proportional component is responsible for the production of an output value which is directly related to the value of the current error. The error generated when multiplied with the proportional gain (K_p) would give what may be referred to as an equivalent gain parameter. This equivalent value of the controller would be given as follows;

Output = $P_{out} = K_p e(t)$

4.3.2 Integral part of controller

The integral part is directly related to the change in the deviation signal and how long this disturbance would last. This equivalent component of the controller can be taken as the overall total for all rapid occurring distortions which have taken place within the whole system. This error is also called counterbalance. Apart from that, the offset or counterbalance signal which is generated with the help of the proportional gain Ki, is afterwards sent to the output of the regulator. Therefore the equivalent component of the regulator would be defined by-

$I_{input}= K_i \int e(t)$

This integral part helps to accelerate the movement of the power system towards the set point and while at the same time would remove the steady-state error which might have accumulated due to the past error.

4.3.3 Derivative part of the controller

The main function of the derivative gain is to obtain the system error and this is done by calculating the error in correlation with time and while at the same time taking its product with the rate of change so as to obtain overall power system error. Therefore the relation of the extent or size of the derivative to that of the overall control process is what may be referred to as derivative gain K_d. It is derived as given by-

$D_{out}= K_d \frac{d}{dx} e(t)$

The working principle of the derivative is that it is able to predict the future value according to the current error of the system. Besides that it helps to improve the system stability.

In the past, the automatic process control of the controller was a mechanical device. These were made-up of things such as lever, spring or mass etc. These mechanical controllers were energized by compressed air, also known as pneumatic controllers and were extensively used in industry. Thereafter came the electronic Analog type of controllers and were constructed using the solid-state electronic devices as well as capacitors and resistors. However, currently the industry have now moved to the latest digital type of controllers which also can be programmed using the microcontrollers

.

Inaddition, these latest PID controllers in industry can be modified with Programmable Logic Controllers PLCs and which are assembled within a panel. The PID controller circuit diagram is given below-

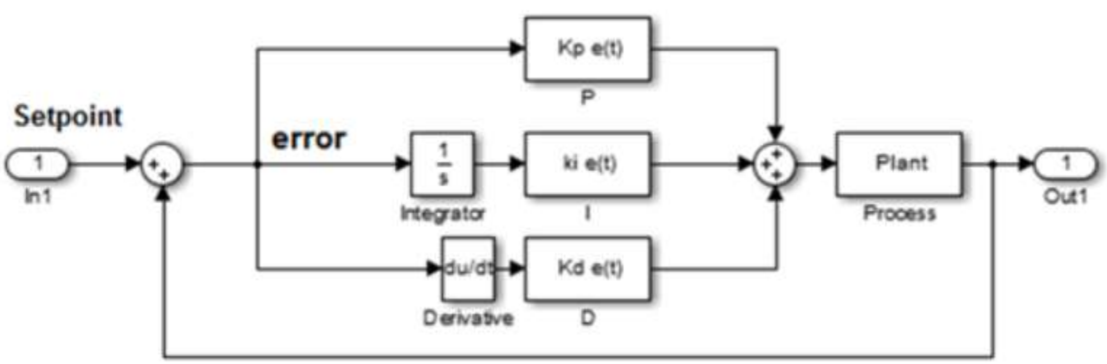

Figure 8: Schematic block assembly of a PID controller

4.4 FUZZY LOGIC OPTIMIZATION TECHNIQUE

4.4.1 Fuzzy Reasoning Methodology: A Detailed Exploration

A Fuzzy Reasoning Methodology possesses both information as well as the knowledge for a specialist, to do with outline related to framework which monitors a certain procedure having input–output correlations as characterized with an arrangement for fuzzy regulation guidelines, such as IF–THEN guidelines [30]. Fuzzy rationale thinking contains two sorts of data. The main concerns the marks and participation capacities relegated to the information and yield factors. The precise determination of these speaks to a standout amongst the most basic stages in the plan display. The other kind of data is identified with lead base which forms the fuzzy estimations of the contributions to fuzzy estimations of the yields [31].

A FIS is made out of three squares. On the other hand, the principal of fuzzification process, changes over fresh esteem contribution to a phonetic variable utilizing the enrollment capacities when installed with a learning foundation. And for the next piece, we have a derivation motor which has been empower or given an errand task involving to carry out an investigation on how information level or threshold point when it comes to enrollment and connection with the Fuzzy Reasoning Methodology, and which would cause it to yield certain characteristics based or utilizing fuzzy principles. At long last, the defuzzifier square changes the fuzzy yield into a fresh esteem. The deduction motor can be considered has being the pumping or distribution station of the entire system and does act or replicate the reasoning of expert knowledge and combines it with other basis leadership skills and therefore would execute surmised thinking to accomplish a control procedure [30]. The derivation would organize and use the fuzzy information qualities to initiate the induction controls and create the fuzzy yield esteem. The nonexclusive design of the fuzzy master framework is appeared as shown in Figure 10 below;

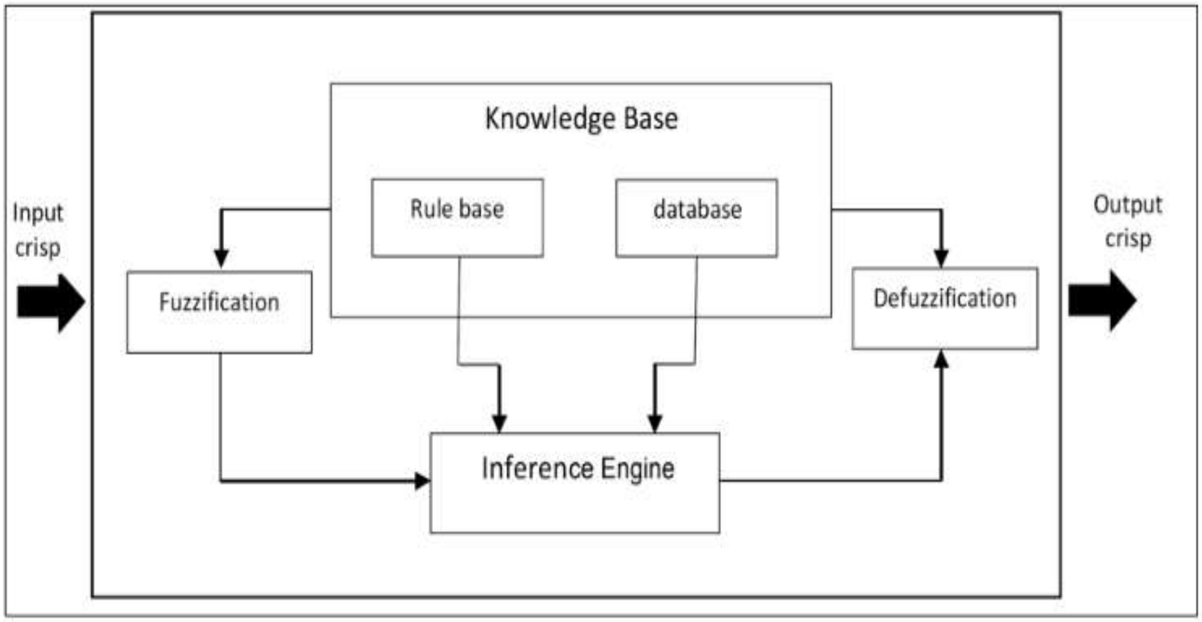

Figure 9: Block layout showing a fuzzy interface.

From a fuzzy derivation interface shown (estimated thinking) the thinking procedure depends on a progression of if-then standards as a sort of master information [32,33]. The restrictive proclamation (or recommendation) components possesses commence commands and which have to be initiated with the use of the if-then statements so as to reach to the end [32,34]. This fuzzy methodology framework incorporate in it a certain kind of expert learning which comprises and gathers a few standards having a shape whose expression uses the if and then statements such as “if Q is C then R is D”, and from a greater perspective, if Q1 is C1 while k takes on the value of C, in that aspect R will become D, where Qk, Q and R would form the fuzzy set [35]. This expert learning fundamentals would grasp and capture extensive information as regards an issue area, whose forerunners and their results are combined on the basis of inference deduced data [36] as shown in the fuzzy interface block above. One of the frequently utilized fuzzy surmising methods was proposed by Mamdani. Be that as it may, in Mamdani-sort FIS the quantity of tenets develops with the quantity of introduce part factors. As the quantity of guidelines develops the action of gathering principles can turn out to be exceptionally oppressive and some of the time it ends up plainly hard to fathom the connections across establishments as well as outcomes [37].

In this dissertation research work, a Sugeno-sort strategy also called as Takagi-Sugeno-Kang fuzzy optimization technique has been applied so as to improve on the performance of the system or the model in question. This technique would mainly work and optimize on the given fuzzy source data to yield fresh or rather directly blended type of information. It has been proven that mathematical calculation analysis is quite productive at the same time reasonable enough when it comes to streamlining while utilizing versatile procedures, thereby making exceptionally satisfactory in terms when it comes to issues to do with monitoring as well as regulation procedures and which caters for the most part for element nonlinear frameworks [38]. Sugeno technique builds up a precise way to deal with produce fuzzy tenets from a given information resulting in a collection of broad range of data. Design alterations can be made at stage of its development and in the process ensuing a particular component in the Mamdani control which does have the capacity to accommodate as well fuzzy equations with their information factors. An expression to demonstrate the application of the Takagi-Sugeno-Kang optimization technique could also be of the form: IF q is Ck AND r is D THEN w is f (q, r) where q, r as well as w are considered as phonetic factors, Ck as well as D will be taken as fuzzy sets in the domain to do with talks between Q as well as R, while f(q, r) corresponds to its numerical capacity [38].

Apart from that, one major difference between the two fuzzy optimization techniques is that the Sugeno-sort fuzzy inference system utilizes data which has been considered to be normal and can be processed with much easy so as yield fresh and new data whereas the Mamdani-sort fuzzy inference system utilizes yet another procedure which is called as defuzzification and which would result in a fuzzy yield. Initially there are two sections of the fuzzy induction handle which have the similar characteristics which include; fuzzifying the sources of information as well as implementing the fuzzy administrator. Another principle distinction between the two is that the Sugeno yield participation capacitieswhich are either straight or stead, while later does not. The different types of unique sorts of fuzzy inference systems are shown in Figure 11 below. In this figure, sort two is that of Mamdani fuzzy inference system (FIS) which yields work in view of general fuzzy yield, while sort three is the Takagi-Sugeno fuzzy derivation.

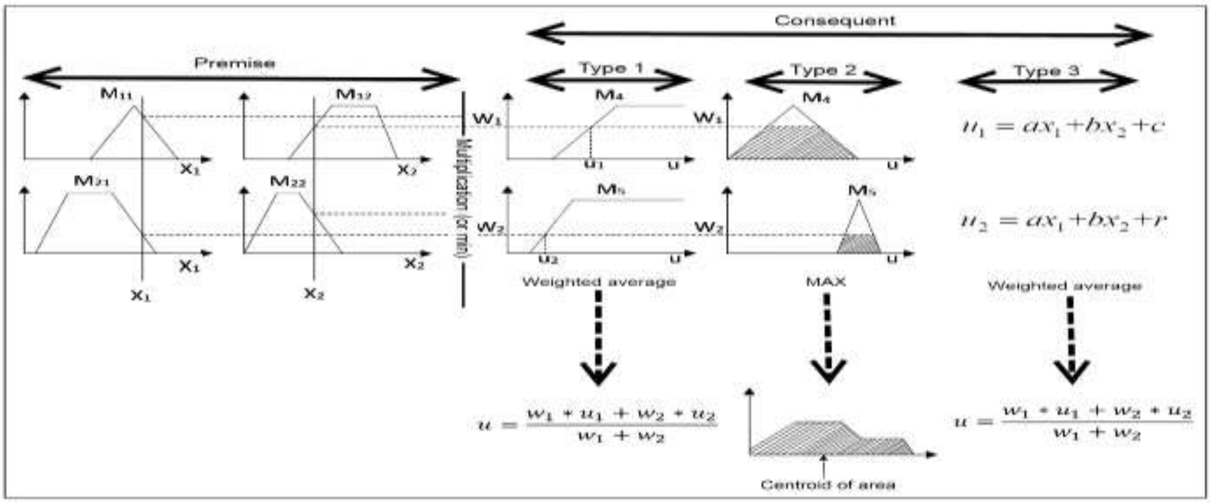

Figure 10: Several types of Fuzzy deduction methodologies [30].

4.4.2 Fuzzy deduction as Applied to load Frequency Control and eigenvalue calculation

Fuzzy derivation is a procedure of acquiring new learning through existing information utilizing fluffy rationale. This procedure of detailing the mapping from an offered contribution to a yield delivers a premise on which choices can be made or designs observed. In this approach, the arrangement of an issue gets from human translation of information, ability, and so on.

An approach is proposed utilizing fuzzy induction to construct a fuzzy file which processes motions as either voltage or current and manages indeterminate information. The initial step of fuzzy master framework configuration is meaning of data sources and yield parameters. We depict the info factors with their enrollment capacities and after that we demonstrate the consequences of the recreation

CHAPTER 5

SIMULATION RESULTS AND DISCUSSION

The technique of using simulations in the monitoring, analysis and verification of the results obtained from power system models is quite very effective and reliable. The three areas depicting a large power pool simlink main model is illustrated below;

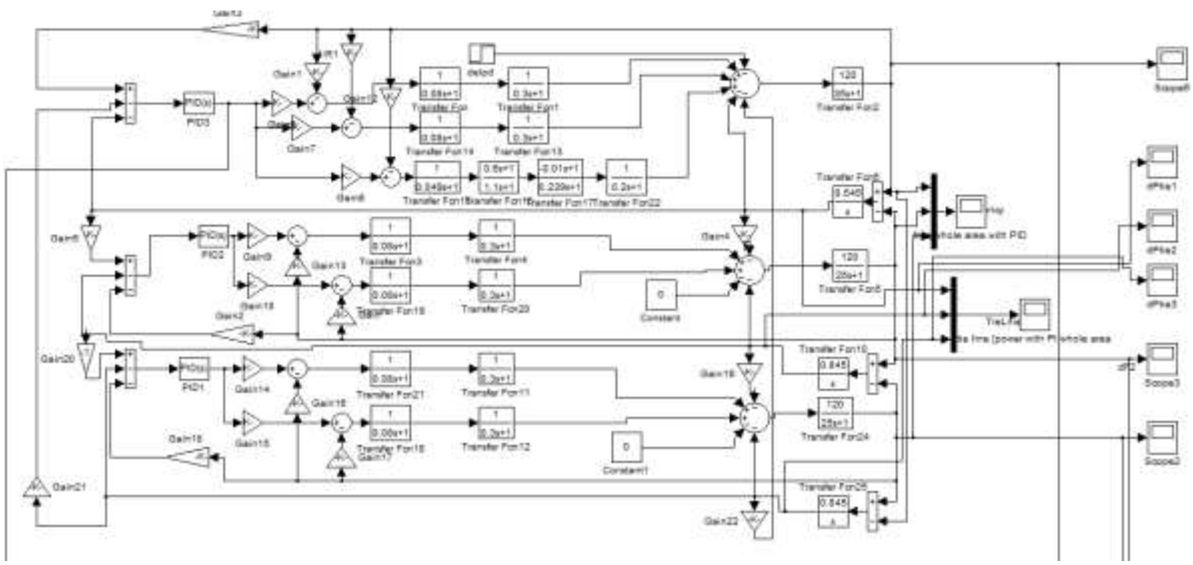

Figure 11: Simulink main model with PID of a three area power pool

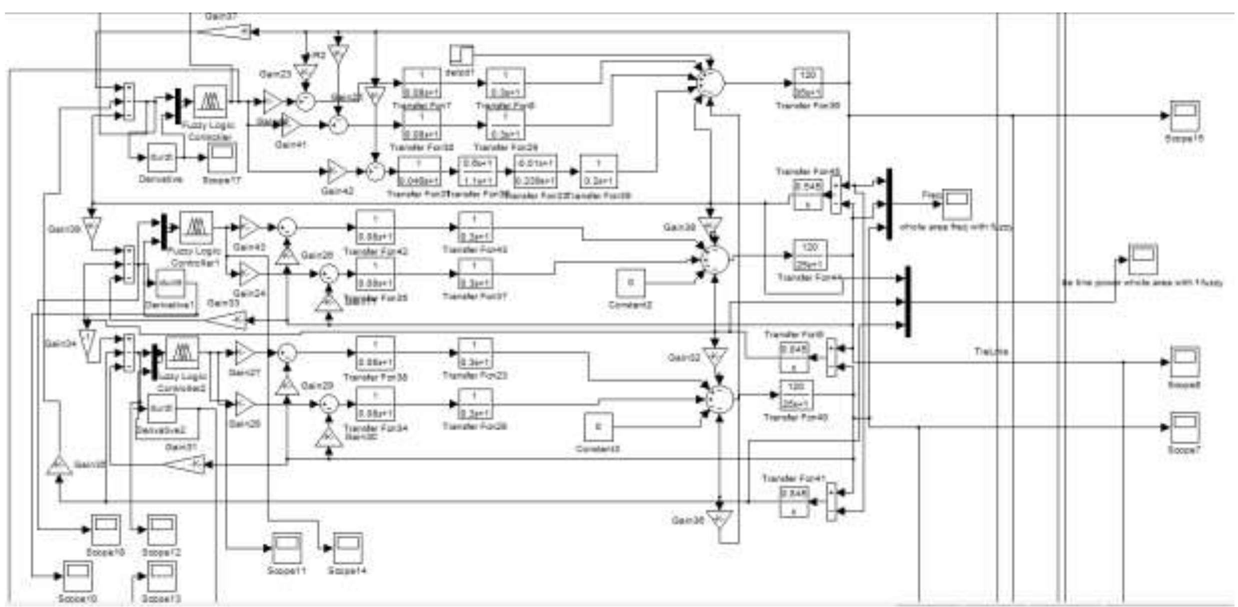

Figure 12: Simulink main model with Fuzzy logic of a three area power pool

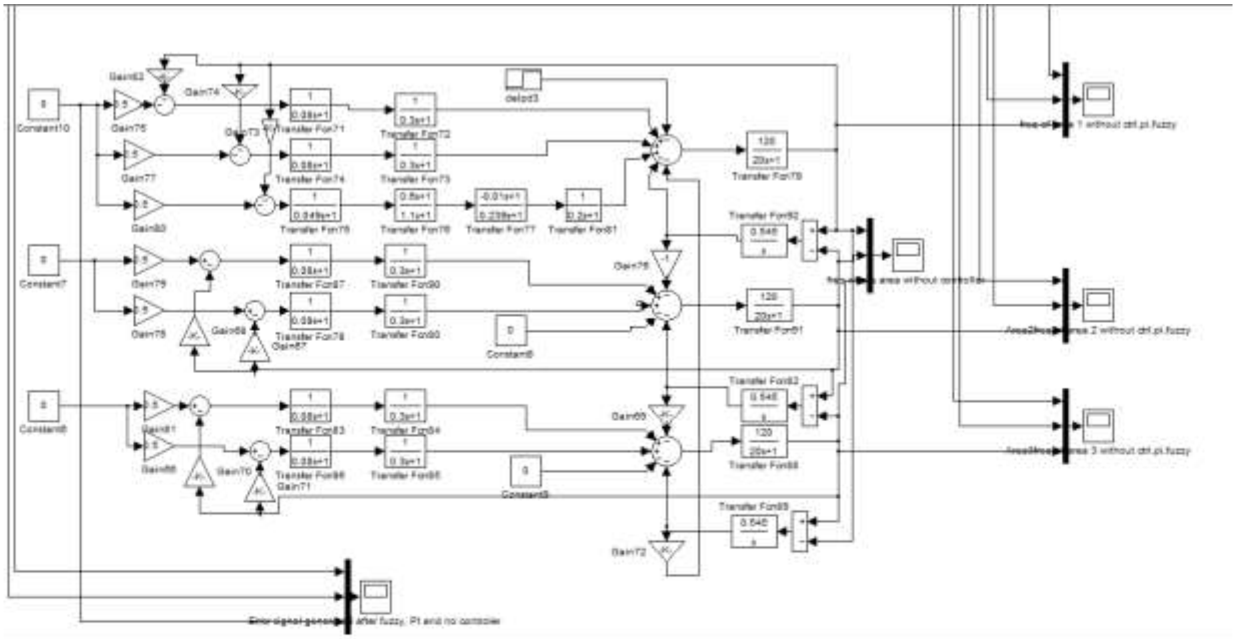

Figure 13: Simulink main model without any controller in a three area power pool

TABLE1 : System parameters for three area system

Name	Kg	Tg (s)	Kt	Tt (s)	H (s)	D (p.u. MW/Hz)	1/R	ΔPL (p.u)
Area 1	1	0.08	1	0.3	35	1.00	125	1
Area 2	1	0.08	1	0.3	25	0.60	10	0
Area 3	1	0.08	1	0.3	25	0.90	2.5	0

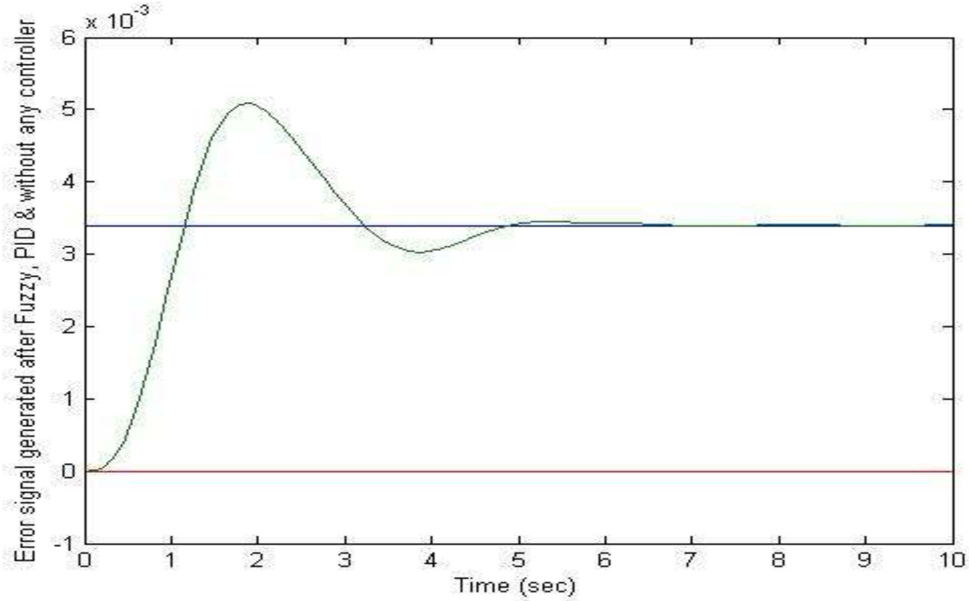

Figure 14: Error signal generated without controller, PID and Fuzzy Controller

As it is shown in the above figure that No Error signal is generated in system if no controller is employed, and with PID controller a steady Error signal is generated. While using Fuzzy controller in the same system Error signal variation is dynamics and depicts the load variation more precisely, hence providing the better results with the proposed strategy.

Moreover, in this simulation result we are able to see that when it comes to power pools which are connected together, due to constant and abrupt fluctuations in the power output, in this case taking into consideration the rapid and spontaneous small variations in the load of the three area control system, there will be a corresponding deviations from their standard values for both recurrence as well as tie-line power passing through these interconnectors. Implementation of the power recurrence regulation is there to ensure that frequency deviations from their acceptable limits are minimized during the slow developing faults or disturbances, and to regulate the exchange of power in these power pools. And the application of the electromechanical regulator is so as to bring the response to a steady state in the shortest possible time due to their instantaneous action because of the proportional regulator incorporated in them. This proportional component of the regulator is responsible as well for generation of a regulating signal which would be corresponding to the deviation response or error of the power transmission network. It would therefore be observed that selection of the right value of Kp in terms of design of controllers is of great importance in as far as reduction of the steady state error in the controllers maybe concerned, and at the same time with increased values of Kp could necessity a reduction in the time constant as well as damping.

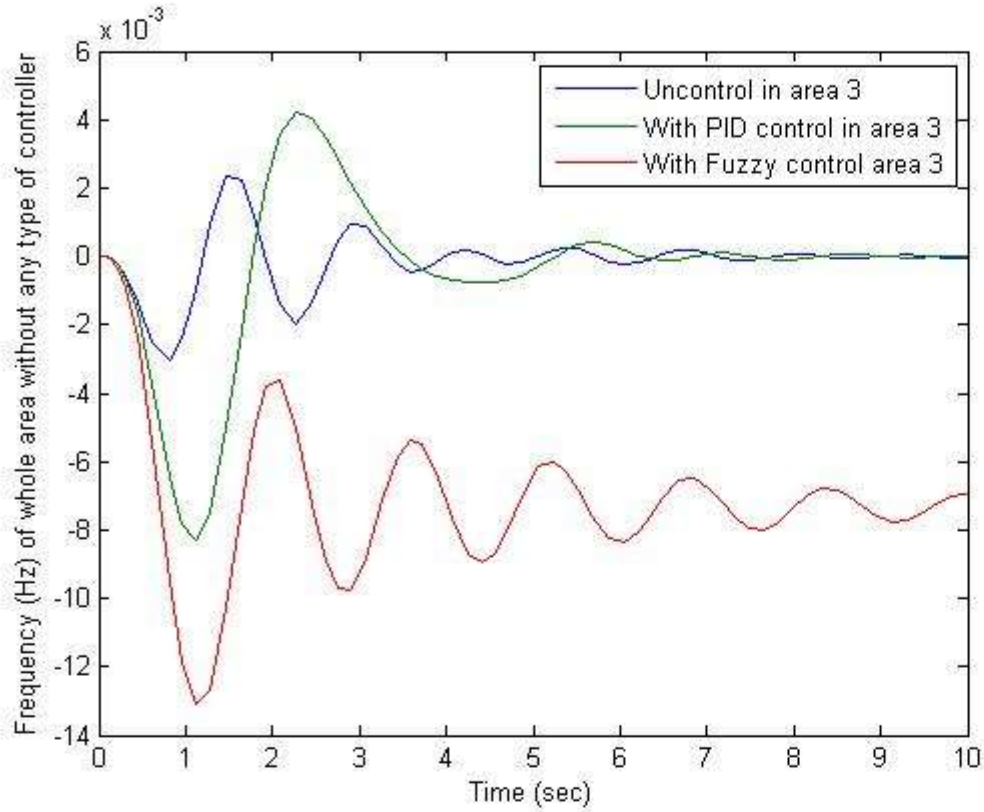

Figure 15: Frequency variation of three areas in system without controller

The figure above shows the frequency variation of the sytsem without controller. It was observed that the oscillations were taking a lot of time coming to steady state stability condition and in such a way that one area was not even able to come to that point of stability after the clearance of transients.

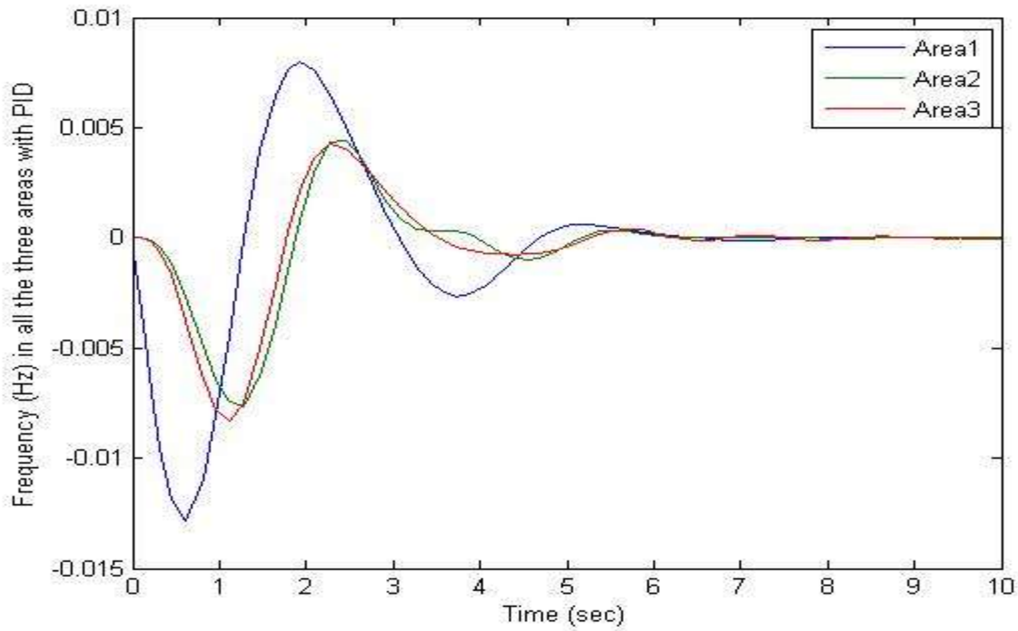

Figure 16: Frequency variation of three areas with PID controller during transients

Frequency variation in all the three areas was analyzed using the simulation process and where it was observed that the system response had to come to a steady state condition after the generation of oscillations by using different controllers. There oscillations are finally reaching to steady state values because of damping provided by PID controller. By using PID controller system stability and performance has increased without increasing the Steady State Error.

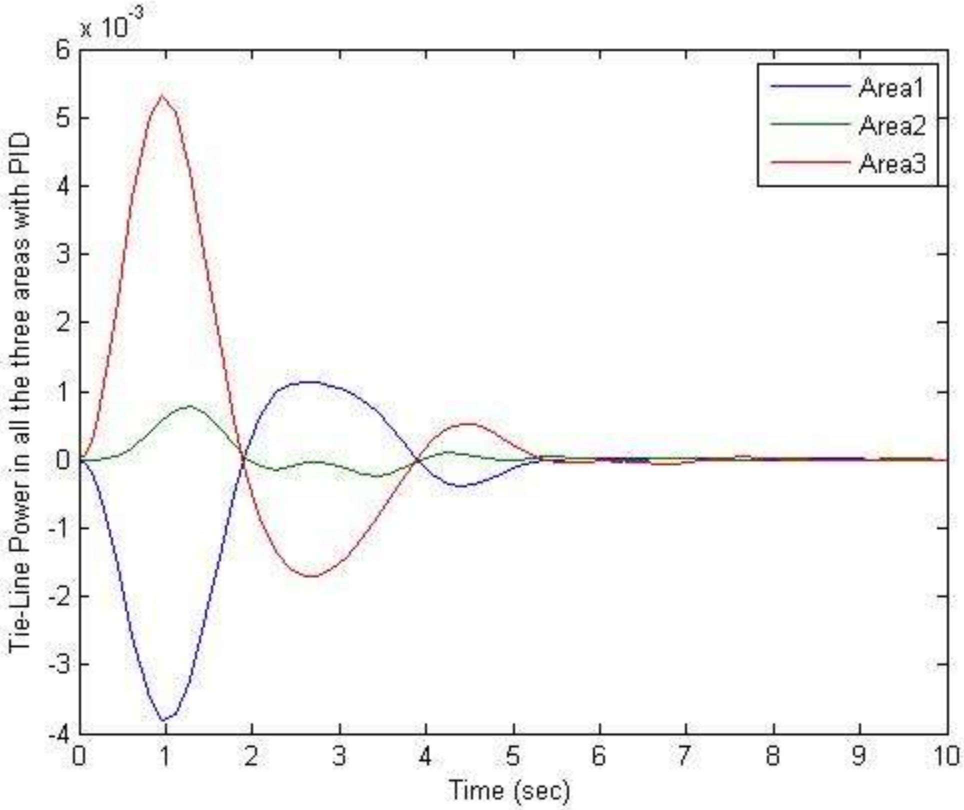

Figure 17: Tie-line power of three areas with PID controller during transients

The tie-line power variations can be as shown in figure above of all the three areas. After providing the load variation in one area, other two areas would as continue to face variation in their behavior while they try to settle down after the occurrence of transients. In this regard, PID controllers would employed so as to make system response stable and sustainable during dynamic conditions.

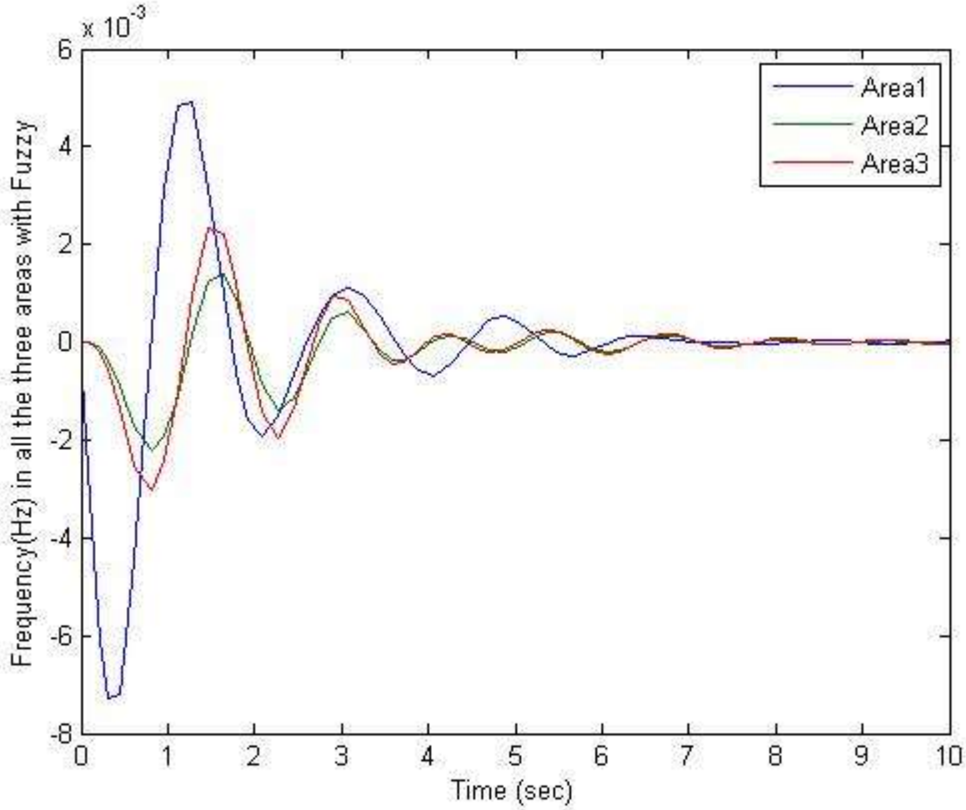

Figure 18: Frequency variation of three areas with fuzzy controller during transients

In this simulation result we are able to see that when it comes to power pools which are connected together, due to constant and abrupt fluctuations in the power output, in this case taking into consideration the rapid and spontaneous small variations in the load of the three area control system, there will be a corresponding deviations from their standard values for both recurrence as well as tie-line power passing through these interconnectors. Implementation of the power recurrence regulation is there to ensure that frequency deviations from their acceptable limits are minimized during the slow developing faults or disturbances, and to regulate the exchange of power in these power pools. In order to optimize the system, the fuzzy logic is employed.

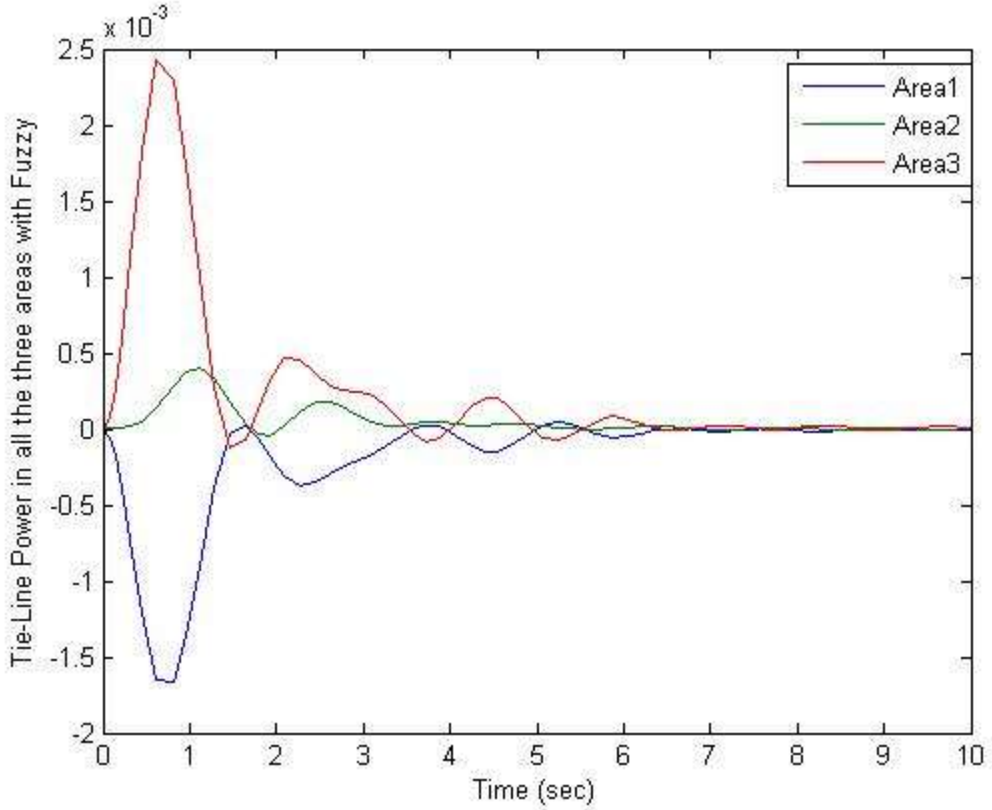

Figure 19: Tie-line power of three areas with fuzzy controller during transients

Tie Line power variation of three area system is projected in figure above and where system was tuned using the fuzzy optimization technique. It can be seen from the figure above that transients generated by load variation have been handelled and system is settelling down to steady state value. The system installed with fuzzy controller is taking less time to reduce oscillation as compared to that one installed with PID controller because of crisp rule set of Fuzzy Matrix.

State Space Matrix for Uncontrolled Syatem.

A =

-0.0270	0	0	0	0	0	3.2430	0	0	-3.2430	0	0
0	-0.0370	0	0	0	0	0	3.2430	0	0	-3.2430	0
0	0	-0.0370	0	0	0	0	0	3.2430	0	0	-3.2430
-1.6670	0	0	0	0	0	-5.0000	0	0	0	0	0
0	-1.0000	0	0	0	0	0	-0.4000	0	0	0	0
0	0	-10.5100	0	0	0	0	0	-7.6920	0	0	0
0	0	0	-2.5000	0	0	2.5000	0	0	0	0	0
0	0	0	0	-5.0000	0	0	5.0000	0	0	0	0
0	0	0	0	0	-4.0000	0	4.0000	0	0	0	0
11.1190	-5.7680	-5.3508	0	0	0	0	0	0	0	0	0
-5.7680	10.0140	-4.2462	0	0	0	0	0	0	0	0	0
-5.3508	-4.2462	9.5970	0	0	0	0	0	0	0	0	0

In the above figure, the mentioned state space matrix for the uncontrolled case, which is needed for finding out the state variables, is tabulated. These state variables are necessary for describing the whole system under different positions and conditions of the system.

Therefore, eigen values of state variables can be calculated by using a MATLAB command of the form;

eigen matrix = eig(A).

Eigenvalue analysis of the system does provide with us better understanding of small signal stability like rotor angle variation, tie line power control and system behavior under transients conditions. The below mentioned values describe the small signal stability when no controller is employed in a simulated three area system.

$$
\begin{bmatrix} \Delta X_{E1} \\ \Delta X_{E2} \\ \Delta X_{E3} \\ \Delta P_{G1} \\ \Delta P_{G2} \\ \Delta P_{G3} \\ \Delta f_1 \\ \Delta f_2 \\ \Delta f_3 \\ \Delta P_{TL1} \\ \Delta P_{TL2} \\ \Delta P_{TL3} \end{bmatrix} = \begin{bmatrix} \dot{x_1} \\ \dot{x_2} \\ \dot{x_3} \\ \dot{x_4} \\ \dot{x_5} \\ \dot{x_6} \\ \dot{x_7} \\ \dot{x_8} \\ \dot{x_9} \\ \dot{x_{10}} \\ \dot{x_{11}} \\ \dot{x_{12}} \end{bmatrix} = \begin{matrix} -0.1474 + 7.3779i \\ -0.1474 - 7.3779i \\ -0.6165 + 6.7835i \\ -0.6165 - 6.7835i \\ 6.7539 \\ 5.4887 \\ 5.1718 \\ -3.7926 \\ -1.7699 + 0.9754i \\ -1.7699 - 0.9754i \\ -1.1551 \\ 0.0000 \end{matrix}
$$

State Space Analysis of system with PID Controller

```
A =

   1.0e+03 *

  -0.0000        0        0        0        0        0  -0.0029        0        0   0.0029        0        0
        0  -0.0000        0        0        0        0        0  -0.0029        0        0   0.0029        0
        0        0  -0.0000        0        0        0        0        0  -0.0029        0        0   0.0029
  -4.0816        0        0        0        0        0  -0.0204        0        0        0        0        0
        0  -0.0313        0        0        0        0        0  -0.0125        0        0        0        0
        0        0  -0.0150        0        0        0        0        0  -0.0125        0        0        0
        0        0        0  -0.0042        0        0   0.0042        0        0        0        0        0
        0        0        0        0  -0.0033        0        0   0.0033        0        0        0        0
        0        0        0        0        0  -0.0033        0   0.0033        0        0        0        0
   0.0111  -0.0058  -0.0054        0        0        0        0        0        0        0        0        0
  -0.0058   0.0100  -0.0042        0        0        0        0        0        0        0        0        0
  -0.0054  -0.0042   0.0096        0        0        0        0        0        0        0        0        0
```

State space matrix for system controlled by PID controller is shown in above figure. These variables of state space matrix have been calculated by solving state space equations.

By using the MATLAB command eigen values can be calculated as follows

$$\begin{bmatrix} \Delta X_{E1} \\ \Delta X_{E2} \\ \Delta X_{E3} \\ \Delta P_{G1} \\ \Delta P_{G2} \\ \Delta P_{G3} \\ \Delta f_1 \\ \Delta f_2 \\ \Delta f_3 \\ \Delta P_{TL1} \\ \Delta P_{TL2} \\ \Delta P_{TL3} \end{bmatrix} = \begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x}_4 \\ \dot{x}_5 \\ \dot{x}_6 \\ \dot{x}_7 \\ \dot{x}_8 \\ \dot{x}_9 \\ \dot{x}_{10} \\ \dot{x}_{11} \\ \dot{x}_{12} \end{bmatrix} = \begin{matrix} 20.2274 + 30.6655i \\ 20.2274 - 30.6655i \\ -36.2542 \\ 6.8842 + 3.6386i \\ 6.8842 - 3.6386i \\ 5.9109 + 1.9387i \\ 5.9109 - 1.9387i \\ -9.1822 \\ -7.4895 \\ -1.7744 \\ -3.9165 \\ 0.0000 \end{matrix}$$

State Space Analysis of system with Fuzzy Controller

A =

-0.0256	0	0	0	0	0	2.5640	0	0	-2.5640	0	0
0	-0.0323	0	0	0	0	0	2.5640	0	0	-2.5640	0
0	0	-0.0323	0	0	0	0	0	2.5640	0	0	-2.5640
-1.2500	0	0	0	0	0	-2.5000	0	0	0	0	0
0	-4.5350	0	0	0	0	0	-1.5870	0	0	0	0
0	0	-2.5280	0	0	0	0	0	-0.8850	0	0	0
0	0	0	-1.6670	0	0	1.6670	0	0	0	0	0
0	0	0	0	-3.3300	0	0	3.3300	0	0	0	0
0	0	0	0	0	-2.2200	0	2.2200	0	0	0	0
11.1190	-5.7680	-5.3508	0	0	0	0	0	0	0	0	0
-5.7680	10.0140	-4.2462	0	0	0	0	0	0	0	0	0
-5.3508	-4.2462	9.5970	0	0	0	0	0	0	0	0	0

By providing the fuzzy controller in system state space matrix is mentioned above, coefficients of matrix have been calculated by solving state space matrix for three area system.

$$\begin{bmatrix} \Delta X_{E1} \\ \Delta X_{E2} \\ \Delta X_{E3} \\ \Delta P_{G1} \\ \Delta P_{G2} \\ \Delta P_{G3} \\ \Delta f_1 \\ \Delta f_2 \\ \Delta f_3 \\ \Delta P_{TL1} \\ \Delta P_{TL2} \\ \Delta P_{TL3} \end{bmatrix} = \begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x}_4 \\ \dot{x}_5 \\ \dot{x}_6 \\ \dot{x}_7 \\ \dot{x}_8 \\ \dot{x}_9 \\ \dot{x}_{10} \\ \dot{x}_{11} \\ \dot{x}_{12} \end{bmatrix} = \begin{matrix} -0.1489 + 6.6025i \\ -0.1489 - 6.6025i \\ -0.3035 + 6.0333i \\ -0.3035 - 6.0333i \\ 5.3006 \\ 3.1697 \\ -0.6831 + 1.8696i \\ -0.6831 - 1.8696i \\ -1.5402 \\ -1.3581 \\ 1.6058 \\ 0.0000 \end{matrix}$$

The above mentioned figures show the eigen values of the whole system with fuzzy logic controller employed.

By comparing the eigen value of state variable in case of uncontrolled, PID and fuzzy controller system state and behavioral analysis can be done. It has been analyzed that by using different controller the Eigen Values started having more negative real part compared to without controller and values become more negative when fuzzy controller is being employed. In multi-area system the behavior of tie-line power and frequency are important to analyze and after using fuzzy controller stability and damping of oscillations have become fast and overall response of system has improved.

CHAPTER 6
CONCLUSION AND FUTURE WORK

6.1 CONCLUSION

This research work has mainly investigated on how small signal stability analysis can be applied in terms of load recurrence variations happening as a result of corresponding variation in the power transfer through the interconnectors between power pools due to fluctuations in the load connected to the power system. Moreover, it has also looked at the implementation of electromechanical tuning controllers, which are compared with the other controllers which uses the fuzzy logic controller in a three area control system so as to optimize or speed up the time of response.

Firstly a secondary control is being introduced for minimizing the inter-area oscillations in frequency. This is usually vital in case of a single area system or an isolated system as the secondary control loop i.e. an integral controller is generally responsible for reducing the changes in the frequency deviations and maintains the system stability. Therefore without the presence of secondary loop the system losses its stability.

Secondly interconnection of two or more systems is being introduced to cope up with the load changes through tie line power exchange. Interconnecting two or more areas ensures the sharing of the power among the systems during the times of load changes which may occur in any area at any time. Therefore the burden on the controllers to minimize the changes in the frequency is reduced as a result of the rise in the power demand can be fulfilled by drawing power from the neighboring areas and thus maintains the stability of the system.

6.2. FUTURE SCOPE

In terms of the future scope we intend to possibly introduce any of the optimization techniques such as Genetic Algorithm (GA) or Bacteria Foraging Optimization Algorithm (BFOA) program so that they can help in speeding up the entire process and to change the values of the various parameters present in the power system under investigation and which can be used in coping up with the changes in the load demand. This therefore will go a long way in terms of contributing to a reduction in the changes to the frequency and a further reduction to the tie line power and thereby helping in maintaining the stability of the system. We may also want to incorporate a programming technique and make comparisons of the values obtained and those with the reference. It is also seen that BF technique has quicker convergence characteristics. Most of these optimization techniques serve to be quite useful for obtaining the optimized values of the various parameters as compared to the general hit and trial technique which is extremely tedious and time taking method.

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