SIMULATION IN AN AGC SYSTEM USING FUZZY CONTROLLER

A Project Report

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BONAFIED CERTIFICATE

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ABSTRACT

The objective of this project deals with power in an interconnected system as economically and deliver power in an interconnected system as economically and reliability while maintaining the voltage and frequency within permissible limit. This can be done by AUTOMATIC GENERATION CONTROL using PI controller. The power generated at the output is fed back to the input through feedback path.

The role of AUTOMATIC GENERATION CONTROL (AGC) is to control the frequency to nominal value as the load changes continuously. AGC divides the load among the system; station and generator to achieve maximum economy and accurate control of scheduled interchange of tie line power maintain a reasonably uniform frequency.

In order to avoid non-linearity's of power control strategy and to achieve better performance an integral controller is added to act on the load reference. PI controller is generally used. Using PI controller all the parameters are optimized around an operating point. For certain condition the PI controller is not suited. The disadvantage of PI controller is that mathematical model of control process may not exist or may be too expensive in terms of control processing powers and memory. In that case a fuzzy controller is incorporated in the system.

Once the system behavior is thoroughly studied using PI controller, a fuzzy controller is used as a secondary regulator. Load varied continuously and the system behavior is studied. This simulation is performed using Mat lab Simulink package. The results are compared. Finally concluding that fuzzy controller is fast in action and gives better performance.

Constancy of system frequency and tie line loading must be maintained for satisfactory performance of transformers, electric clocks, auxillary induction motor drives of generating units in generating stations and large ac drives of various industries in very large scale integrated system. This project is done on regulating environment and it can extend to deregulated environment.

செயல் சுருக்கம்

இந்த செயல் திட்டத்தின் நோக்கம் மின்னாற்றலை எந்தவித இழப்பும் இல்லாமல் வீரியமாக பாய்ச்ச ஒரு அமைப்பினை உருவாக்குவது ஆகும். இதில் மின்னழுத்தமும் அதிர்வுகளும் கட்டுப்படுத்தப்படுகின்றன். இந்த அமைப்பில் ''தானியங்கி உற்பத்தி கட்டுப்பாட்டு முறை'' அறிமுகப்படுத்தப்படுகிறது. இந்த அமைப்பில் ஒரு மூடிய அமைப்பு சுற்றுமுறை அறிமுகப்படுத்தப்படுகிறது.

தானியங்கி உற்பத்தி கட்டுப்பாட்டு முறை இயல்பான அதிர்வுகளை தொடர்ந்து உருவாக்குகிறது. இது பளுவை மின் நிலையம் மற்றும் மின் உற்பத்தி இயந்திரம் ஆகியவற்றில் சீரான முறையில் வகுத்து மின்னாற்றலை இழப்பின்றி பாய்ச்சுகிறது.

மின்னாற்றலை கட்டுப்படுத்த 'சரிசமவிகித கட்டுப்படுத்தி'யை உபயோகித்து எல்லா அளவுகளையும் கட்டுக்குள் கொண்டு வந்து செயல்முறை சீராக்கப்படுகிறது. சரிசமவிகித கட்டுப்படுத்தியில் சில குறைகள் அறியப்பட்டன. அவை கடின கணித முறை மற்றும் உயர்ந்த விலை எனவே ''∵.பஸி கட்டுப்பாட்டு முறை'' என்ற புதிய இயங்கி அறிமுகப்படுத்தப்படுகிறது.

சரிசமவிகித கட்டுப்படுத்தியை பயன்படுத்தி அமைப்பை ஆய்வு செய்த பின்பு ''∵.பஸி கட்டுப்படுத்தியை பயன்படுத்தி ஆய்வுகள் மேற்கொள்ளப்பட்டது. இதில் ∴.பஸி கட்டுப்படுத்தி சரிசமவிகித கட்டுப்படுத்தியை விட மிக வேகமாக அதிர்வுகளை கட்டுப்படுத்தி அமைப்பை செயல்படுத்தி சீரமைக்கிறது.

இந்த ∴.பஸி கட்டுப்படுத்தி முறை, மின்மாற்றி, மின்சார கடிகாரம் மற்றும் மின் தூண்டும் இயந்திரம் இன்ன பிற பெரிய மின் உற்பத்தி நிலையங்களில் அதிர்வுகளையும் மின்னழுத்தத்தையும் கட்டுப்படுத்தி திருப்தியான செயல்முறைகள் தருகிறது.

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P_m	- Mechanical power input
ΔP_m	- Change in mechanical power input
e(k)	-Change in error using PI Controller
K_I	-Integral error constant
P_e	- Electrical power output
Pg	- Electrical power generated
ΔP_e	- Change in electrical power output
P_L	- Electrical load power demand
ΔP_L	- Change in electrical load power demand
ΔPg	- Change in electrical power generated
δ	- Torque angle/power angle
δm	- Mechanical torque angle/power angle
δc	- Electrical torque angle/ power angle
H	- Machine inertia constant in system base
J	- Machine inertia constant
ω	- Rotor angular velocity with reference to synchronous Rotating frame
$\Delta\omega$	- Change in rotor angular velocity wiyh reference to Synchronous rotating frame.
D	- Ratio of percent change in load to percent change in velocity
τg	- Time constant of governor
$\Delta\Omega$	- Frequency deviation
$\Delta\omega s$	- steady state value angular velocity
Tt	- turbine relay time constant
P_{min}	-Minimum shaft position
P_{max}	- Maximum shaft position
ACE	- Automatic control error

P_{12}	-Tie line power of area 1 and area2
P_{23}	-Tie line power of area 2 and area3
P_{31}	-Tie line power of area 3 and area1
P_{01}	-Power delivered at area1
P_{02}	-Power delivered at area2
P_{03}	-Power delivered at area3
NV	- Negative very large error
NS	-Negative small error
ZE	-zero error
PS	-Positive small error
PV	- Positive large error

CHAPTER 1

INTRODUCTION

This project deals with control of active and reactive power in order to keep the system in steady state. In addition, simple models of essential components used in the control systems are presented. The objective of control strategy is to generate and deliver power in an interconnected system as economically and reliably as possible while maintaining the voltage and frequency within permissible limits.

Changes in real power affect mainly the system frequency, while reactive power less sensitive to changes in frequency .LFC loop controls the real power and frequency and the automatic voltage regulator AVR loop regulates the relative power and voltage magnitude. Load frequency control (LFC) has gained in importance with the growth of interconnected systems and has made the operation of interconnected systems possible today it is still the basis of many advanced concepts for the control of large systems.

Automatic generation control plays an important role (AGC) in power system operation with reference to the tie line power control under normal operating condition. The load is equally divided among system, station and generator to achieve maximum economy and accurate control of the scheduled interchanges of tie line power while maintaining uniform frequency. During large transient disturbances and other emergency control takes over. Thus automatic generation control in response to area load changes and abnormal system operating parameters and conditions in large scale power system has essentially three objectives.1.system frequency is to be satisfactorily maintained at or, very close to specified nominal value (i.e.) deviation in frequency (Δf) must be made zero as quickly as possible.2.Deviation in tie line interchanges (ΔPtie) from the pre-scheduled contracted interchanges among the areas must also be zero as fast as possible generation scheduling. Over the last few decades various load frequency control strategies have been developed in order to have better dynamic transient responses. Fixed integral gain controllers have been proposed for normal operating conditions but they have fail to provide best control performance over wide range of off-nominal operating conditions. So to achieve optimal performance, various other state feedback and state adaptive optimal controllers have been proposed, which require very large, complicated computational burden, memory and time. More recently, fast acting artificial neural networks (ANN) have been developed to cater for the uncertainties in the operating power system parameters. But ANN approach has many inherent drawbacks like requiring of large historical database for proper training, network topology dependence and choice of proper response functions etc due to which exactly similar performance may not be obtained.

So here mamdani type fuzzy controller is developed to change the integral gain settings automatically to restore nominal system frequency and tie line loadings for various wide range off-nominal power system parameters and area load changes.

Fuzzy subsets and corresponding membership functions are designed for operating input parameters. Decisions are obtained for optimal integral gain K as the output. The overall computational and memory burden are very low, hence becoming very fast acting and adaptive. Typical responses to real power demand are illustrated using latest simulation technique available by MATLAB SIMULINK package. On stability of both speed and excitation with use of suitable feedback signals are examined

The methods developed for controls of individual generators, and eventually control of large interconnections, play a vital role in modern energy control centers. Modern energy control centers are equipped with on line computers. Performing all signal processing through the remote acquisition systems known as supervisory control and data acquisition (SCADA) systems.

1.1 LITERATURE SURVEY

Large-scale power system is normally composed of central areas or region representing coherent groups of generator. The various areas are connected by tie lines. Load frequency control and automatic voltage regulator have gained importance with the growth of interconnected system. This takes care of small changes in load demand while maintaining the frequency and voltage magnitude with in the specified limits. Many investigations in the area of LFC problem of interconnected power system have been reported over the past few decades. A number of control strategies have been employed in the design of load frequency controllers in order to achieve better dynamic Performance, which is proportional integral (PI) controller. An inherent disadvantage of PI controller is the possible adverse effects caused by large errors signals. The large error can be caused by a large demand deviation or when initially during starting of the system. This is a problem caused by a large sustained error signal, which will eventually cause the controller to drive to its limits.

A number of control strategies exist to achieve better performance. Due to non-linearity of power system, system parameters are linearized around an operating point. PI controller is generally used. It uses the analytical expression of the following form to compute the control action.

$$U = K_P e + K_I \int_t e\, dt \qquad - \qquad 1.1$$

When this expression is differentiated we get

$$U = K_P e + K_I e \qquad - \qquad 1.2$$

The discrete time version of this equation is

$$\Delta u\,(k) = K_p\, \Delta e\,(k) + K_I\, e(k) \qquad - \qquad 1.3$$ where

- $\Delta u(k)$ is the change of control output and u(k) is the control out put then

$$\Delta u(k) = u(k) + u(k+1) \qquad - \qquad 1.4$$

- $e(k)$ is the error and where $y(k)$ is the system output and y_{sp} is the set point or desired system output. Then we have

$$e(k) = y_{sp} - y(k) \qquad - \qquad 1.5$$

- $\Delta e(k)$ the- change of error and we have

$$\Delta e(k) = e(k) - e(k+1) \qquad - \qquad 1.6$$

- K is the k^{th} sampling time.

The control objective listed above requires various gain near the set point. It is found that K_I value at y_{sp} should be small and at constrains should be very. Thus a simple PI controller is inherently incapable of achieving all the above control objectives and has to be implemented with help of additional heuristic logic, which would allow the desired gain.In the classical control paradigm much stress is laid on the precision of the input, the intermediate steps that processes them and model of the system in question, even with great sophisticated classical controllers developed, in the real world of complexity there exist so many parameters that have not been properly accounted for and many which are totally ignorant off, where as a fuzzy logic solution is tolerant to the lack of precision in the inputs and the model of the system and still produce an output that is desired out of the system.

Recently the resurgence of interest in the field of artificial neural network has injected a new driving force into the fuzzy literatures. As a result, a fuzzy inference system can now not only take linguistic information (linguistic rule) from human experts, but also adapts it using numerical data (input & output pair) to achieve better performance. A class of adaptive networks that acts as a fundamental framework for adaptive fuzzy inference systems is introduced in this section.

1.2 OBJECTIVE

- To develop a system model and analyze the performance in three interconnected area and to control the power delivered by controlling the voltage and frequency.The normal value of frequency is 50 Hz.
- To simulate the system model using MATLAB 7

The change in load changes the output frequency. The power system components like transformer, turbine blades may damage due to this frequency change. This can be prohibited by 'Automatic generation control'. In this control a PI CONTROLER is added and all the parameters are optimized around an operating point. Then a FUZZY logic controller is developed in order to bring the frequency to normal value. Rules developed using mamdani type of fuzzy system.

Simulation is performed using Matlab 7.Results are compared. The change in frequency is made to zero quicker and normal frequency is obtained faster only by applying fuzzy logic controller than that of the PI controller.

1.3 METHODOLOGY

When load in the system increases turbine speed drops before the governor can respond. As the change in the value of speed decreases the error signal becomes smaller and the position of the governor valve get close to the required position, to maintain constant speed. However the constant speed will not be the set point and there will be an offset, to overcome this problem an integrator is added, which will automatically adjust the generation to restore the frequency to normal value. This scheme is called automatic generation control (AGC). The role of AGC is to divide the loads among the system, station and generator to achieve maximum economy and accurate control of the scheduled interchanges of tie-line power while maintaining a reasonably uniform frequency.

The synchronization of different system with interconnected system depends on (i) voltage magnitude (ii) frequency and (iii) phase sequence. Any wide deviation from the nominal value of frequency or voltage will lead to total collapse. Hence AGC has gained importance with the growth of interconnected systems and will rise in size of interconnected system automation of control system have aroused. A number of control strategies exist to achieve better performance. Due to non-linearity of power system, system parameters are linearised around an operating point. PI controller is generally used. The drawback of PI controller is that mathematical model of the control process may not exist or may too expensive in case of computer processing and memory. A system based on empirical rule will be more effective. In PI control much stress is laid on the precision of the input, the intermediate steps that process them and model of the system is questioned.

While designing a PI controller following hindrance have to be overcome.viz (a) operating interfacing (b) smooth switching operation of the components,(c) transient parameter changes,(d) effects of non linear actuator,(e) maximum and minimum selecting and built up of integral terms i.e. heuristics plays an important part. Once the system behavior is thoroughly studied, then with the help of intelligent trail and error science the heuristics rules that describe the equation can be formulated. A fuzzy controller is designed. It is fine-tuned using ANFIS. ANFIS proven to be excellent function approximation tool. It implements the first order mamdani fuzzy sustem. The membership function is of triangular form. 5-membership function is formed and it is fine-tuned. A Study performed comparing the operation using fuzzy controller and PI controller. The simulation is done using Mat lab Simulink Package and various results are obtained by varying the load. Instead of Mamdani fuzzy interface, Surgeon System also is implemented. This work is done in regulated environment and it also implemented in deregulated environment. In deregulated environment all the parameters are standardized under the control of ISO (International standard organization) and the will be disco participation matrix comes in order to transfer the power and other performance.

1.4 Organization of the report

1.4.1Project overview

While transmitting the power in an interconnected area the change in frequency problem arise. This change in frequency is caused due to change in load in the input side of the generator. So a system is developed that regulates a frequency to a normal value of 50 Hz through a closed path. This normal frequency is obtained by using PI controller. Gain value of PI controller is adjusted to make the change in frequency to zero. A fuzzy controller is introduced instead of PI controller and performance is analyzed. The result says that FUZZY controller brings the frequency to normal value faster than that of the PI controller.

1.4.2 Report layout

This report contains six chapters. The first chapter introduces the concept and tells the objective and methodology. It contains Literature survey. In Second chapter load frequency problem and reasons for limiting the frequency is analyzed. In the third chapter generator model, load model, turbine model are developed using transfer function method under the topic of 'Model development'. Chapter 4 contains details about 'Automatic generation control' and the automatic generation control in three interconnected areas are presented. Chapter 5 introduces the fuzzy logic concept. The fuzzy logic concept contains the details about Fuzzification, Inference, Defuzzification, Tuning and system enhancement. The fuzzy logic toolbox contains the details about the tools used in fuzzy logic controller and there is another subtopic, which consists of some of steps in developing the fuzzy controller. The rules and membership functions are developed in steps. Chapter 6 tells about the simulation. And the chapter 6.1 compares the simulation results comparing the PI and FUZZY controller. Different case studies for various loads are presented in this chapter.

CHAPTER 2

LOAD FREQUENCY PROBLEM

If the system of a single machine connected to a group of loads the speed and frequency change in accordance with the governor characteristics as the load changes. If it is not important to keep frequency constant no regulation control is required. The frequency normally would vary by about 5% between light load and full load conditions. On the other hand if constant frequency is required the operator can adjust the speed of the turbine by changing the governor characteristic as and when desired.

If a change in load is taken care of by three machines running in parallel the complexity of the system is increased. The possibility of sharing the load by the three machines is as follows: Say, there are three stations S_1, S2 and S3 interconnected through a tie line. If the change in load is either at S_1 or S_2 and if the generation of S_1 alone is regulated to adjust this change so as to have constant frequency, the method of regulation is known as Flat Frequency Regulation. Under such situation station S_2 is said to be operating on base load. The major drawback of flat frequency regulation is that S_1 must absorb all load changes for the entire system thereby the tie-line between the two stations would have to absorb all load changes at station S_2 since the generator at S_2 would maintain its output constant. The operation of generator S_2 on base load has the advantages when S_2 is much more efficient than the other station and it is desirable to obtain maximum output of S_2.

The other possibility of sharing the change in load is that S_1 S_2 and S3 would regulate their generations to maintain the frequency constant. This is known as parallel frequency regulation. The third possibility is that the change in a particular area is taken care of by the generator in that area thereby the tie-line loading remains constant. This method of regulating the generation for keeping constant frequency is known as flat-tie line loading control. This arrangement has the advantage that load swings on station S_1 and the tie line would be reduced as compared with the flat frequency regulation. Automatic equipment permits various types of system control. The various methods discussed above can be performed with the help of automatic control equipments. Besides these, two other types of controls arc widely used in automatic arrangements. They are Selective Frequency Control and (ii) Tie-line load-bias Control.

The common method of operating a large interconnected system assigns frequency control to a central system; the other systems are then controlled on the basis of system frequency and tie-line loading. The tie line loading as the basis of automatic control is used in three different ways. One of these is known as Selective Frequency Control. Here each system in the group takes care of the load changes on its own system and does not aid the other systems in the group for changes outside its own limits.

The most commonly used method is the tie-line load bias control in which all power systems in the interconnection aid in regulating frequency, regardless of where the frequency change originates. The equipment consists of master load frequency controller and a tie-line recorder measuring the power input on the tie, as for selective frequency control. The tie-line instrument biases the load frequency controller by changing the control point until the desired relationship exists between tie-line loading and system frequency.

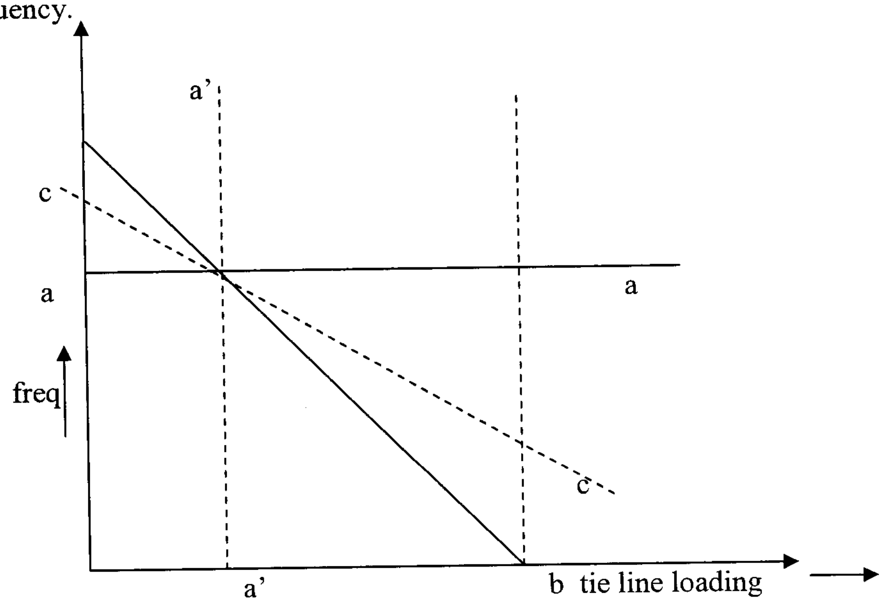


Fig 2.2 . Load Frequency Control Characteristics

The solid line *bb* represents a characteristic similar to the governor characteristic. The solid line *aa* represents a constant frequency characteristic. If the station is trying to maintain constant frequency, the tie-line load changes would vary over very wide limits whereas if it were working along *a'a'*, the tie-line load would be held constant regardless of the frequency. The actual operating point in tie-line load-bias control lies between these two extreme limits such as *bb* or *cc*.

In order to explain this method refer to 2.2 and consider that there is increase in load on station S_1 as a result there is reduction in frequency, the control at S_2, being immediately responsive to frequency, increases its generation to restore frequency to normal. The amount of load picked up depends on the bias for which the regulating equipment has been set. If initially x is the operating frequency and if it drops to y due to increase in load, the load picked up on the tie line will be shown by the shaded area under xy. The tie line has definitely gone off schedule, but this power is contributed to the interconnection in a direction to improve system regulation. The amount of bias is adjustable, depending on the extent to which station S2 is scheduled to contribute to system regulation.

In a large interconnected system, as has been stressed previously that manual regulation is not feasible and, therefore, load frequency equipment is installed for each generator. Similarly for voltage control also voltage regulation equipment is installed on each generator. The controllers are set for a particular operating condition and they take care of small changes in load demand without voltage and frequency exceeding the pre-specified limits. If the operating conditions change materially the controllers must be re-set either manually or automatically.

It is known that small changes in load depend upon the change in rotor angle δ and is independent of the bus voltage whereas the bus voltage is dependent on machine excitation (i.e., on the reactive generation Q, and is independent of rotor angle δ. Therefore, the two controls, i.e. load frequency and excitation voltage controls are non-interactive for small changes and can be modeled and analyzed independently. Besides, the load frequency controller is slow acting because of the large time constant contributed by the turbine and generator moment of inertia, and excitation voltage control is fast acting as the time constant of the field winding is relatively smaller, thus excitation voltage control is much faster and do not affect the of load frequency control. We will consider here only the load frequency control aspect of regulation. Here that the regulator designed for control should not be insensitive to fast random changes; otherwise the system will be prone to hunting, resulting in excessive wear and tear of control equipments and the rotating machines.

The main objective of the load frequency controller is to exert control of frequency and at the same time of real power exchange via the outgoing lines. The change in frequency and the tie line real power are sensed which is a measure of the change in rotor angle δ, i.e., the error $\Delta\delta_i$ to be corrected. The error signals, i.e., Δf_i and ΔP_{tie} are amplified mixed and transformed into a real power command signal ΔP_{ci} which is sent to the prime mover to call for an increment in the torque. The prime mover, therefore, brings change in the generator output by an amount ΔP_{Gi} which will change the values of Δf_i and ΔP_{tie}. The process continues till the deviation Δf_i and ΔP_{tie} are well below the specified tolerances.

2.1.REASONS FOR LIMITS ON FREQUENCY

The following are the reasons for keeping strict limits on the system frequency variations:

(i) The speed of a.c. motors is directly related to the frequency. Even though most of the a.c. drives are not much affected for a frequency variation of even 50 ± 5 Hz but there are certain applications where speed consistency must be of high order.

(ii) The electric clocks are driven by synchronous motors and the accuracy of these clocks is not only a function of frequency error but is actually of the integral of this error.

(iii) If the normal frequency is 50 Hz and the turbines are run at speeds corresponding to frequency less than 47.5 Hz or more than 52.5 Hz, the blades of the turbine are likely to get damaged, hence a strict limit on frequency must be adhered to as stalling of the generator will further aggravate the problem if the system is operating at the lower limit of frequency.

(iv) The under frequency operation of the power transformer is not desirable. For constant system voltage if the frequency is below the normal value the flux in the core increases. Since we design these transformers corresponding to the 'knee point' on the B-H curve (B) a small increase in B drives the transformer into saturation region (B').

As a result the magnetizing current even exceeds the normal full load current, The sustained under frequency operation of the power transformer results not only in low efficiency but it may even damage the transformer winding due to overheating, The problem is further aggravated by the fact that to transmit one MW of power from generating station to the consumer end 41lW equivalent capacity transformers are installed, Hence a strict limit on the frequency operation of power system is desirable.

(v) The system operation at subnormal frequency and voltage leads to loss of revenue to the suppliers due to accompanying reduction in load demand.

(vi) The most serious effect of subnormal frequency is on the operation of thermal power plants. With reduced frequency the blast by fans decreases, as a result of which the generation also decreases and thus it becomes a cumulative action and may result in complete shut-down of the plant if corrective measures like load shedding is not resorted to. Load shedding is done with the help of under frequency relay, which automatically disconnects blocks of loads. The setting of the under frequency relays is so adjusted that the least important load is disconnected at a relatively higher frequency and vice versa.

(vii) The overall operation of power system can be better controlled if a strict limit on frequency deviation is maintained. The frequency is closely related to the real power balance in the overall network. Under normal operating conditions the generators run synchronously and the generated power equals the load demand plus the losses at any instant of time. When a generator is connected to the grid, its speed gets locked to the grid system. Now if we want to control the real power output from this generator, we must control the torque from 'its' prime mover. By opening the steam valve and thus increasing the steam pressure on. The turbine blade, greater torque can be applied to the generator thereby tending to accelerate the generator. However, its speed is tied to the grid and hence the motor advances its torque angle by few degrees depending upon the load increase requirements. This results in increased delivered current and power. The increased current thus develops a decelerating torque within the machine, which exactly balances the increase in accelerating torque. Unfortunately the counterbalancing electromagnetic torque is not developed instantly.

The duration for which the unbalance exists depends upon the change in load and the total inertia of the system. If the change in load is small as compared to the total inertia of the system, the frequency remains almost constant throughout the operation of the system. However the load fluctuations are entirely random and also are the operating conditions of the system network and hence it is impossible to obtain a perfect instant-by-instant match between generation and the load. There will always be a surplus or deficiency in the generation and hence this ever-present mismatch will cause frequency fluctuation.

Suppose initially there is perfect matching between the power generated and the load demand and say the system frequency is 50 Hz. Let the system load decrease by some amount. The prime mover does not respond to the load change instantly as it is ignorant of the 10300 change. The decrease in load results in decrease in current supplied by the generators, which results in decrease in electromechanical torques in all the generators. Every generator would thus experience a small surplus accelerating torque, which results in increase in speed of generators and thus the increase in frequency. All the motors which are fed by the network would experience increase in speed and thus their torques would increase, as the torque developed by the motors increases the power drawn by the motors from the network increases, If the prime-mover remains ineffective during this period, the frequency would off at a new higher value.

In a single area uncontrolled system whenever a load increase takes place it is taken care of by the system in the following three ways:

(i) 'Borrowed' kinetic energy from the rotating machines of the system i.e., initially the increase in load is supplied from the stored energy of the synchronous generators, as a result the speed of the machine goes down and the system frequency decreases.

(ii) "Released" customer load i.e., the reduction in the effective 'old' load. Since the frequency of the system decreases, the speed of the various motors decreases and hence the effective 'old load' decreases. Thus allowing the already available generation to partly meet the load demand.

(iii) Increased generation: The reduction in system frequency actuates the speed governing system of the generating units which then increases the input to the prime movers causing increased generation which subsequently arrests a further drop in frequency. The units behave coherently, maintaining thereby equal frequency deviations among them. Initially corresponding to synchronous speed the last two components are zero and as the speed decreases, they contribute to the increased generations. However, it is to be noted that the contribution due to the last two factors is very small and the major contribution is due to the increased generation due to governor action.)

CHAPTER 3
MODEL DEVELOPMENT

3.1 Load Frequency control

The operational objectives of load frequency control (LFC) are to maintain reasonably uniform frequency to divide the load between generators and the change in real power is sensed. . The error signal ΔF and ΔP are amplified, mixed and transformed into a real power command signal ΔPv which is sent to the prime mover to call for an increment in torque. The prime mover therefore brings change in generator output by an amount ΔPg will change the frequency and ΔPtie within the specified tolerance.

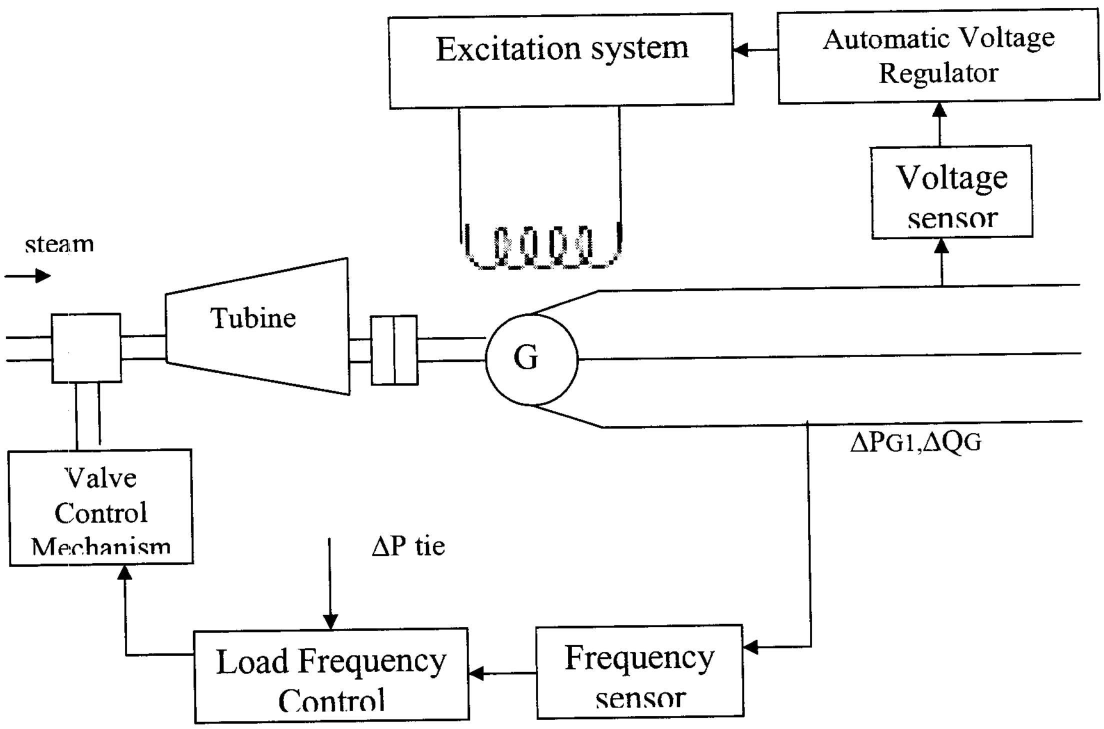


Fig3.1Schematic Diagram of LFC and AVR of a Synchronous Generator

In large interconnected system the manual regulation is not feasible and therefore load frequency equipment is installed for each generator. Similarly for voltage control also voltage regulation equipment is installed on each generator. Fig gives the schematic diagram of load frequency control and automatic voltage regulator of a synchronous generator. The controllers are set for a particular operating condition and they take care of small changes in load demand without voltage and frequency exceeding the pre-specified limit. If the operating conditions change materially the controller must rest either manually or automatically.

Small changes in real power are meanly depending on changes in rotor angle δ and thus the frequency. The reactive power is mainly dependent on the voltage magnitude (i.e. on the generator excitation). The excitation system time constant is much smaller than the prime mover time constant and its transient decay much taster and does not affect the LFC Loop and AVR Loop is negligible and the load frequency excitation voltage control are analyzed independently.

3.1.1 Mathematical Modeling

The first step in analysis and design of control system to Mathematical modeling of the system. The two most common methods are transfer function method and state variable approach. The state variable approach can be applied to portray linear as well as nonlinear systems. In order to use the transfer function and linear state equations the system must first be linearised. Proper assumptions and approximations are made to linearise the mathematical equations describing the system and a transfer function model is obtained for the following components.

3.1.2 Generator Model

Applying the swing equation of a synchronous machine we have

$$\frac{2H}{ws} \frac{d^2\Delta\delta}{dt^2} = \Delta Pm - \Delta Pe \qquad \text{........................} \quad 3.1$$

or in terms of small deviation in speed

$$\frac{2H \frac{w}{ws}}{Ws} = \frac{1}{2H} (\Delta Pm - \Delta Pe) \qquad \ldots\ldots\ldots\ldots \quad 3.2$$

With the speed expressed in per unit, without explicit per unit notation we have

$$\frac{D\Delta w}{dt} = \frac{1}{2H} (\Delta Pm - \Delta Pe) \qquad \ldots\ldots\ldots\ldots \quad 3.3$$

Taking laplace transform we obtain

$$\frac{D\Delta w}{dt} = \frac{1}{2H} (\Delta Pm - \Delta Pe) \qquad \ldots\ldots\ldots\ldots \quad 3.4$$

Taking laplace transform of 3.4 we obtain

$$\Delta\Omega(s) = \frac{1}{2Hs} [\Delta Pm(s) - \Delta Pe\,(s)] \qquad \ldots\ldots\ldots\ldots \quad 3.5$$

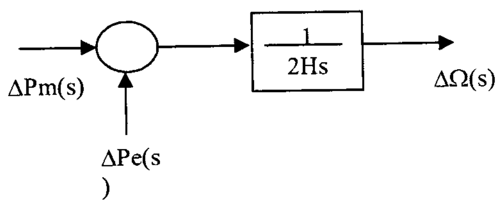


Fig 3.2 Generator Block Diagram

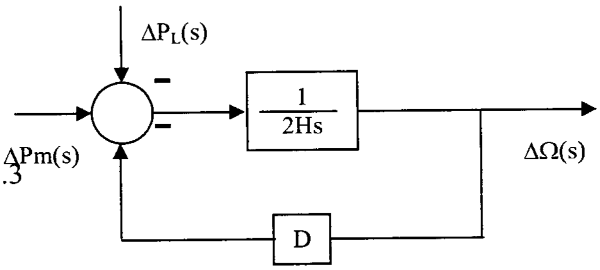
3.1.3. Load Model

The load on a power system consists of a variety of electrical devices. For resistive loads, such as lighting and heating loads, the electrical power is independent of frequency. Motor loads are sensitive to changes in frequency. How sensitive it is to frequency depends on the composite of the speed – load characteristics of all the driven devices. The speed – load characteristics of a composite load is approximated by

$$\Delta Pe = \Delta P_L + D\Delta w \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 3.6$$

Where ΔPl is the non-frequency – sensitive load change and $D\Delta w$ is the frequency sensitive load change D is expressed as percent change in load divided by percent change in frequency. For example if load is changed by 1.6 percent for a 1 percent change in frequency then D=1.6. Including the load model in the generator block diagram results in the block diagram eliminating the simple feedback loop fig. 3.3 results in block diagram as shown in fig 3.4

Fig3.3



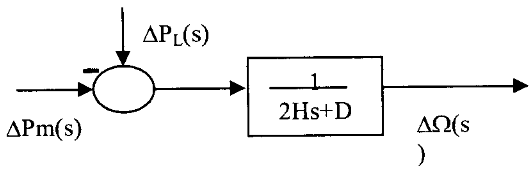


Fig 3.4 Generator and load block diagram

3.1.4 Prime mover Model

The source of mechanical power, commonly known as the prime mover, may be hydraulic turbine at waterfalls, steam turbines whose energy comes from burning of coal, gas, nuclear fuel, and gas turbine. The Model for the turbine relates changes in mechanical power output ΔPm to changes in steam valve position ΔPv. Different types of turbines vary widely in characteristics. The simplest prime mover model for the non-reheat steam turbine can be approximated with a single time constant τ_T resulting in following transfer function

$$G_T(s) = \frac{\Delta Pm(s)}{\Delta Pm(s)} = \frac{1}{1+\tau+s} \qquad \text{........................} \quad 3.7$$

The block diagram for a simple turbine is shown in Fig 3.5

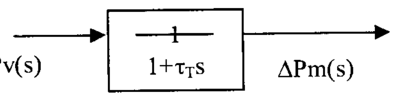


Fig 3.5 Block diagram for a simple nonreheat steam turbine.

The time constant τ_T is in the range of 0.2 to 2.0 seconds

3.1.5 Governor Model

When the generator electrical load is supplied is suddenly increased the electrical power exceeds the mechanical power input. The power deficiency is supplied by the kinetic energy stored in the rotating system. The reduction in kinetic energy causes the turbine speed and the generator frequency to fall. The change in speed is sensed by turbine governor, which acts to adjust the turbine input valve to change mechanical power output to bring the speed to new steady state. The earliest governors were the watt governors which sense the speed by means of rotating fly balls and provides mechanical motion in response to speed changes Fig 3.6 shows schematically the essential elements of conventional watt governor which consists of following major parts.

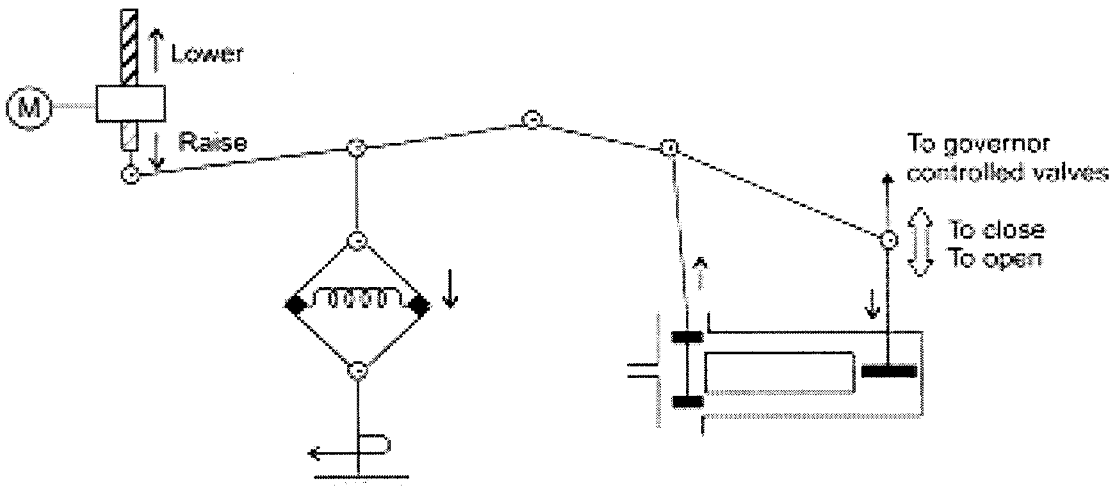


Fig 3.6Speed Governing System

1.Speed Governor

The essential part is centrifugal fly balls driven directly or through gearing by turbine shaft. The mechanism provides upward and downward movements proportional to change in speed.

2. Linkage mechanism

These are links for transforming the flyballs movement to the turbine valve through a hydraulic amplifier and providing a feedback from turbine valve movement.

3. Hydraulic Amplifier

Very large mechanical forces are needed to operate the steam valve. Therefore the governor movements are transformed into high power forces several stages of hydraulic amplifiers.

4. Speed changer

The speed changer consists of a servomotor, which can be operated manually or automatically, or scheduling load at normal frequency.

By adjusting this set point a desired load dispatch can be scheduled at nominal frequency. For stable operation the governors are designed to permit the speed to drop as the load is increased. The steady state characteristics of such a governor is shown in fig 3.7

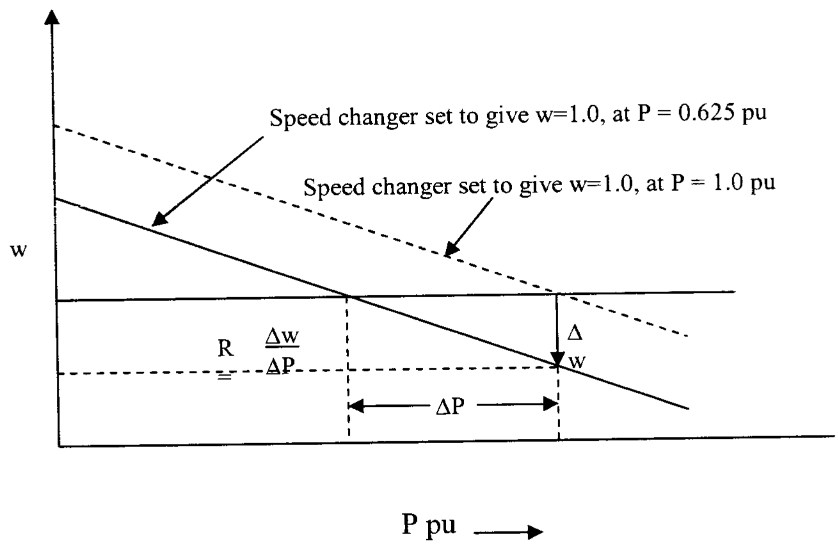


Fig 3.7 Governor steady state Characteristics

The slope of the curve represents the speed regulation R. Governors typically have a speed regulation of 5 – 6 percent from zero to full load. The speed governor mechanism acts as a comparator whose output ΔP_g is the difference between the reference set power ΔPref and the power 1/R(Δw) as given from the governor speed characteristics i.e.

or in δ domain

$$\Delta P_g(s) = \Delta Pref(s) - \frac{1}{R} \Delta\Omega(s) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 3.8$$

The command ΔP_g is transformed through the hydraulic amplifier to the steam valve position command ΔP_v. Assuming a linear relationship and considering a sample time constant τ_g we have the following δ domain relation.

$$\Delta Pv(s) = \frac{1}{1+\tau_g} \Delta\Omega(s) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 3.9$$

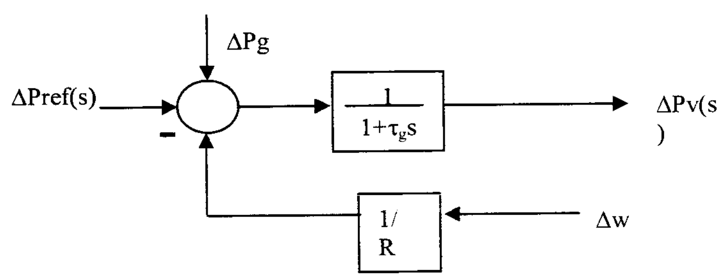


Fig 3.8block diagram representation of speed governing system for steam turbine

Equations 3.8 and 3.9 are represented by block diagram shown in fig 3.8. The complete block diagram of the load frequency control of an isolated power station shown in fig 3.9 with the load

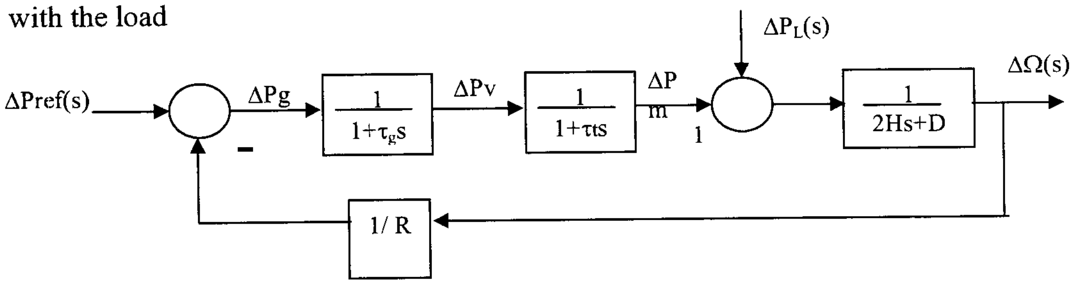


Fig 3.9Load frequency control block diagram of an isolated power system.

Change - ΔPL(s) as the input and frequency deviation ΔΩ(s) as the output results in the block diagram shown in fig 3.10. is

$$KG(s)H(s) = \frac{1}{R} \frac{1}{(2H_s+D)(1+\tau_g s)(1+\tau_t s)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad 3.10$$

And the closed loop transfer function relating the load change ΔP_L to the frequency deviation $\Delta\Omega$ is

$$\frac{\Delta\Omega(s)}{-\Delta P_L(s)} = \frac{(1+\tau_g s)(1+\tau t s)}{(2H_s+D)(1+\tau_g s)(1+\tau\, t\, s) + 1/2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad 3.11$$

$$\Delta\Omega(s) = -P_L(s)T(s) \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad 3.12$$

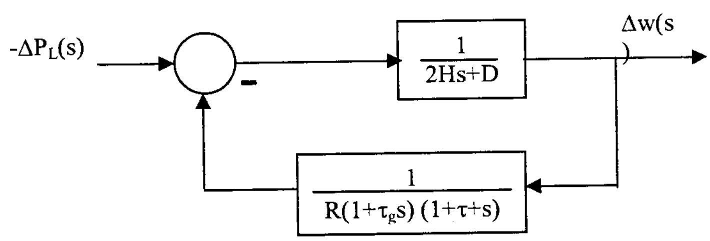


Fig 3.10 .LFC block diagram with input $\Delta P_L(s)$ and output $\Delta\Omega(s)$

The load change is step input i.e. $\Delta P_L(s) = \Delta PL/s$ utilizing the final value theorem the steady state value Δw is

$$\Delta w_{ss} = \lim_{S \to 0} S\Delta\Omega(s) = (-\Delta P_L) \frac{1}{D + 1/R} \qquad \ldots\ldots\ldots\ldots\ldots\ldots 3.13$$

It is clear that for the cause with no frequency sensitive load (i.e. with D=0) the steady state deviation in frequency is determined by governor speed regulation and is

$$\Delta w_{ss} = (-P_L)R \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad 3.14$$

When several generators with governor speed regulation $R_1, R_2, \ldots\ldots\ldots\ldots R_n$ are connected to the system, the steady state deviation is given by

$$\Delta w_{ss} = (-\Delta P_L) \frac{1}{D + 1/R_1 + 1/R_2 + \ldots + 1/R_n} \quad \ldots\ldots\ldots\ldots\ldots 3.15$$

The closed loop transfer function of the control system with only $-\Delta P_L$ is input become

$$\frac{\Delta\Omega(s)}{-\Delta P_L(s)} = \frac{s\,(1+\tau_g s)\,(1+\tau\, t\, s)}{s\,(2H_s + D)\,(1+\tau_g s)\,(1+\tau\, t\, s) + K_I + S/R} \quad \ldots\ldots\ldots\ldots 3.16$$

CHAPTER 4

AUTOMATIC GENERATION CONTROL

When the load in the system increases turbine speed drops before the governor can adjust the input. As the change in the value of speed decreases the error signal becomes smaller and the positions of governor value get close to the required position, to maintain constant speed. However the constant speed will not be the set point and there will be on offset, to overcome this problem an integrator is added which is automatically adjusted the generation to restore the frequency to it's normal value. This scheme is called automatic generation control (AGC).

The role of AGC is to divide the loads among the system, station and generator to achieve maximum economy and accurate control of the schedule interchanges of the line power while maintaining a reasonably uniform frequency. The synchronization of different system to inter connected system depends upon (1) voltage magnitude (2) Frequency (3) phase sequence. Any wide variation from nominal value of frequency and voltage will lead the system to total collapse. Hence AGC has gained importance with the growth of interconnected systems and with rise in size of interconnected system automation of the control system have aroused. A number of control strategies exist to achieve better performance. Due to non-linearity of power system, system parameters are linearized around an operating point. PI controller is generally used. The gain value is adjusted for satisfactory transient response.

Controlling the mechanical power output of a prime mover such as steam turbine, or water turbine controls the power delivered by a generator. The mechanical power is controlled by opening and closing valves regulating steam or water flows.

Since the load of the power system is always changing load in order to maintain the power balance. This is commonly referred to as the unit on regulation. If then load increases the generated power must increase. This steam and /or water valves must open wider. If the load decreases, generation must also decrease and this requires valve opening to be smaller. The way we sense the power imbalance is through it's effect on generator speeds and/or frequency. Thus if there is excess generation the generator sets will tend to speed up and frequency will rise. If there is deficiency of generation, the generator speeds and frequency will drop. These deviations from nominal speed and/or frequency are used as control signals to cause appropriate value action automatically. The control function in the case is provided by the governor mechanism. This is referred to as primary control

4.1 AGC IN THREE AREA SYSTEM

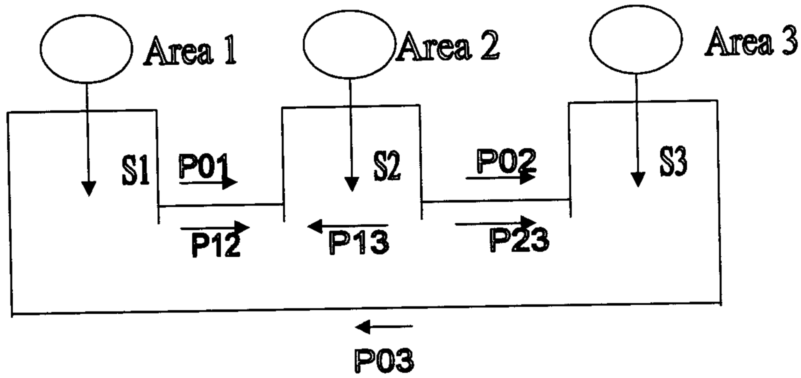


Fig4.1 Three-area delta connected system

The system consisting turbine, generator, load and its accessories as shown in fig (4.1) the typical values of each constant are given in table . Assumption made while developing the block diagram is that there are no generation rate constraints on turbines and generators. Also, generators in a sub areas are tightly coupled together so as to form coherent group i.e, all generators responds in unisons to changes in load changer settings. Such a coherent area is called control area, in which frequency is assumed to be constant during static and dynamic conditional. For the purpose of developing a suitable control strategy, a control area can be reduced to a single speed governor, turbo-generator and load system

An extended power system can be divided into a number of load frequency control area interconnected by means of tie line. The control objective now is to regulate the frequency of each area and simultaneously regulate the tie line power as per inter-area power contracts it is conveniently assumed that each control area can be represented by an equivalent turbine, generator &governor system. Symbols used with suffix "1" "2" &"3" referring area "1" "2" &"3" respectively. The tie line transports power in and out of an area, this is accounted for in incremental power balance equation of each area

Where incremental tie power can be represented as

$\Delta Ptie = T12(\Delta\delta 1 - \Delta\delta 2)$

$\Delta Ptie = 2\,\Pi T12[\int f1dt - [\int f2dt]$

$ACE1 = \Delta Ptie12 + B1\Delta f1$

$ACE2 = \Delta Ptie23 + B2\Delta f2$

$ACE3 = \Delta Ptie31 + B3\Delta f3$

The change in frequency, area control error (ACE) will be redefined as a linear combination of incremental frequency and tie line power thus For the study 3 areas connected in delta connection as shown in fig 4.1

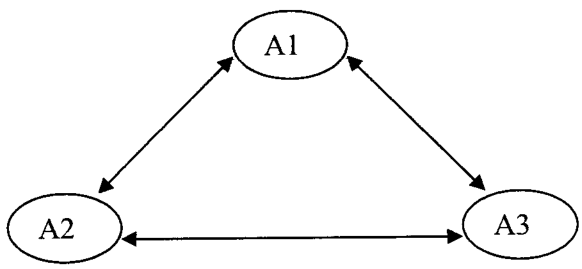
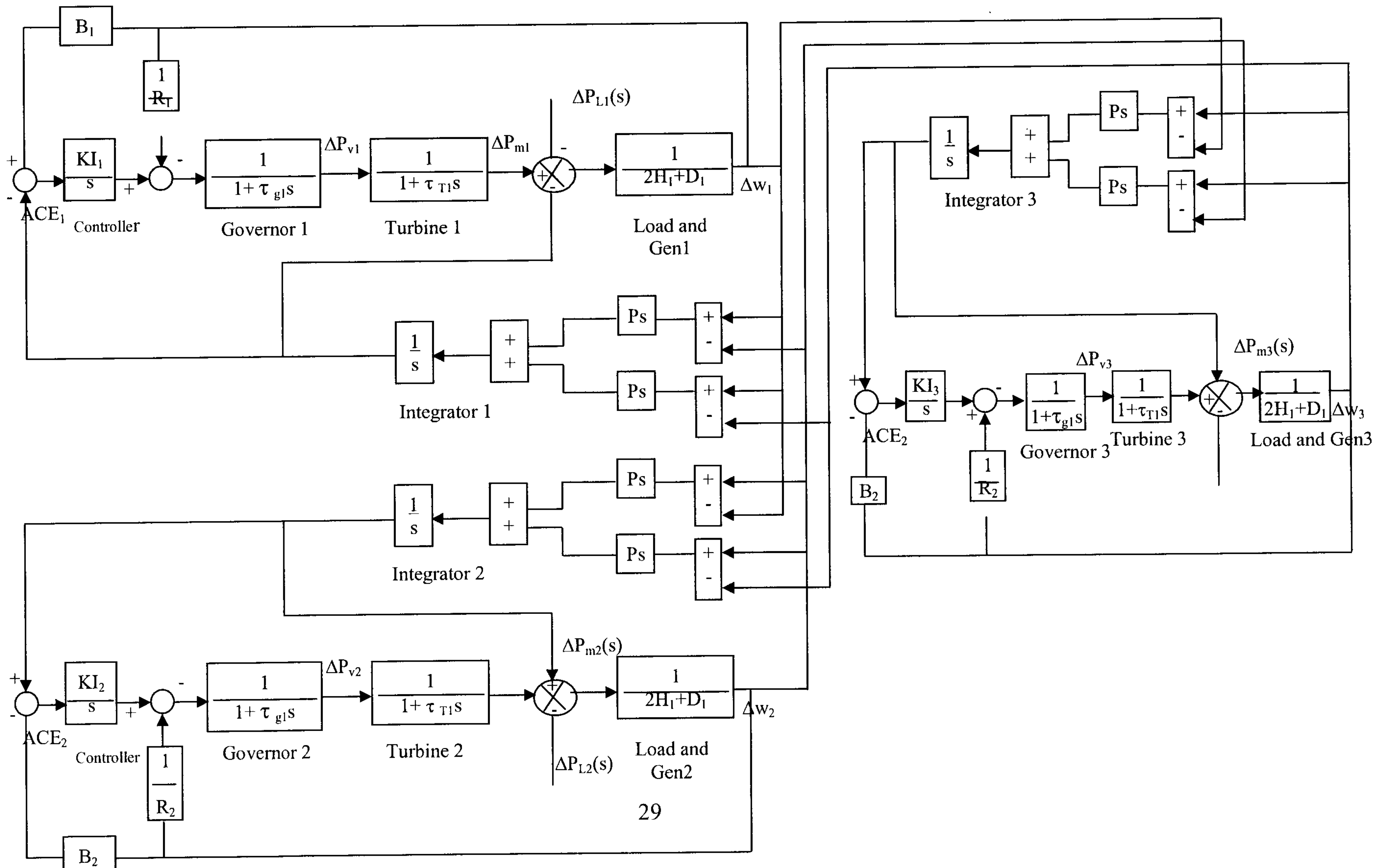


Fig4.2 System of study

This system was loaded in systematic way and their effect on frequency in the ACE was studied. On introducing PI controller the frequency change was also studied .

Fig 4.3 ..BLOCK DIAGRAM OF AGC IN A THREE-AREA SYSTEM



CHAPTER 5

RESPONSE OF AGC USING FUZZY CONTROLLER

Interconnection between power utilities and areas, from an important pan in the overall power system and they contribute greatly to increase the reliability of supply and economy of the power production in order to study power system dynamics under various disturbance conditions, it is desirable to model an interconnected power system in the laboratory.

For carrying out study a 3 area closed delta connection system with unknown deterministic power demand has been transformed into mathematical model and simulated. Usually output error and derivative error are selected as controller inputs.

5.1 FUZZY LOGIC

Fuzzy logic is super-set of Boolean logic, which has been extended to allow partial truths. This means that it can handle things, which are neither completely true nor completely false. Fuzzy interference system has been successfully applied in fields such as automatic control, data classification, and decision analysis, export systems and computer vision.

Some of terms that are used in fuzzy sets are Degree of membership which is defined as how much of member the fuzzy subset f at a set s is Ao responses complete non membership and 1 represents complete membership. Any numbers in between represent how much of member f is of s. Membership function is the mapping of the values of a set s onto the range [-1,1].

Fuzzy logic implemented in three phases.

1. Fuzzification (crisp input to fuzzy set mapping)
2. Inference (Fuzzy rule generation)
3. Defuzzification (Fuzzy to crisp output transformation)

5.1.1 Fuzzification

Establishes the fact base of the fuzzy system. First it identifies the input and output of the system. Fuzzification then defines appropriate IF THEN rules and uses raw data to derive a membership function. At this point, one is ready to apply fuzzy logic to the system. In the first fuzzy logic phase – fuzzification – actual measured input values are mapped into fuzzy membership functions. The fuzzification can be logical, Normalization or knowledge based.

5.1.2 Inference

The next step is to define the fuzzy rules. The fuzzy rules are mearly a series of if-then statements as mentioned above. These statements are usually derived by an expert to achieve optimum results. An inputs are received by the system interference evaluated all IF THEN rules and determines the truth-values. If a given input does not precisely correspond to an IF THEN rule then partial matching of input data is used to incorporate an answer.

The logical products for each rule must be combined or inferred before being passed on to the defuzzification process for crisp output generation, several interference method exist.

5.1.3 Defuzzification

Combines all fizzy conclusions obtained by interference into a single conclusion. Different fuzzy rules have different conclusion. So it is necessary to consider all rules. There are number of composition methods are available but they lie beyond the scope of this introduction.

The different defuzzification methods are

1) Maximum of Maximum.
2) Sum of Maximum
3) Center of Gravity

4) Smallest of Maximum

5) Mean of maximum.

5.1.4 Tuning and System Enhancement

Tuning the system can be done by changing the rule antecedents or conclusions, changing the centers of the input / or output functions such as low, medium and high levels of "error-dot" output response. Those new levels would generate additional rules and membership functions which would overlap with adjacent functions forming longer "mountain ranger" of functions and responses. These techniques for doing this systematically are a subject unto itself.

5.1.5 Fuzzy Logic Tool box

This package has two general methods, which may be used for fuzzy interference.

1. The Mamdani form of fuzzy rules where the right hand side of each rule is a fuzzy set. The rules are evaluated using one of variants of mamdani interference
2. The mamdani fuzzy rules where right hand side is either a constant (zero-order) or a more general functions of the inputs. The results are combined using a weighed average.The FIS editor displays a menu bar that allows you to open related rules.

Five pops up menus are provided to change the functionality of five basic steps in fuzzy implication process. They are a) And Method, 2) Or method, 3) Implication Method, 4) Aggregation Method and 5) Defuzzification Method.

5.2 Steps of designing of a Fuzzy Controller

Step 1: First step is to determine the input variables and determine the degree to which they belong to each of appropriate fuzzy set in a membership function. The input δ are always a crisp numerical value limited to universe of discourse of the input variable and the output is fuzzy degree of membership in qualifying linguistic set. There are seven linguistic variables namely ZE – zero error, NV – Negative large value, PV – positive large value, NS – Negative small value, PS – Positive small value. Each linguistic variable has a fuzzy membership function. The membership function is shown in fig (5.1a,5.1b,5.1c) for the crispness the membership functions are symmetrical and each one overlaps the adjacent one by 50% as shown in fig for our study we have the and Ptie of each area as input variable.

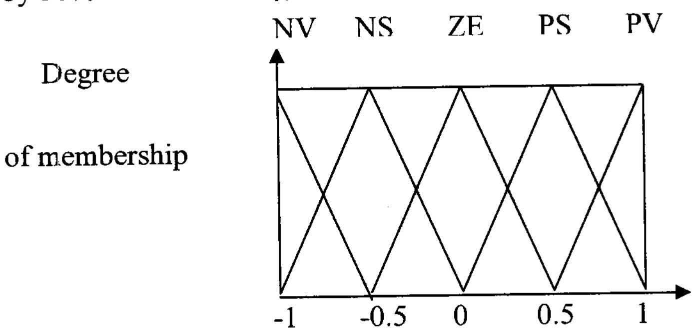


FIG 5.1a Membership function for del F

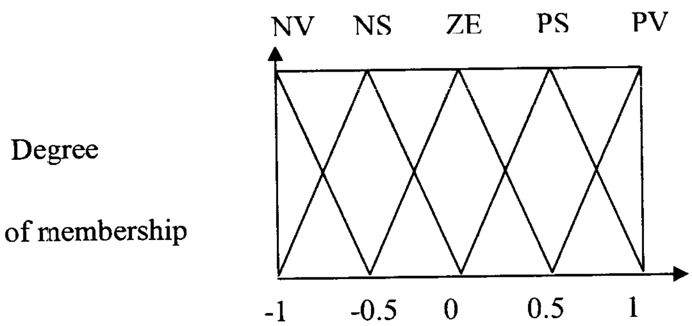


Fig 5.1b Membership function of del Ptie

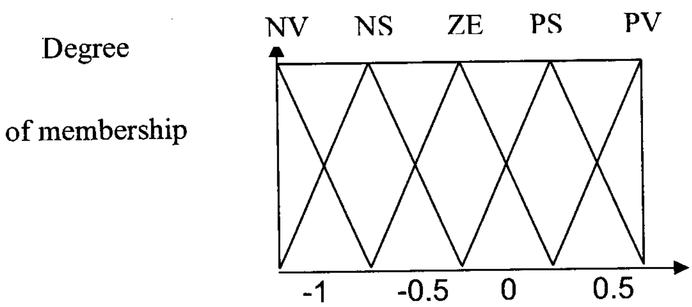


fig 5.1 c Membership function of control signal

Membership functions are defined for f and in the range of –1 to +1. Membership function was defined for P tie taken in the same range.

Step 2: Once the inputs have been fuzzified we know the degree to which each port of the antecedent has been satisfied for each rule. If the antecedent of a given rule has more than one part. The fuzzy operator is applied to obtain one number that represent the results of the antecedent for that rule. This number will then be applied to output function. For the study "OR" method supported by

Table 5.1 Rule base of fuzzy element

CHANGE IN FREQUENCY del f	CHANGE IN TIE LINE POWER del ptie				
	NV	NS	ZE	PS	PV
NV	NV	NV	NV	NS	ZE
NS	NV	NV	NS	ZE	PS
ZE	NS	NS	ZE	PS	PS
PS	NS	ZE	PS	PV	PV
PV	ZE	PS	PV	PV	PV

'Maximum' and probabilistic method that is knows as the algebraic sum was applied while framing the rules. Totally 25 rules are trained for study.

Step 3: Every rule has a weight (a number between 0 and 1) that is applied to the number given by the antecedent funereally this weight is 1 so it has no effect at all on the implication process.

Step 4: Aggregation is the process by which fuzzy sets that represents the output of each rule are combined into a single fuzzy set. The input of aggregation process for each rule. The three methods for study are (a) Maximum (b) Probabilistic (c) sum.

Step 5: The final desired output each variable is generally a simple number. However the aggregate of a fuzzy set encompasses a range of output value. Which is defuzzified in order to resolve a single output value from the set. The five different methods are

(a) Centroid

(b) Bisector

(c) Middle of maximum

(d) Largest of maximum

(e) Smallest of maximum.

CHAPTER 6

SIMULATION

At the MATLAB prompt, typing SIMULINK the SIMULINK BLOCK appears. The SIMULINK block library containing seven icons and five pull down heads appears. Each icon contains various components in a titled category. To see the content of each category double click on it's icon. The easy to use pull down menus allow to create a SIMULINK block diagram or open an existing file, perform the simulation and make any modifications. Basically one has to specify the model of the system (state space, discrete, transfer functions, non linear ode's etc) the input (source) to the system, and where the output of the simulation of the system will go. Generally when building a model, add the blocks to the model window before adding the lines that connect them.

SIMULINK is an interactive environment for modeling, analyzing and simulating a wide variety of dynamic systems. SIMULINK provides a graphical user interface for constructing block diagram models using "drag and drop" operations. A system is configured in terms of block diagram representation from a library of standard components. SIMULINK is very easy to learn. A system in block diagram representation is built easily and simulation results are displayed quickly.

Simulation algorithms and parameters can be changed in the middle of the simulation with intuitive results thus providing the user with ready access learning tool for simulating many of operational problems found in the real world. SIMULINK is particularly useful for studying the effects of nonlineritres on the behavior of the system, and such, tit also an ideal research tool. The key features of simulink are

- Interactive simulations with live display.
- A comprehensive block library for creating linear, non linear, discrete or hybrid multi-input / output systems.
- Seven integration methods for fixed step, variable step and stiff systems.

- Unlimited hierarchical model structure.
- Scalar and vector connections.
- Mask facility for creating custom blocks and block libraries. SIMULINK provides an open architecture that allows extending the simulation environment.
- We can easily perform "What if" analyses by changing model parameters – either interactively or in batch mode. While the simulation are running.
- Creating customs blocks and block libraries with own icons and user interfaces from MATLAB
- The C code can be generated from SIMULINK models for embedded applications and for rapid prototyping of control systems.
- We can create hierarchical models for embedded applications and for rapid prototyping of control systems.
- SIMULINK provides immediate access to the mathematical, graphical and programming capabilities of MATLAB. We can analyze data, automate procedures and optimize directly from SIMULINK.
- The advanced design and analysis capabilities of the toolboxes can be executed from with a simulation using mask facility in SIMULINK.
- The SIMULINK block library can be extended with special – purpose block sets. The DSP block set can be used for DSP algorithm development, while the fixed point block set extends SIMULINK for modeling and simulating digital control systems and digital filters.

SIMULATION PARAMETERS

The simulation parameters are set. The solver is selected by choosing parameters from the simulation menu. SIMULINK displays the simulation parameters dialog box, which uses three pages to manage simulation parameters. Solver, workspace I/O, and diagnostics.

SOLVER PAGE

The solver page appears when choosing parameters from simulation menu or when selecting the solver tab. The solver page allows to.

- Se the start and stop times I/O. The start time and stop time for the simulation can be changed by entering new values in start time and stop time fields. The default start time is 0.0 seconds and default stop time is 10-0 seconds.

- Choose the solver and specify solver parameters. The default solver provides accurate and efficient results for most problems. Some solver may be more efficient than others at solving a particular problem. We can choose between variable step and fixed solvers can modify their step sizes during simulation. These are m ode 45-ode 23, ode 113, ode 158, ode 235 and discrete. The default is ode 45 for variable step solver we can set the maximum and suggested initial step size parameters. By default, these parameters are automatically determined indicated by value auto. For fixed sep solvers, choose ode 5, ode 4, ode 3, ode 2, and ode 1 and discrete.

REVERT: Change the parameter values back to the values they had when the dialog box was most recently opened and applies the parameters.

HELP:Displays help text for the dialog box page. Parameter

CLOSE: Applies the values and closes the dialog box. During a simulation the parameter values are applied immediately.

To stop a simulation choose step from the simulation menu. The keyboard shortcut for stopping a simulation is ctrl –T. We can suspend a running simulation by choosing pause from the simulation menu. When select pause, the menu item changes to continue. Proceed with a suspend simulation by choosing continue.

Output Options

The output options area of the dialog box enables to control how much output the simulation generates. We can choose from three pops up options. Those are Refine output, produce additional output, and produce specified output only.

Workspace I/O Page

The workspace I/o page manages the input from and the output to the MATLAB workspace and allows.

- Loading input from the workspace – Input can be specified either as MATLAB command or as a matrix for the import blocks.
- Saving the output to the workspace, by specifying return variables by selecting the time, state, and/or output check boxes in the save to workspace area.

DIAGNOSTIC PAGE

The diagnostic page allows selecting the level of warning messages displayed during simulation.

The Simulation Parameters Dialog Box

Table below summarizes the action performed by the dialog box

Button	Action
Apply	- Applies the current parameter values and keeps the dialog box open. During a simulation the parameter values are applied immediately.

auxiliary induction motor drives of generating units ingenerating stations and large ac drives of various industries in very large-scale interconnected system

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6.1 SIMULATION COMPARING PI AND FUZZY CONTROLLER

The simulation is performed using MATLAB 6.5 using various parameters and tools. By interconnecting the tie line areas the following block diagram is obtained.

Here the change in power and the frequency are the two input variables. These input variables are taken from the output by feedback. The input variables are change in number. They are always crisp values.

The overall system connections and assumed tie line power are simulated. The automatic generation control of these closed loop control system minimizing the area control errors (ACE) so that the system and tie line interchanges are maintained at their scheduled values. The system simulated by varying the loads of area1, area2 and area3. The load variation may be as follows

Here the interconnection of governor1, turbine1, generator1, load is denoted as area1.similarly three areas constructed. Each area loaded separately. The load is varied equally, unequally, with small changes and with large changes as shown below.

Case1: equal load (p.u)
Case2: unequal load with small changes (p.u)
Case3: unequal load with moderate changes (p.u)
Case4: unequal load with large changes (p.u)

This is clearly shown in table1 in appendices

The variation in load causes change in frequency in generation side. Similarly the power changes. This change in frequency and tie line power are feedback to the input side ie to the PI controller. The operation of the PI controller reduces the error.

- If the load increases the power generated increases, which cause the frequency to decrease. This decrease in frequency is sensed by the sensor and send load frequency controller (here PI and fuzzy controller) through a close path.
- The PI controller controls the prime mover valve to open.ie the gain value is adjusted .
- Now the valve of the prime mover is controlled in such a way to allow require amount of steam to be passed on to the generator.
- The frequency is now comes to normal value.
- Different loads are given to generator and simulated.
- The results are shown in appendices table 3
- Table 2 shows the parameters given to the governor, turbine and generator

Simulation using fuzzy controller:

Here the PI controller is replaced by a fuzzy controller and system performance studied. Rules are developed. IF –THEN logic is used to develop the rules. Rule viewer shown in appendices

The simulation results are as shown in fig that fuzzy controller is too fast in settling the frequency deviation to zero.

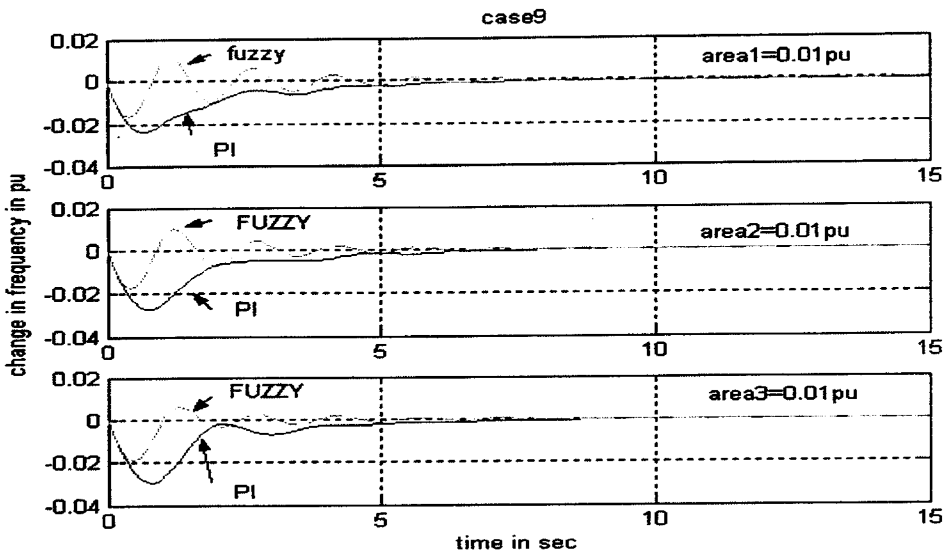

Fig 6.1aSimulation result for unequal loads using PI and FUZZY controller

Here the load is varied equally in three areas. The load is taken as 0.01 pu. The graphs are indicated by separate colors. i.e. blue indicates the operation result using PI controller and green indicates the operation result using fuzzy controller.

Table 6.1 shows the simulation workspace readings. From the table the three area loaded equally and unequally and the settling time is noted. The settling time is noted by simulating using PI and FUZZY controller.

The change in frequency settles to zero at T_s=12 sec using PI controller and it settles to zero at Ts=7.5 sec using fuzzy controller at area1

The change in frequency settles to zero at Ts=10 sec using PI controller and it settles to zero at Ts=9 sec using fuzzy controller at area2

The change in frequency settles to zero at Ts=12.5sec using PI controller and it settles to zero at Ts=10.5 sec using fuzzy controller at area3

Similarly the load varied as in TABLE 1 in APPENDICES and simulated.

Some of results are shown below

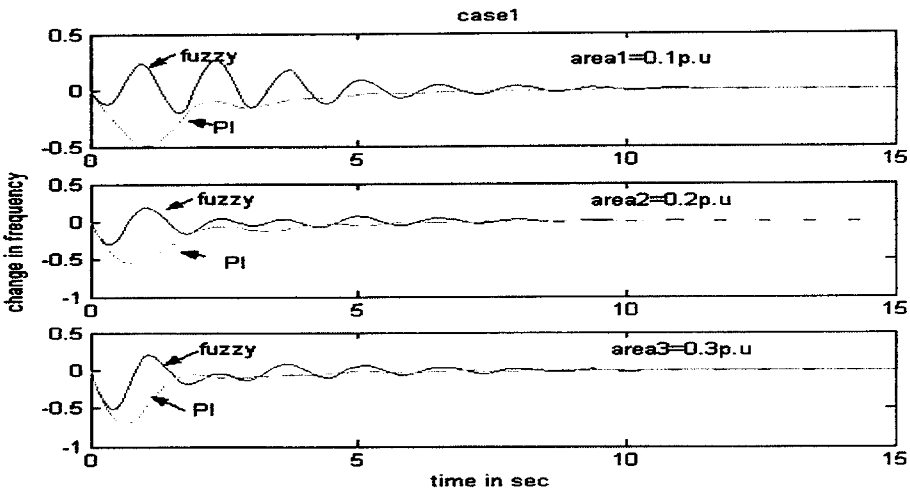

Fig 6.1 Simulation result AGC for unequal load variation with small changes (Area 1 is loaded 0.1 pu area2 is loaded 0.2 pu area3 is loaded 0.3 pu)

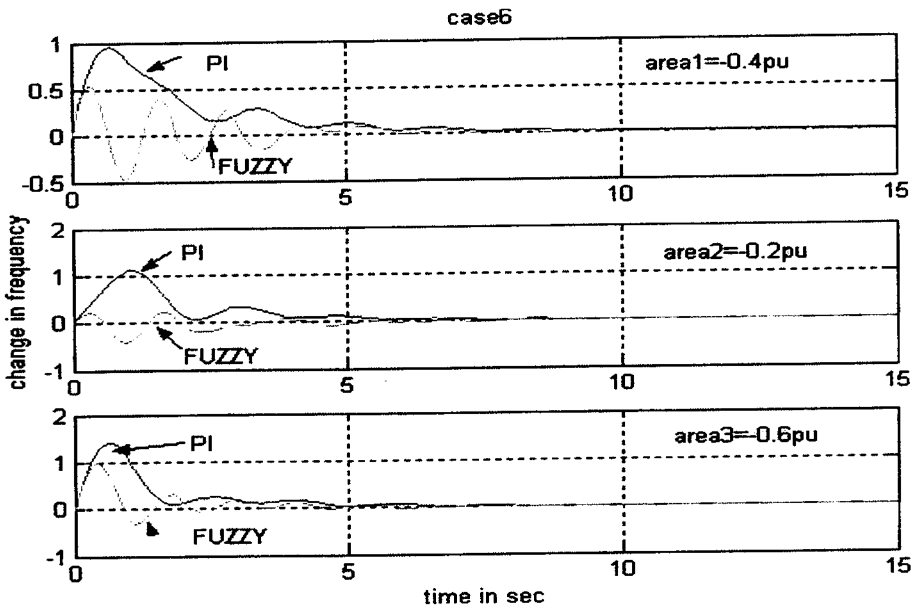

Fig 6.1c Simulation result for unequal load with moderate changes

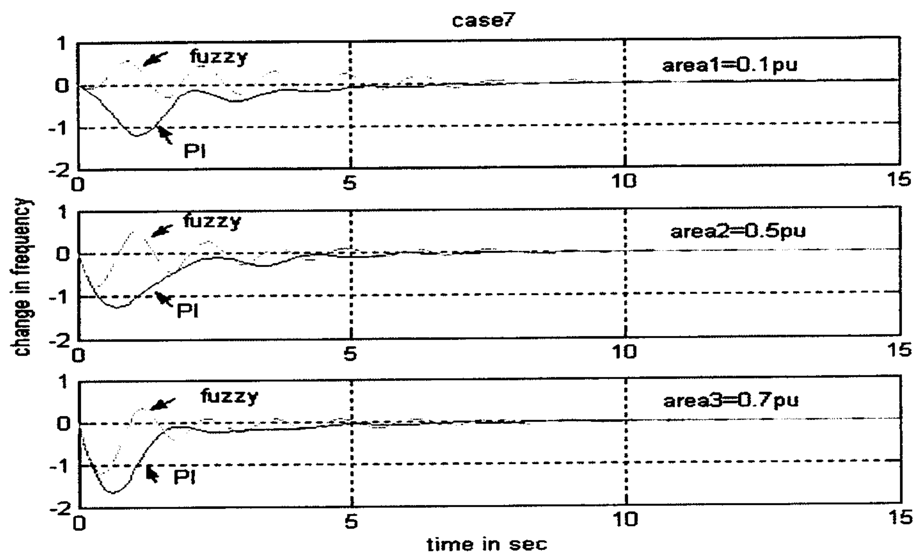

Fig 6. 1d Simulation result for unequal load with large changes

The computer simulation was performed for different load changes in different areas. Some of the results are shown below

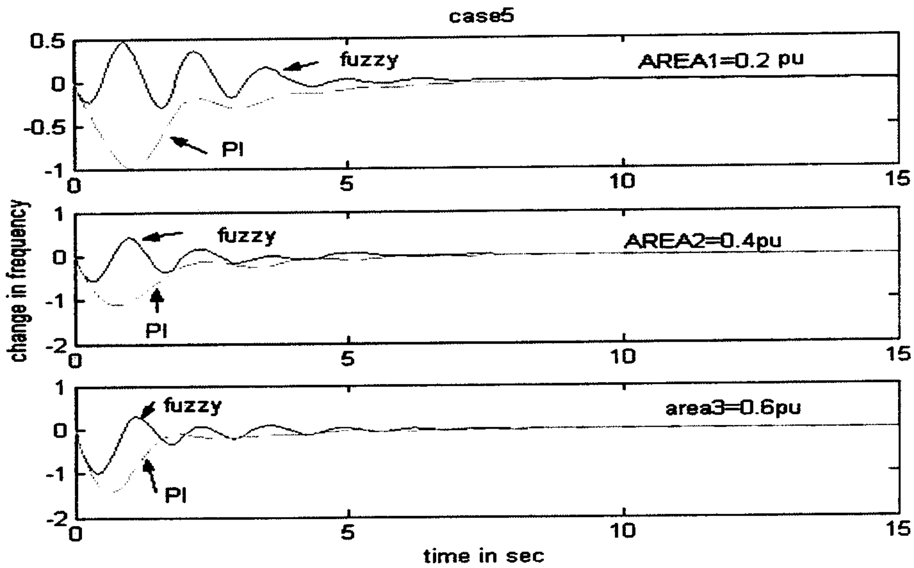

Fig 6.1e Simulation result for Load varied unequally with moderate changes in three areas

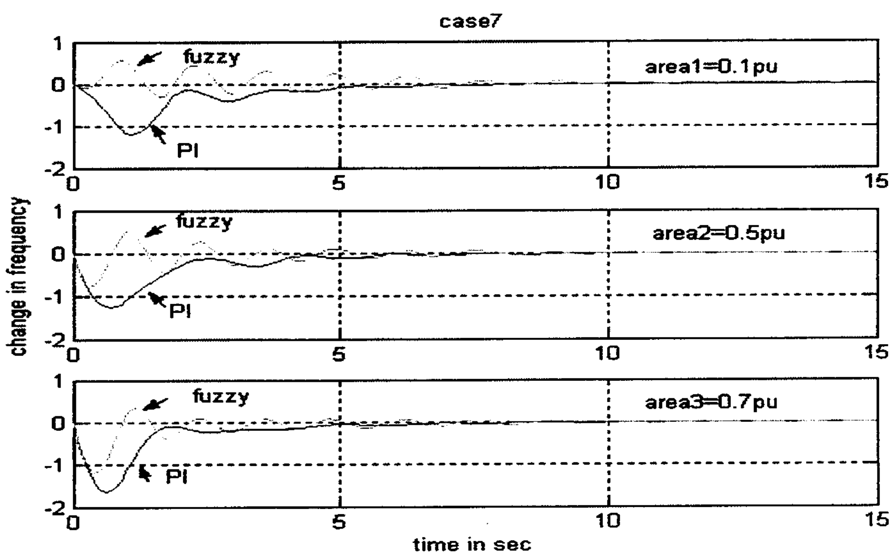

Fig 6.1f load varied Unequally with large changes in value(area1 loaded to 0.1 pu., loaded to 0.5 p.u area 3 loaded to 0.7 pu)

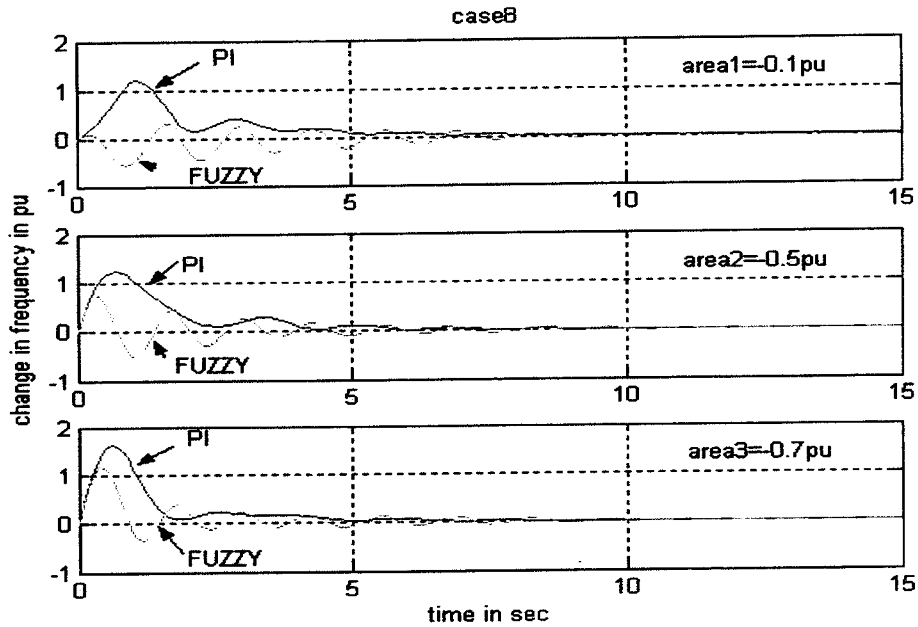

Fig 6.1g load varied Unequally with large changes in value(area1 loaded to -0.1 pu., area loaded to - 0.5 p.u area 3 loaded to - 0.7 pu)

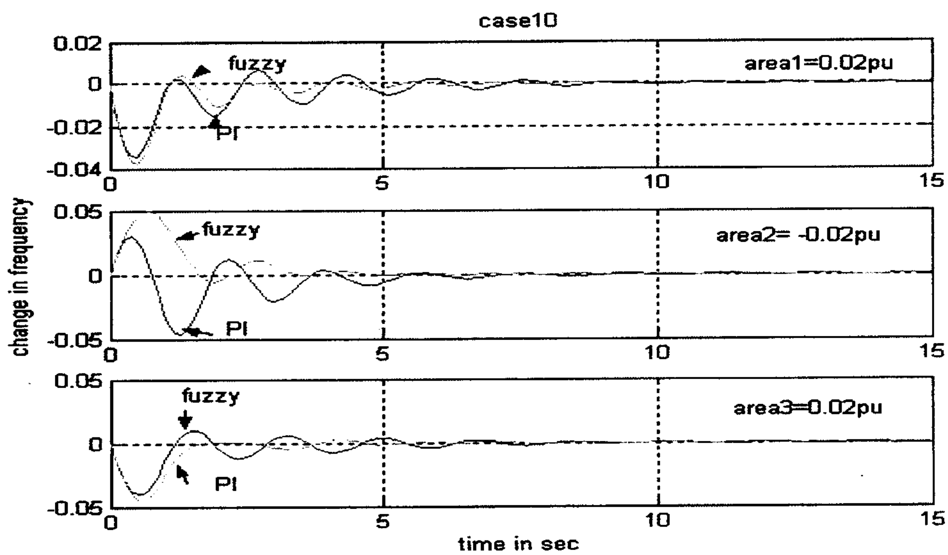

Fig6.1h load varied equally (area1 loaded to 0.02 pu., area 2 loaded to – 0.02 p.u area 3 loaded to +0.02 pu)

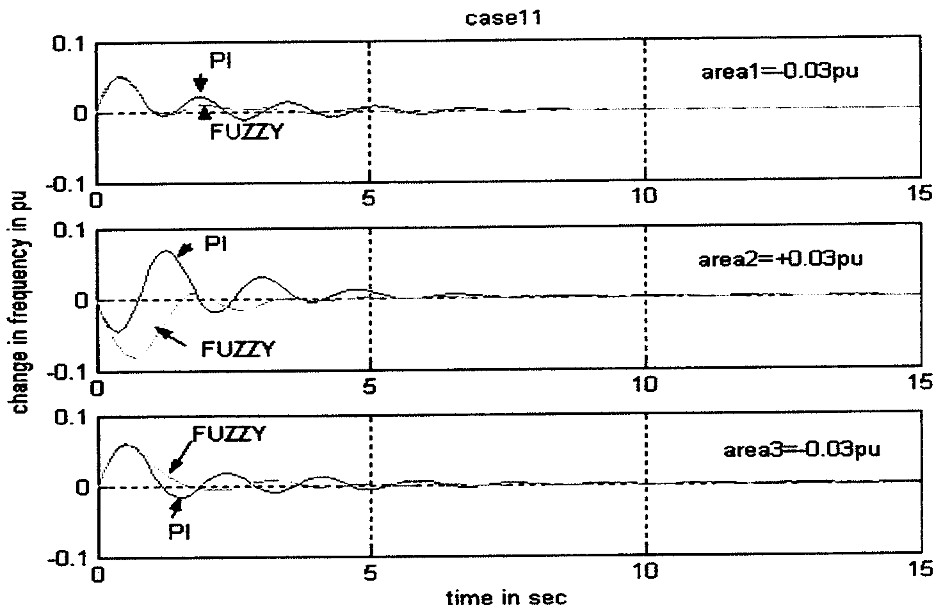

Fig 6.1i load varied equally (area1 loaded to - 0.03 pu., area 2 loaded to +0.03 p.u area 3 loaded to –0.03 pu)

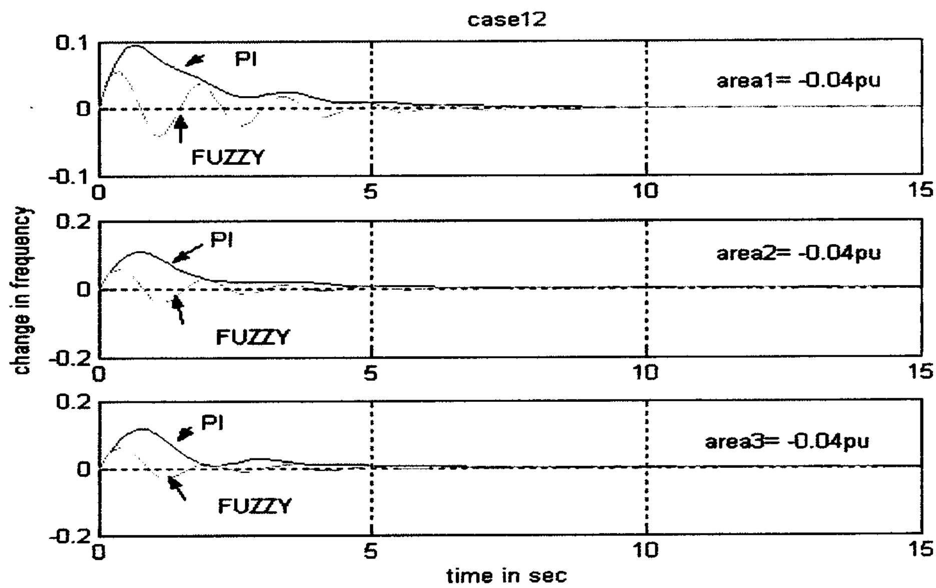

Fig 6.1 j load varied equally (area1 loaded to- 0.04 pu., area 2 loaded to -0.04 p.u area 3 loaded to –0.04 pu)

TABLE 6.1 Comparison result of PI and Fuzzy controller

Case1 Equal load	Area1 (0.01 pu)		Area2(0.01 pu)		Area3(0.01)	
	PI	FUZZY	PI	FUZZY	PI	FUZZY
Peak value Mp In Hz	0.0224	0.052	0.024	0.0070	0.0250	0.038
Settling time Ts in sec	12	7.5	10	9	12.5	10.5
Case2 Unequal load	Area1= 0.02 pu		Area2= 0.01pu		Area3= 0.03pu	
Peak valueMp In Hz	0.0493	0.293	0.055	0.0280	0.0677	0.0546
Settling time Ts in sec	13	10.5	13	10.5	14	12
Case 3 Equal load	Area1= 0.25 pu		Area2=0.25 pu		Area3= 0.25 pu	
Mp in Hz	0.4288	0.4376	0.226	0.1553	0.2279	0.1576
Ts in sec	13.5	10.5	15	10.5	14.5	13.5

Here the change in frequency is using PI controller and FUZZY controller is noted.This change in frequency comes to zero fastly when FUZZY controller is used than that of the PI controller. The above table 6.1 shows that the settling time (TS) using fuzzy controller is low than using fuzzy controller. Fuzzy controller sets the frequency to normal value quickly by fast bringing of zero frequency deviation. controller comes to zero value faster. Instead of Fuzzy controller, ANN approach can also be tried in future. This project is done on regulated environment and this can also extend to the deregulated environment.

CONCLUSIONS

The computer simulation was performed for different load changes in different areas. This simulation results are compared. The results clearly indicate that the fuzzy controller minimizes the oscillation and settling time comparing to PI controller.

The fuzzy logic approach to integral gain scheduling yields overall better performance regarding transient responses in comparison to the case of fixed integral gain.

- The fuzzy logic approach yields automatic, self-adjusting outputs irrespective of widely varying, uncertain of normal conditions.

- The memory burden and computational burden and time reduce drastically in the fuzzy logic approach as it involves only IF-THEN logic in fuzzy interference engine and accordingly output decision is taken.

Hence when fuzzy system is applied to appropriate problems in control systems, their typical characteristics show a faster and smother response than conventional system. These translate to efficient and more controllable operation for controlling various parameters in a plant. In fuzzy control system proposed rules are usually simpler, easier and often requiring fewer rules, thus the system execution is faster.

This fuzzy system often achieves tractability, robustness and overall cost effectiveness. Hence implementation of this technology in the area of power system leads to increase reliability and better quality of power supply to the consumers.

The fuzzy logic controller applies very simple and sophisticated methods, and the integral gain constants are adjusted to a value, which makes the system to operate in a very quick manner than that of conventional PI controller.

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APPENDICES

TABLE A : CASES-STUDIED USING DIFFERENT LOAD (P.U) AT DIFFERENT AREA

Cases	Area1	Area2	Area3
1.1	+0.01	+0.01	+0.01
1.2	+0.02	-0.02	+0.02
1.3	-0.03	+0.03	-0.03
1.4	-0.04	-0.04	-0.04
2.1	0.01	0.02	0.03
2.2	0.03	-0.02	+0.01
2.3	-0.01	+0.03	-0.02
2.4	-0.02	-0.01	-0.03
3.1	0.02	+0.04	+0.06
3.2	+0.06	+0.06	-0.04
3.3	-0.02	+0.06	_0.04
3.4	-0.04	-0.02	-0.06
4.1	+0.01	+0.04	+0.07
4.2	-0.01	-0.07	+0.04
4.3	-0.07	+0.04	-0.01
4.4	-0.07	+0.01	-0.04

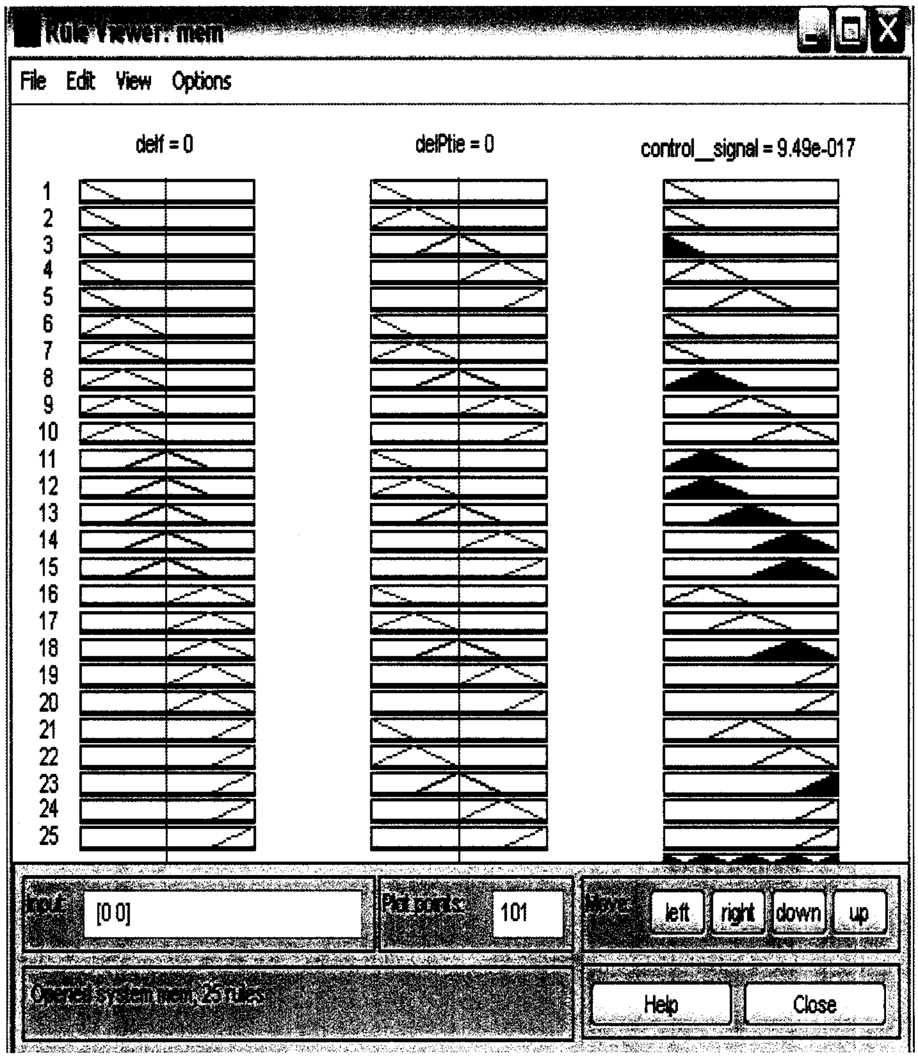
5.1	+0.1	+0.2	+0.3
5.2	+0.1	-0.3	+0.2
5.3	-0.2	+0.1	-0.3
5.4	-0.3	-0.2	-0.1
6.1	+0.1	+0.1	+0.1
6.2	-0.2	-0.2	+0.2
6.3	-0.3	+0.3	-0.3
6.4	-0.4	-0.4	-0.4
7.1	+0.2	+0.4	+0.6
7.2	+0.4	-0.6	+0.2
7.3	+0.6	+0.2	-0.4
7.4	-0.4	-0.2	-0.6
8.1	+0.1	+0.5	+0.7
8.2	+0.7	-0.5	+0.1
8.3	-0.1	+0.7	-0.5
8.4	-0.5	-0.1	-0.7

APPENDIX B

	Area1 (in pu)	Area2 (in pu)	Area3(in pu)
Turbine constant	0.6	0.6	0.6
Governor constant	0.3	0.3	0.3
D(%change in load/%change in frequency)	1	1	1

Table B. System parameters while simulating three-area network

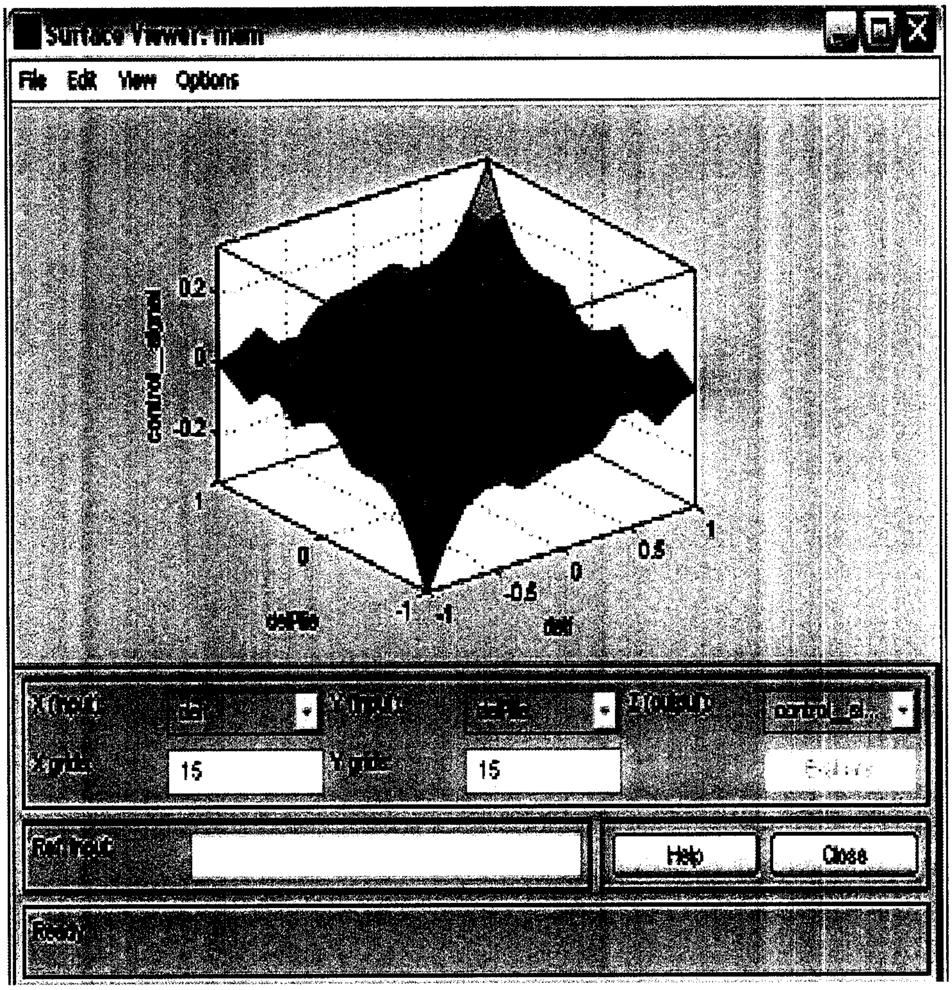
APPENDIX C



Rule Viewer: mem
File Edit View Options
delf = 0
delPtie = 0
control__signal = 9.49e-017
Input:
[0 0]
Plot points:
101
Move:
left
right
down
up
Opened system mem, 25 rules
Help
Close

APPENDIX D

FIG D., SURFACE OF THE RULES



THIS CERTIFIES THAT

~~Prof.~~/~~Dr.~~/~~Mr.~~/Ms. R. Vanitha

of Kumaraguru College of Technology has participated in the SECOND NATIONAL CONFERENCE on "CUTTING EDGE TECHNOLOGIES IN POWER CONVERSION AND INDUSTRIAL DRIVES", PCID-2006 held on 24-25, March 2006 and presented a paper titled "Simulation in AGC system after Deregulation."

in the session Power System of the conference.

Dr. A. Nirmal Kumar	Dr. G. Gurusamy	Dr. A. Shanmugam
CONVENOR PCID-2006	**DEAN EEE**	**PRINCIPAL**

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