IMPLEMENTATION OF FUZZY LOGIC CONTROLLER FOR LOAD FREQUENCY CONTROL IN TWO AREA POWER SYSTEM

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT OF THE DEGREE
Bachelor of Technology in Electrical Engineering

SUBMITTED BY

Nirakar Rout (110ee0563)
Jagadish Kumar Sethy (110ee0230)

Department of Electrical Engineering

National Institute of Technology, Rourkela

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Under supervision of
Prof. Gopalakrishna Srungavarapu

Department of Electrical Engineering

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&

ALL OUR GOOD WISHERS

National Institute Of Technology, Rourkela

CERTIFICATE

This is to endorse that **Mr. Nirakar Rout**, **110EE0563 and Mr. Jagadish Kumar Sethy 110EE0230,** student of National Institute of Technology Rourkela has successfully completed his project "**Implementation of Fuzzy Logic Controller for Load Frequency Control In Two Area Power System " .** During his project, he remained sincere and obedient. He reflected eagerness to learn, devotion to work and skills of being practical about the concepts. This thesis contains his authenticated work under my supervision. It has been verified that this project report is complete in all manners.

Date:

Place:

Dr. S. Gopalakrishna
Assistant Professor
Department of Electrical Engineering
National Institute of Technology, Rourkela
769008

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Nirakar Rout (110EE0563)

Jagadish Kumar Sethy (110EE0230)

ABSTRACT

Currently as there has been an increase in the interconnected systems as far as power systems are concerned. Load as well as power flow in tie-line are varying dynamically. So there is a need of robust control of system frequency as well as tie-line power flow system. This robust control could be achieved by the help of fuzzy logic controllers in the place of orthodox system using proportional, PI and PID controllers. This is due to the fact that gain constants in the case of conventional controllers remain same throughout, for changes in the load value. But Load can't be the same throughout, load deviates from time to time. So as to get rid of these disadvantages related to conventional controllers, a lot many schemes have been put forth in literature. With regard to this work, fuzzy logic base controller has been considered for problems pertaining to load frequency control. There queried rules are carried out with respect to the variation in load to diminish the error. In fuzzy logic controller, we take the help of triangular membership function in the formulation of the rule base, because triangular membership function gives easy way to make the rule base compared to other membership functions. Then simulation is done by using Matlab/Simulink software.

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LIST OF ABBREVIATIONS:-

LFC:- Load Frequency Control

AGC:- Automatic Generation Control

ACE:-Area Control Error

GA:- Genetic Algorithm

BFOA:- Bacteria Foraging Optimization Algorithm

PI:- Proportional Integral

FLC:-Fuzzy Logic Controller

NB :- Negative Big

NM:-Negative Medium

NS:-Negative Small

ZO:-Zero

PS:-Positive Small

PM:-Positive Medium

PB:- Positive Big

LIST OF SYMBOLS:-

f = the system frequency (Hz),

Ri = regulation constant (Hz/per unit),

T_g = speed governor time constant (s),

T_t = turbine time constant (s)

T_p = power system time constant (s).

$x(t)$ = the state disturbance vector

$u(t)$ = control disturbance vectors

$d(t)$ = load changes disturbance vectors

bi = frequency bias constant

Δfi = frequency deviation

$\Delta P_{tie,}i$ = change in tie line power for Area i

C = output matrix .

CHAPTER-1

1.1. INTRODUCTION

1.2. SOURCE OF INSPIRATION AND MOTIVATION

CHAPTER: 1

1.1 INTRODUCTION:

For extensive level power systems which consist of of interconnected control regions, load frequency; then it's paramount to hold onto the frequency and entomb territory tie power close to the booked qualities. The input mechanical power is utilized to control the frequency of the generators and the variation in the frequency and tie-line power are detected, which is the extent of the alteration in rotor angle. A decently outlined power framework ought to have the capacity to give the satisfactory levels of power quality by keeping the frequency and voltage size inside middle of as far as possible.

Changes in the power system load influences chiefly the system frequency, while the reactive power is less delicate to changes in frequency and is fundamentally reliant on vacillations of voltage size. So the control of the true and reactive power in the power system is managed independently. The load frequency control fundamentally manages the control of the system frequency and genuine power inasmuch as the programmed Voltage controller circle directs the progressions in the reactive power and voltage extent. Load frequency control is the premise of numerous progressed ideas of the vast scale control of the power system..

As the loading in a power system is not constant so the controllers for the system must be aimed to provide quality service in the power system. The power flow and frequency in an interconnected system is well regulated by AGC. The main purpose of the AGC is to retain the system frequency constant and almost inert to any disturbances. Generally two things are being controlled in AGC i.e. voltage and frequency. Both have separate control loops and independent of each other.

.Apart from controlling the frequency the secondary majors is to maintain a zero steady state error and to ensure optimal transient behavior within the interconnected Areas. The objective is to design a controller to apprehend preferred power flow and frequency in multi-Area power systems.

1.2 SOURCE OF INSPIRATION AND MOTIVATION:

Resent blackout in the northern power grid due to mismatch of load has lead us to pursue our interest in this field. Load frequency control is a burning topic for young researchers.

CHAPTER – 2

2.1. LITERATURE REVIEW
2.2. REASONS FOR THE LIMIT ON FREQUENCY
2.3. LOAD FREQUENCY CONTROL

CHAPTER-2

2.1 LITERATURE REVIEW:-

There are many experiments & researches about control of load frequency in power systems connected to each other. In several papers, there are many control strategies centered on conventional linear control theory. To some authors, the system frequency stability is maintained by a flexible arrangement system control [1]. But, it requires some data for the system conditions, to which we don't have access fully.

Conferring to Ref. [3], conventional PID control systems shan't extent to great result. A gain forecasting controller is used [2]. Gain forecasting is a controller model method used in the non-linear systems. In it, the control variables is changed promptly, as variables valuation isn't needed. It is at ease to catch than programmed change or variation of the controller parameters. But the transient response may be uneven because of unexpectedness in the system parameters. Also, precise linear time invariant prototypes at variable operating marks can't be gained [4].

Fuzzy methods were used for control of load-frequency in power systems by Chang and Fu [2] and Akalın and coworkers [6]. Both established some fuzzy rules for the P and PI gains discretely. In this paper, the system result is enhanced by the gain rules, which are selected alike. By the proposed controller, the overshoots and settling time are efficient than the other controllers.

2.2. REASONS FOR THE LIMITS ON FREQUENCY:-

Below are the causes for keeping a stringent limit on the frequency variation in an Area:

1. Due to the dependency of speed of the alternating current motors on frequency of the power supply. There are situations where speed consistency is expected to be of high order.

2. The electric clocks are driven by the synchronous motors. The accuracy of the clocks are not only dependent on the frequency but also is an integral of the frequency error.

3. If the normal frequency id 50 Hertz and the system frequency falls below 47.5 Hertz or goes up above 52.5 Hertz then the blades of the turbine are likely to get damaged so as to prevent the stalling of the generator.

4. The under frequency operation of the power transformer is not desirable. For constant system voltage if the frequency is below the desired level than the normal flux in the core increases. This sustained under frequency operation of the power transformer results in low efficiency and over-heating of the transformer windings.

5. the most serious effect of subnormal frequency operation is observed in the case of Thermal Power Plants. Due to the subnormal frequency operation the blast of the ID and FD fans in the power stations get reduced and thereby reduce the generation power in the thermal plants. This phenomenon has got a cumulative effect and in turn is able to make complete shutdown of the power plant if proper steps of load shedding technique is not engaged. It is pertinent to mention that, in load shedding technique a sizable chunk of load from the power system is disconnected from the generating units so as to restore the frequency to the desired level.

2.3 LOAD FREQUENCY CONTROL:

With many loads linked to a system in a power system, speed and frequency vary with the characteristics of the governor with variations in loads. No need to modify the setting of the generator if maintaining of constant frequency is not needed. When constant frequency is needed the turbine speed can be adjusted by varying the governor characteristic. Complications arise when 2 generating stations in parallel, are handling the variation in load. Chances of distribution of load in two systems are mentioned below:

- Let both generating stations are interconnected through a tie line. If load varies at X or Y & A generation has to maintain the constant frequency, at that time it's known as **Flat Frequency Regulation.**
- Secondly where both X & Y have to maintain the constant frequency. It's known as **parallel frequency regulation.**
- Thirdly where frequency maintenance is done of a certain Area by its own generator & keeping constant the tie-line loading. It's called **flat tie-line loading control**.
- In **Selective Frequency control** individually system handles the variation in load itself & without interfering, beyond its limits, the maintenance of the other one in that group.
- In **Tie-line Load-bias control** all systems in the interconnection help in maintaining frequency no matter where the variation is created. It has a principal load frequency controller & a tie line plotter determining input power on the tie for proper control of frequency.

CHAPTER -3

3.1. TWO AREA POWER SYSTEM
3.2. FUZZY LOGIC IN POWER SYSTEM
3.3. DESIGN OF FUZZY LOGIC CONTROLLER

CHAPTER: 3

3.1 TWO AREA POWER SYSTEM:-

Generally, power systems obligate composite & multi-variable configurations and they have many non minimum and nonlinear phase systems. Power networks are distributed by tie lines into regulator Areas. Generators are expected to maintain synchronism with the tie line and connected Areas. From experimentations on different power networks, it's realized that individual Area requires precise control of its tie line power & system frequency. There are basically two types of control mechanism to control frequency in interconnected power systems i.e. first one is primary speed control & second one is secondary speed controller . The first speed control creates the preliminary rough alteration of frequency. For its activities, the variation in load is being tracked by the generators and share among them according to their ratings. The inherent time lags of the system and the turbine itself is the major cause for the slow response of the system. Liable on the turbine kind, the primary loop classically responds in 2–18 s. The later speed control follows the well alteration of frequency by varying the frequency inaccuracy to zero by an integral control action. The association among the load and speed is accustomed by varying a load set point input. In exercise, the tuning of the load reference mark point is being done by functioning the speed changing motor. In production of every division at a specified system frequency is changed only by varying its load reference, which manages to change the speed-droop characteristic up and down. This control is significantly sluggish and drives to action only when the job is done by the primary speed control. Reaction period can be very low like I minute. Regulation of the frequency is done by the speed-governing system. The isochronous governor changes the turbine valve/door to get the frequency once again to the ostensible or booked rate. An isochronous governor performs attractively when a generator is providing a disconnected load or when one and only generator in a multi generator framework is obliged to react to the heap variations. For power and load imparting around generators joined with the framework, speed regulation or droop attributes must be given. The speed-droop or regulation trademark can be acquired via including an unfaltering state sentiment circle about the integrator. An unrestrained two Area connected power system is presented in Fig. 1 .

The complete structure is showed as a multi-parameterized system in the arrangement of

Equation (1)

$$\dot{x} = A(x) + Bu(t) + Ld(t)$$

Here *A* stands for the system matrix, then *B* and *L* stand for the input and disorder dispersal matrices respectively , $x(t)$, $u(t)$ and $d(t)$ stand for the state vector , control vector and load changes disturbance vector , correspondingly.

$$x(t) = [\Delta f_1 \;\; \Delta P_{g1} \;\; \Delta P_{v1} \;\; \Delta P_{tie12} \; \Delta f_2 \;\; \Delta P_{g2} \;\; \Delta P_{v2} \;]^T$$

$$u(t) = [\, u_1 \quad u_2 \,]^T$$

$$d(t) = [\, \Delta P_{d1} \;\; \Delta\, P_{d2} \,]^T$$

where Δ signifies variation starting from the minimal values. u_1 and u_2 are the controller results . The classification result, which rest on the ACE presented in Fig. 1, is

Equation (2)

$$Y(t) = \begin{bmatrix} Y_1(t) \\ Y_2(t) \end{bmatrix} = \begin{bmatrix} ACE_1 \\ ACE_2 \end{bmatrix} = Cx(t)$$

equation (3)

$ACE_i = \Delta P_{tie,i} + b_i \Delta f_i$

bi stands for frequency bias constant. Δfi stands for the frequency variation and $\Delta P_{tie,}i$ stands for variation in tie line power in Area *i* & *C* is the result matrix .

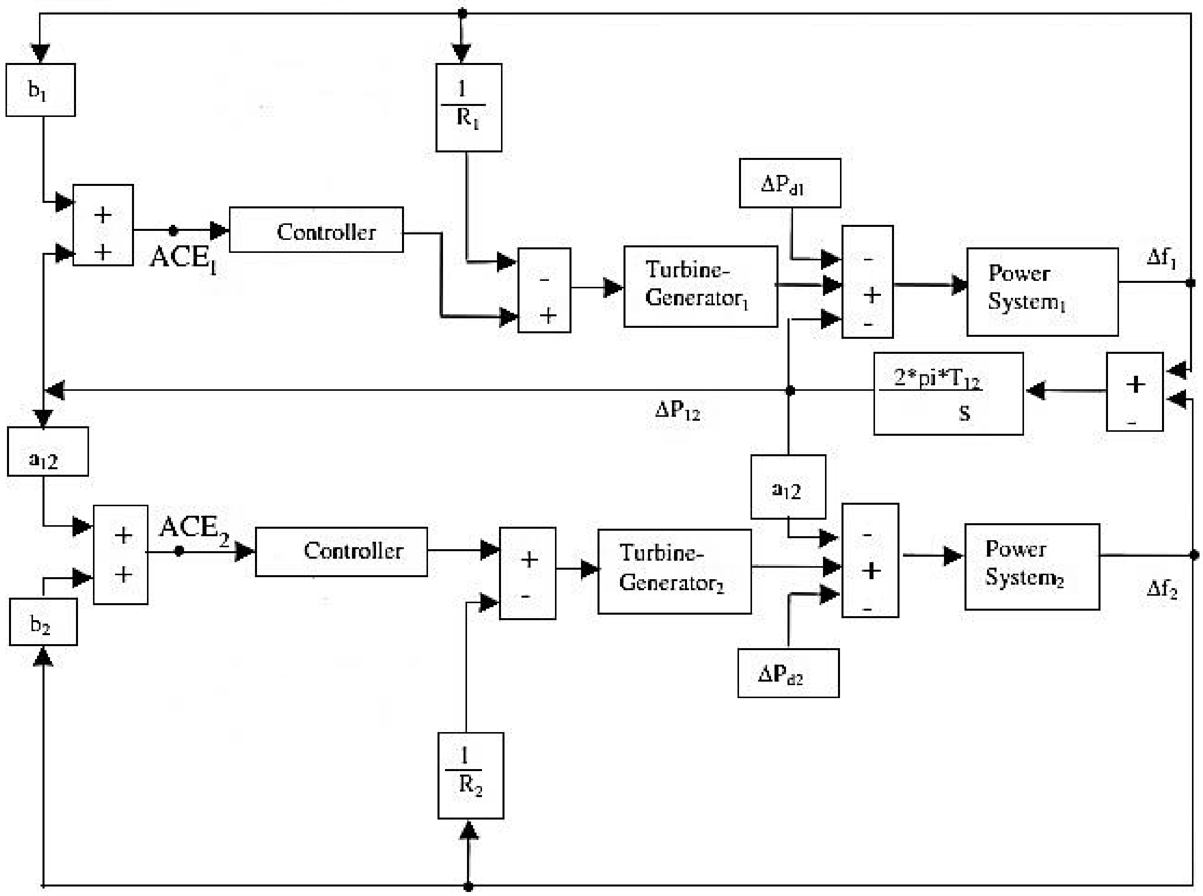

Figure 3.1: Two Area power system

3.2 FUZZY LOGIC IN POWER SYSTEM:

Fuzzy set hypothesis and fuzzy rationale secure guidelines of a nonlinear plotting. Utilization of fuzzy sets gives a premise to a organized path for the requisition of indeterminate and inconclusive prototypes. Fuzzy controller is focused around a legitimate structure termed fuzzy rationale is very nearer in soul to human intuition and regular dialect than established intelligent systems. These days fuzzy rationale is utilized as a part of very nearly all parts of manufacturing and science. From those LFC is one. The primary objective of LFC in connected power networks is to secure the harmony among handling and utilization. In light of the multifaceted nature and multi-parameterized states of the power system, traditional controller strategies possibly will not give acceptable results. Then again, their strength and unwavering quality make fuzzy controllers helpful in understanding an extensive variety of control issues. The fundamental constructing units of a Fuzzy Logic Controller are a fuzzification unit, a fuzzy rationale thinking unit, a learning base, and a defuzzification unit. It is the procedure to change the convinced fuzzy control movements to a fresh control movement.

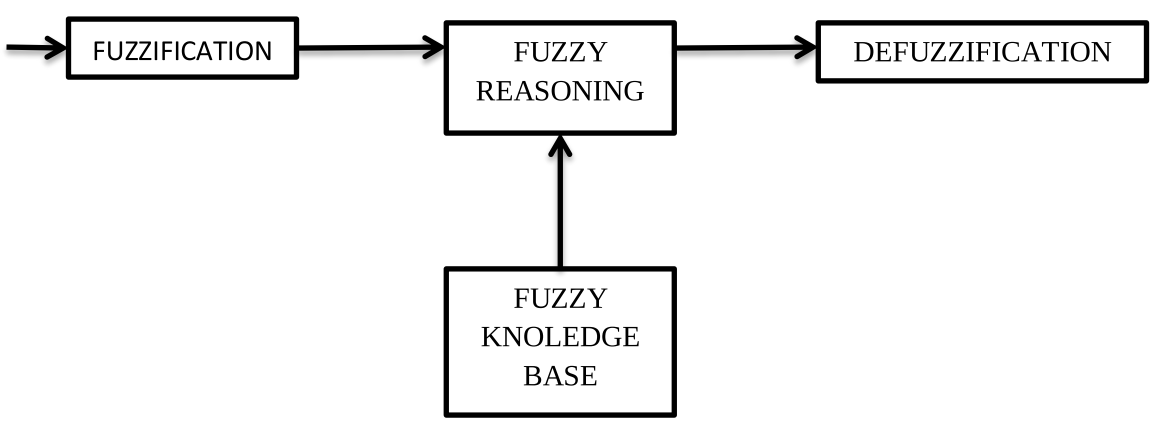

Figure 3.2: Block diagram of fuzzy logic model

3.3 DESIGN OF Fuzzy Logic Controller:

Assumptions in FLC system:

- The input and output variables can be witnessed and calculated.
- An acceptable result, not certainly a best, is adequate.
- A linguistic design may be created centered on the facts of a human expert.
- The human expert helps in modeling the linguistic model based on his knowledge

The basic building block of a fuzzy logic controller consist of four parts namely fuzzification of input followed by fuzzy reasoning and rule base to make perfect decisions. Then this block is being followed by knowledge base which defines all variables and parameters. The last block is the defuzzification block whose main function is to convert the fuzzy outputs to definite crisp values.

CHAPTER-4

CHAPTER-4

4.1 SIMULATION:

4.1.1 FOR STEP INCREASE IN THE LOAD DEMAND IN AREA 1:-

As the first test case, at Area 1 a step increase in load is applied. Then the first Area frequency deviation Δf_1, the second Area frequency deviation Δf_2, tie line power and ACE deviation are shown in Fig. 3, Fig. 4, Fig. 5, Fig. 6, Fig. 7. In these Figures, it is quite evident that the performance of conventional PI controller is not satisfactory; the main problem arises due to its high settling time. To improve the system characteristic the proposed method is more suitable.

Case 1:-

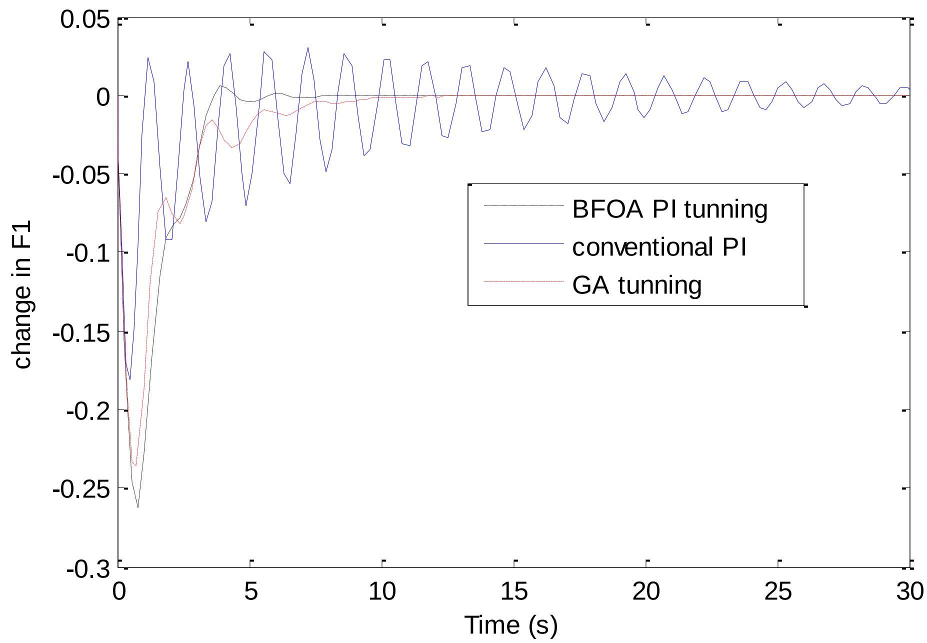

Figure 4.1: Variation in frequency of Area 1 with 0.1 per unit variation in Area 1

Case 2:-

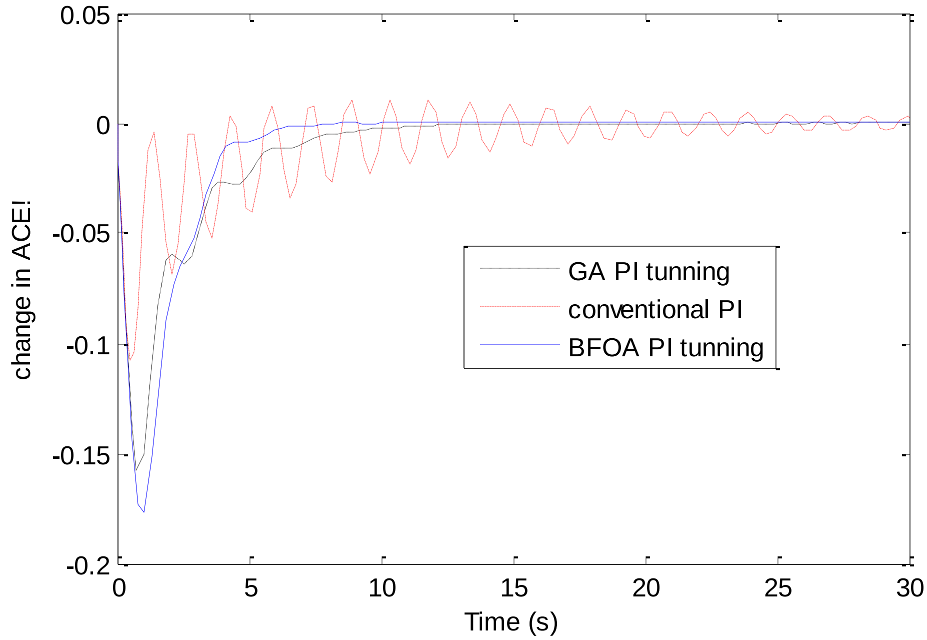

Figure 4.2: Variation of ACE1 with 0.1 per unit variation in Area 1

Case 3:-

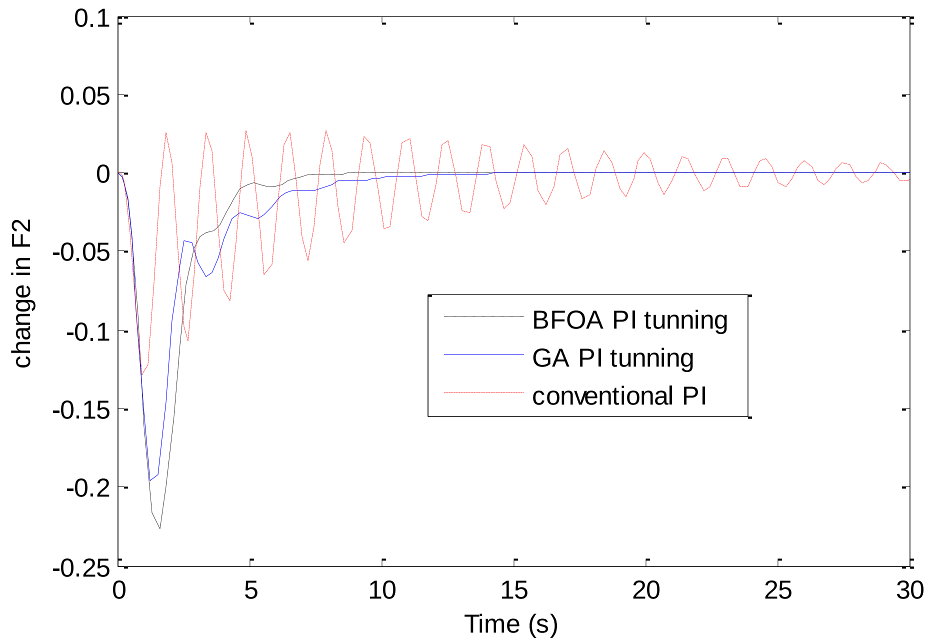

Figure 4.3: Frequency variation of Area 2 with 0.1 per unit variation in Area 1

Case 4:-

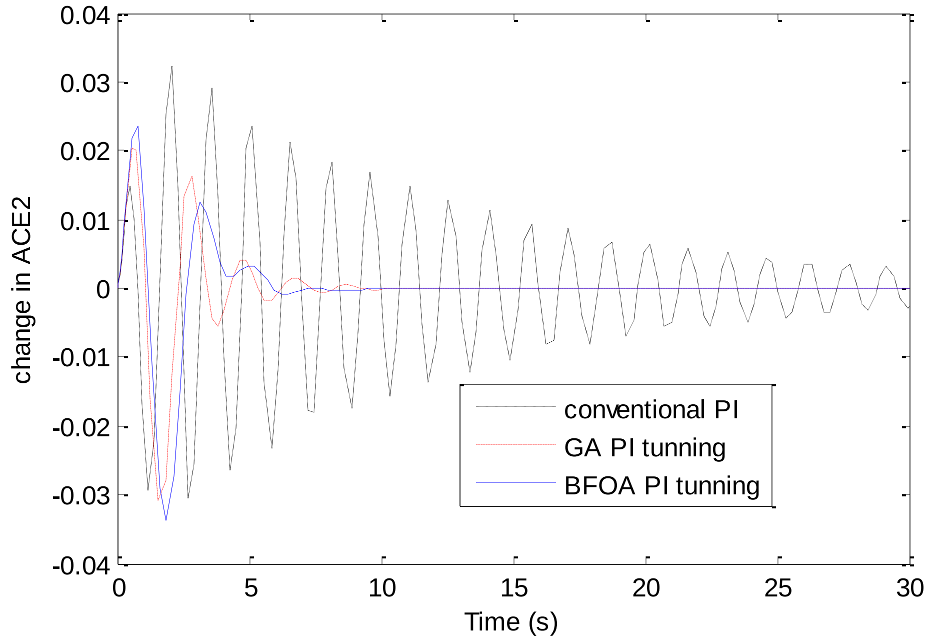

Figure 4.4: Variation of ACE2 with 0.1per unit variation in Area 1

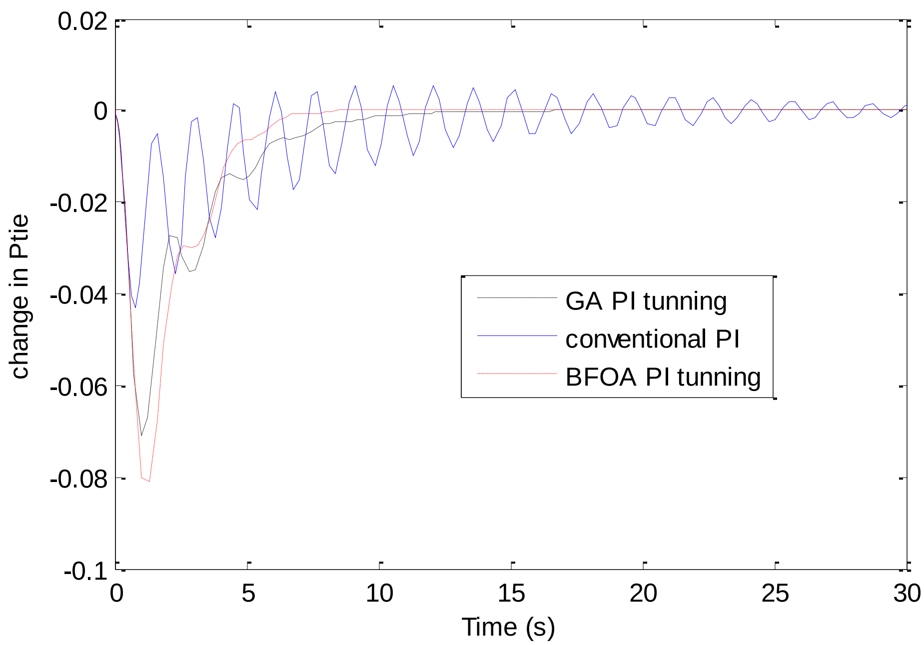

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Figure 4.5: Variation of Ptie with 0.1per unit variation in Area 1

4.1.2 FOR STEP INCREASE IN THE LOAD FOR BOTH THE AREAS

To both the Areas ΔP_{D1} and ΔP_{D2} are subjected to go through a load change of .1 p.u. The plots of the closed loop system are presented inFig-7, Fig-8, Fig. 9 and Fig. 10. From the figures, it is evident that the damping factor in case of conventional PI controller is not satisfactory. And comparing with GA the strategic way has a smaller settling time and system response is reduced to zero quickly. Also the potential and benefit of the planned way over the conventional and GA is tested.

Case 1:-

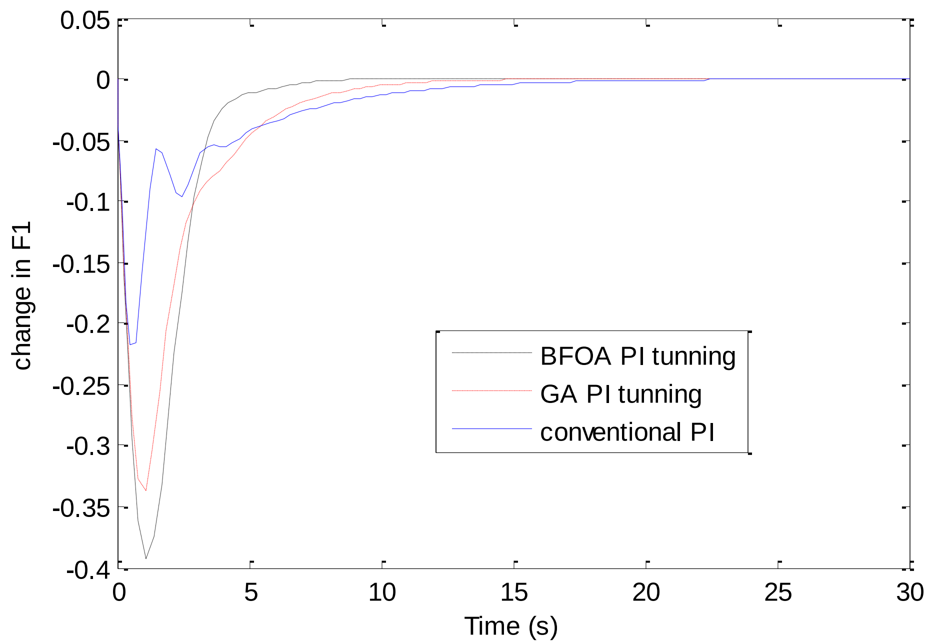

Figure 4.6: Effect on frequency of Area 1 with 0.1 per unit variation in all the Areas

Case 2:-

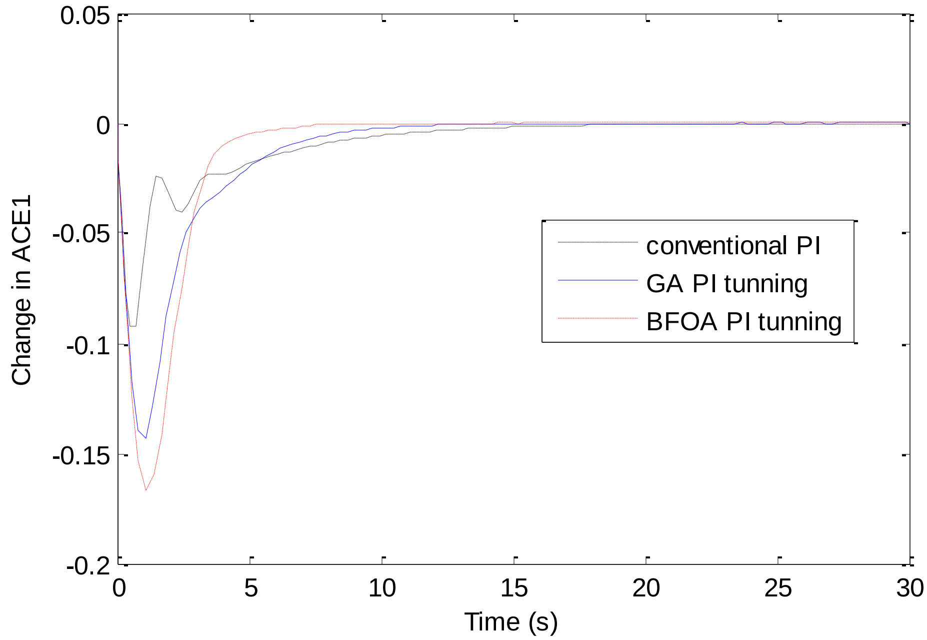

Figure 4.7: Effect on ACE of Area 1 with 0.1 per unit variation in all the Areas

Case 3:-

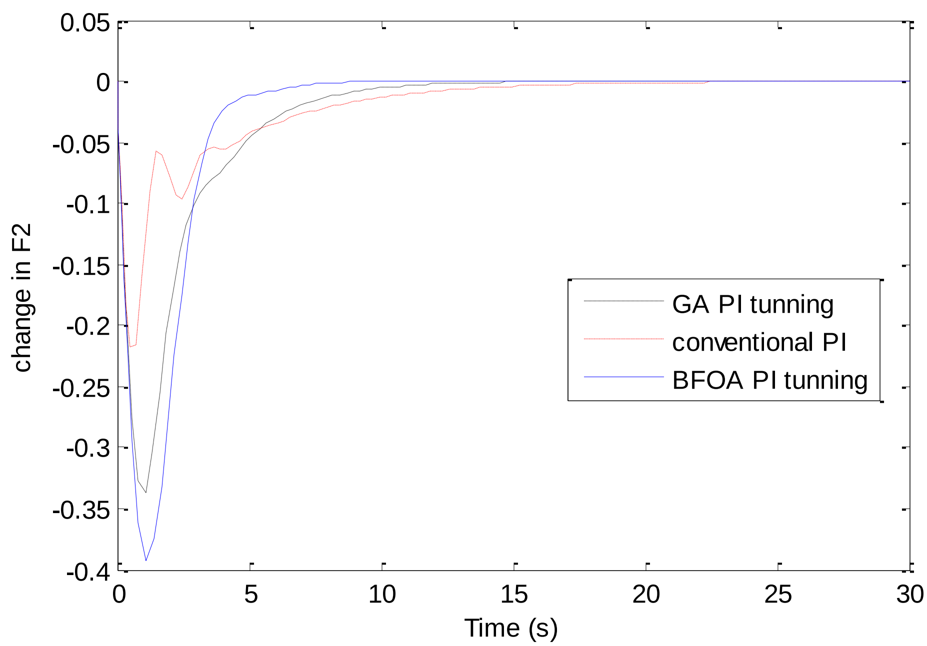

Figure 4.8: Effect on frequency of Area 2 with 0.1 per unit variation in all the Areas

Case 4:-

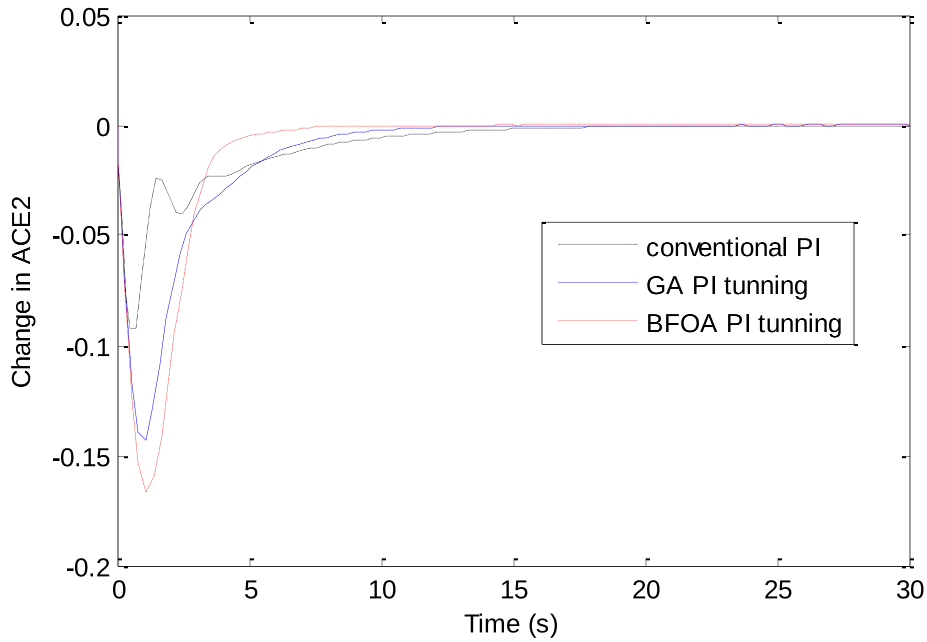

Figure 4.9: Effect on ACE of Area 2 with 0.1 per unit variation in all the Areas

4.1.3 IMPEMENTATION OF FUZZY BASED CONTROLLER:

To achieve better performance fuzzy logic can be implemented in a more effective way for load frequency controller. The fuzzy controller comprise of two phases, first one fuzzy system unit where the Area control error (ACE) and its derivative (ΔACE) are set as input parameters and then fuzzy rules are given and in accordance to the rules, the output was the control action. When many loads are considered, it’s somewhat hard to set the load perturbation as an input parameter of fuzzy logic controller. Modifying the PI controller, frequency control is achieved in old fashioned power system and finest results are acquired, but in changing working condition this cannot give an optimal solution.

Table 4.1: The fuzzy rule set

ACE/DACE	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZO
NM	NB	NB	NB	NM	NS	ZO	PS
NS	NB	NB	NM	NS	ZO	PS	PM
ZO	NB	NM	NS	ZO	PS	PM	PB
PS	NM	NS	ZO	PS	PM	PB	PB
PM	NS	ZO	PS	PM	PB	PB	PB
PB	ZO	PS	PM	PB	PB	PB	PB

The fuzzy codes are written in the fis.file in MATLAB using AND function in the Mamdani inference using Triangular Membership function, efficient 1. The rules highly depend on the membership function, the rules are set in appropriate collection of input and output parameters.

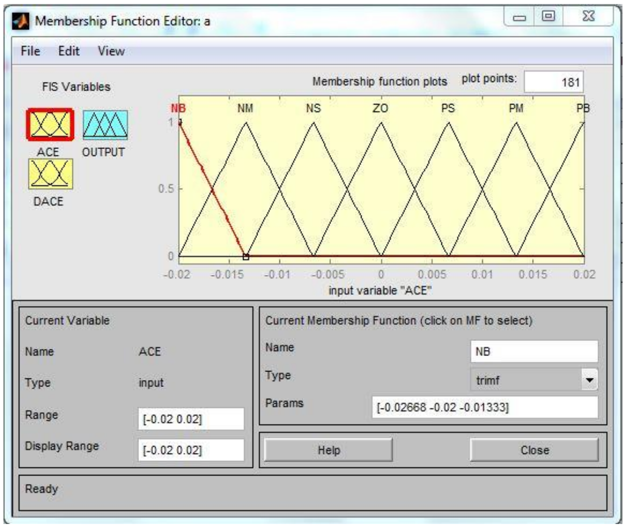

Figure 4.10:Membership function of input variable ACE.

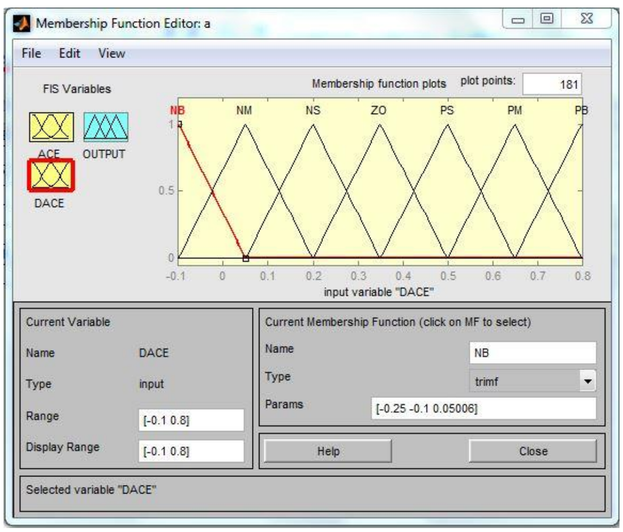

Figure 4.11:Membership function of variable ΔACE.

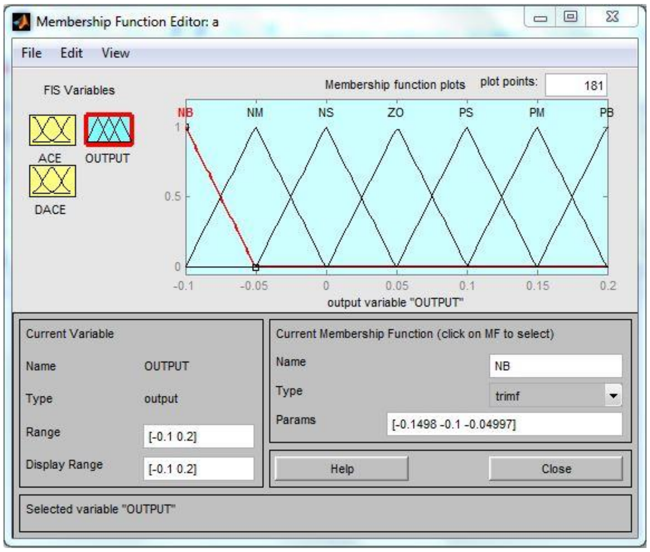

Figure 4.12: Output membership function

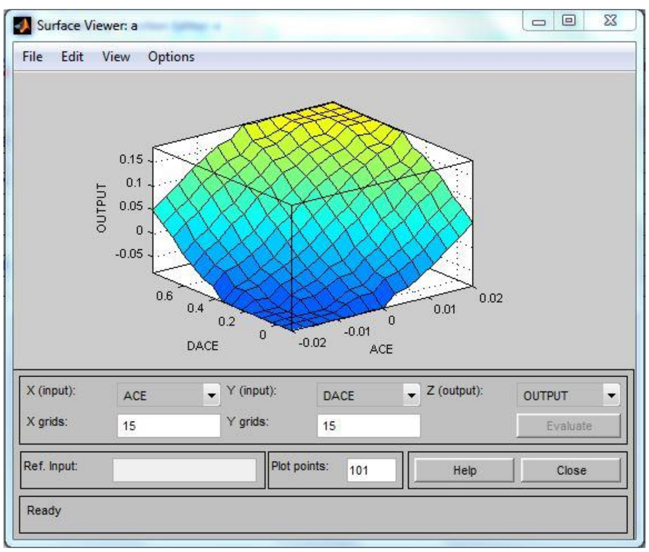

Figure 4.13 : Surface view

4.2 RESULT & COMPARISON:

Case 1 :- Comparison between controllers for settling a 0.1 per unit frequency variation in Area 1

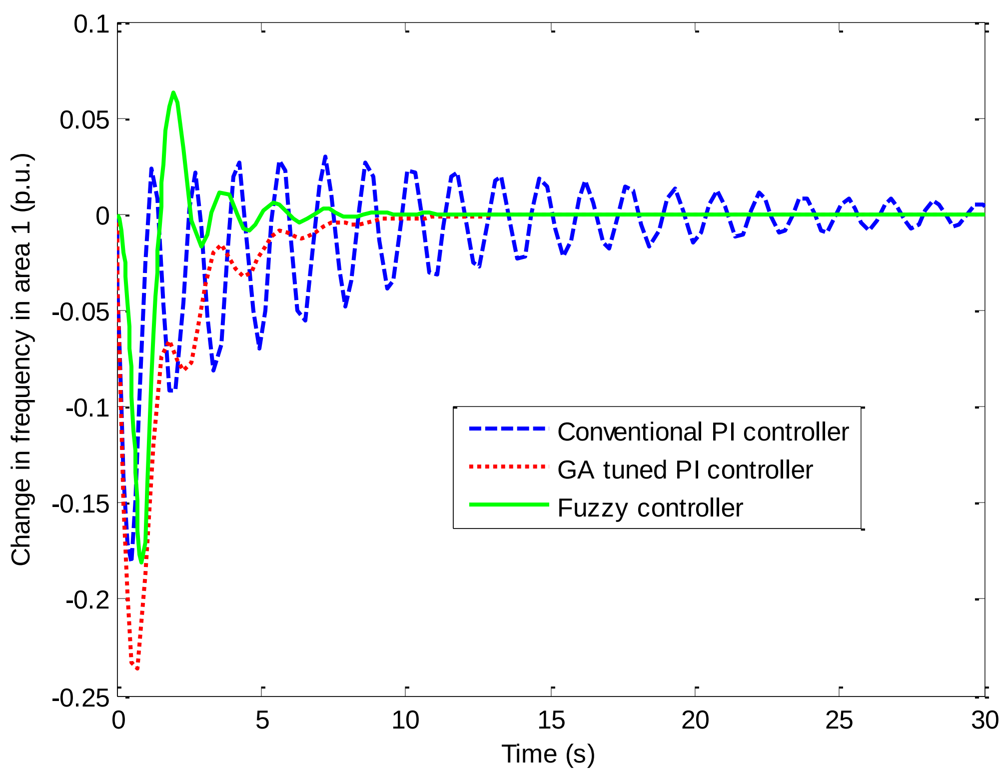

Figure 4.14: Comparison between controllers for settling a 0.1 per unit frequency variation in Area 1.

Case 2:- Variation in frequency of Area 2 with 0.1 per unit variation in Area 1 :-

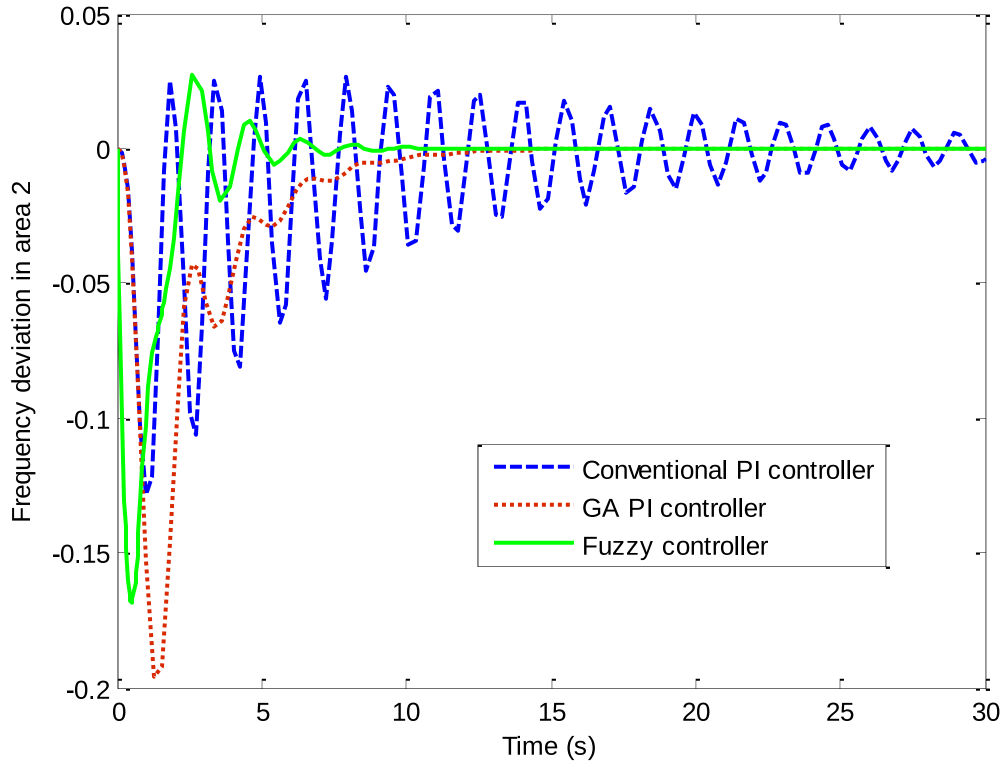

Figure 4.15: Variation in frequency of Area 2 with 0.1 per unit variation in Area 1

The above graph shows the comparison between the results obtained by conventional PI, GA PI controller and fuzzy controller. From the above two responses it is quite evident that the performance of fuzzy logic controller over conventional PI and GA PI is better in aspects like settling time. The transients are taking very less time to die out.

COMPARISON OF SYSTEM PARAMETERS:-

Table 4.2: Comparison of system parameters

		Conventional PI controller	GA PI controller	Fuzzy based controller
System modes		-13.7342 -13.6218 -0.086±4.1699i 0.9568±3.402i -1.8538 -0.2359 -0.2355	-13.1203 -13.1043 -0.5605±3.1716i -1.1751±1.9112i -1.1967 -0.4456 -0.4288	-13.2651 -0.4973 + 3.5221i -0.4973 - 3.5221i -1.6236 -13.2902 -1.2966 + 2.5127i -1.2966 - 2.5127i
Minimum damping ratio		0.021	0.174	.1398
Controller constants	K_p	0.7005	-0.2346	-------------
	K_i	0.3802	0.2662	-------------
Settling time	Area 1	29.4190	8.6625	5.6135
	Area 2	29.8219	7.3804	5.6367

CHAPTER :5

5.1. CONCLUSION

5.2. FUTURE SCOPE

CHAPTER 5.

1. CONCLUSION:

In instance of the uncontrolled studies it has been witnessed that as the load fluctuation is increased the area control errors are also aggregated. The effect of FLC when placed in both the areas for a step load change in Area 1 is that the variations in Δf_1 , Δf_2 and ΔP_{tie} are completely nonoscillatory. Comparable deductions can be drawn for equal step load changes in both the areas having FLC in area 1. The retorts are generated with FLC placed in both Areas. When FLC are placed in both the areas the abnormalities are small and the oscillations die out easily.. Altogether implementation of the fuzzy controller gives an improved result compared to conventional and GA PI controller. The settling time, rise time has decreased significantly. The transient is settling quite easily. It has been given away that the projected controller is effective and provides significant improvement in system performance

2. FUTURE SCOPE:

1. The result can be enhanced further through Integral – fuzzy controller.
2. By adding generation control and governor dead band into the system the system will look more realistic and nonlinear.

APPENDIX:

The values for the system parameters is listed below :

$T_{P1} = T_{P2} = 20$ s, power system time constant;

$T_{T1} = T_{T2} = 0.3$ s, turbine time constant;

$T_{12} = 0.545$ p.u; tie line time constant;

$T_{G1} = T_{G2} = 0.08$ s; governor time constant;

Kp1 = Kp2 = 120 Hz/p.u MW; gain of power system;

$R_1 = R_2 = 2.4$ Hz/p.u MW; speed regulation constant;

B1 = B2 = 0.425 p.u MW/Hz; feedback bias control;

$K_{P} =$ Proportionality constant of controller;

$K_{I} =$ integral constant of controller;

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