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CONTROLLERS ANALYSIS FOR GENERATION CONTROL OF TWO AREA INTERCONNECTED POWER SYSTEM

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Abstract

This paper presents AGC of an interconnected two unequal area provided with Non-reheat thermal system. A maiden attempt is made to apply Fuzzy-PID Controller in AGC. Controller gain is two unequal area systems are optimized using a more recent and powerful evolutionary computational technique called PSO technique. According to this investigation comparison that integral (I), proportional (P), Proportional-integral-derivative (PID) all provided more or less response whereas Fuzzy-PID Controller provides much better response. In this work Fuzzy-Tuned Controller is analyzed as the control structure in two areas interconnected P.S. and study is extended for the transient response of the proposed system. In this paper all the prominent controller & their response have been studied and tuned Fuzzy-PID controller with PSO technique provided better stability & dynamic response for the system compared other existing controller. The system performance is examined considering 1% step load perturbations in area1.

Index Terms- Automatic Generation Control, Step Load Perturbation, Fuzzy-Tuned Controller, Particle Swarm Optimization, Characteristics.

Nomenclature

f = nominal system frequency (Hz)

R_{TH1} =Governor speed regulation parameter of area1 (Hz/pu MW)

R_{TH2} = Governor speed regulation parameter of area2 (Hz/pu MW)

K_{ps1} = proportional gain of area1

K_{ps2} = proportional gain of area2

T_{SG1}= Governor Speed time constant in area2

T_{SG2}= Governor Speed time constant in area1

TT_1= Turbine time constant of area1

TT_2= Turbine time constant of area2

B_1 = Area frequency response of area1

B_2 = Area frequency response of area2

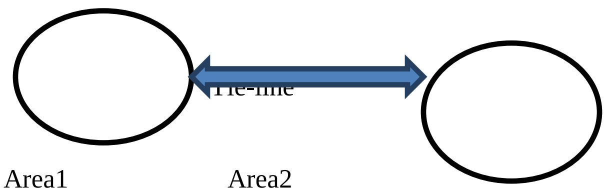
Introduction

In AGC, two area control system is interconnected of power system which are interconnected through a tie-line. When two power systems are interconnected one system is to be able to trade the power with neighboring system with neighboring system whose operating costs make such merchandise profitable. If one system experience a sudden loss of a generation, the unit throughout all the interconnection will experience a frequency change & can help in restoring frequency [1-2]. In utility system, electrical generator converts mechanical power into electrical power and steam turbine that drive the generator convert fuel energy into electrical energy. AGC has three major objectives;

1. To screw the system frequency at or close to a specified nominal value.
2. To balance each unit's generation at the most economic value.
3. To balance the interchange of power between the control areas.

The work of the control areas controls the load and generation of an interconnected power system. Mainly two types of control loops are available in AGC such as; (1) primary control (load frequency control), (2) secondary control (Automatic voltage regulator). AGC is one of the most important auxiliary services to be maintained for minimizing frequency divisions, maintain of generation and load demand [3]. Load frequency control problem in power system operation & control has a long history [5]. The load frequency control is the one of the most important role in modern energy management systems [6]. The utility systems have non-linear and time varying nature [7-9].

From the investigations have been carried out to design an optimal automatic generation controller to enhance the stability and preserve the security of the system [10]. Dynamic performance of all conventional classical controllers [4] like Integral, P, PI, PID controllers and soft controller(Fuzzy-Tuned Controller) [13]. A more recent and powerful evolutionary computational technique Particle Swarm Optimization (PSO) is used here for simultaneous optimization of several parameters for both primary and secondary control loops of the governor with different types of classical controller and soft controllers. This classical controller and soft controller are tried and their performance compared so as to assess the best controller. Sensitivity analysis has been carried out too for the best controller.



Area1 Area2

Fig.1. two area interconnected system.

System Investigation

Investigation has been carried out on two unequal area system area1 = 2000MW; area2 = 4000MW provided with non-reheat Turbine in both control areas. Integral, Proportional, PI, PID and Fuzzy PID controller are considered for investigation [15] and shown in appendix. A parameter a12 = -1 is considered in two area system. The Transfer Function model of a two area systems with PID Controller is shown in fig.4. MATLAB version 8.0 has been used to obtain dynamic responses for a step load perturbation of 1%.

Fuzzy- Tuned Controller

Now a day's fuzzy logic is needed in all section of industry and services and also used in Automatic generation Control. The Fuzzy-Tuned Controller of the system is designed Fuzzy dissection logic controller. The fuzzy logic is based on logical system and this logical system is called Fuzzy logic which is based on human thinking and natural language than classical logical system [16]. The fuzzy-Tuned Controller is based on Artificial Intelligent and this controller is designing for non-linear system. Fuzzy system means the human knowledge is converted in mathematical formula [17]. The Fuzzy-Tuned Controller is mainly consisted of four components; (i) Fuzzification, (ii) The Interface engine, (iii) The rule base, (iv) TheDefuzzification. In Fuzzification the Fuzzifier converts nmeric value/crisp value into Fuzzy sets. Thecorefactor of the fuzzy-tuned controlleris the interface engine, which makes all logic operations in a fuzzy-tuned controller. The rule base contains of membership function and control rules. Finally, the result come out through interface process is an output of the fuzzy-tuned controller should be a numeric/crisp value. The result of interface process in fuzzy set and this result are converted into a numeric value by using defuzzifier. This operation is called Defuzzification.The response of the proportional gain and Integral gain shown in fig.2. and fig.3.

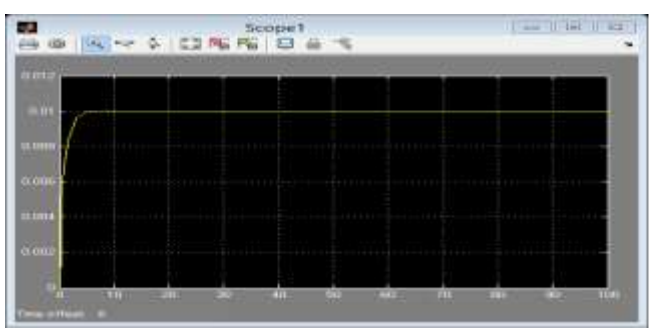


Fig.2. Response of $K_P$parameter.

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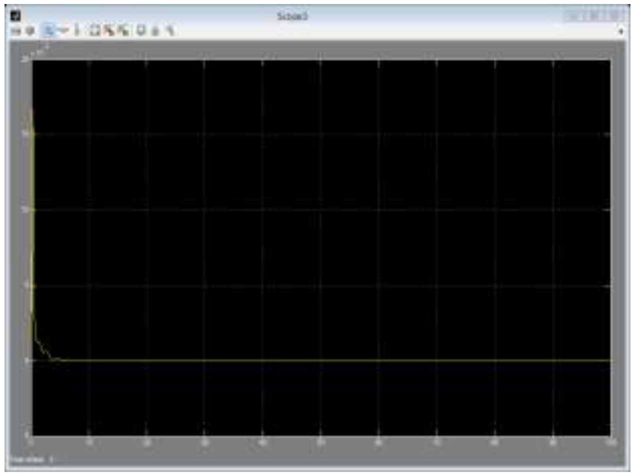

Fig.3. Response of K_I parameter.

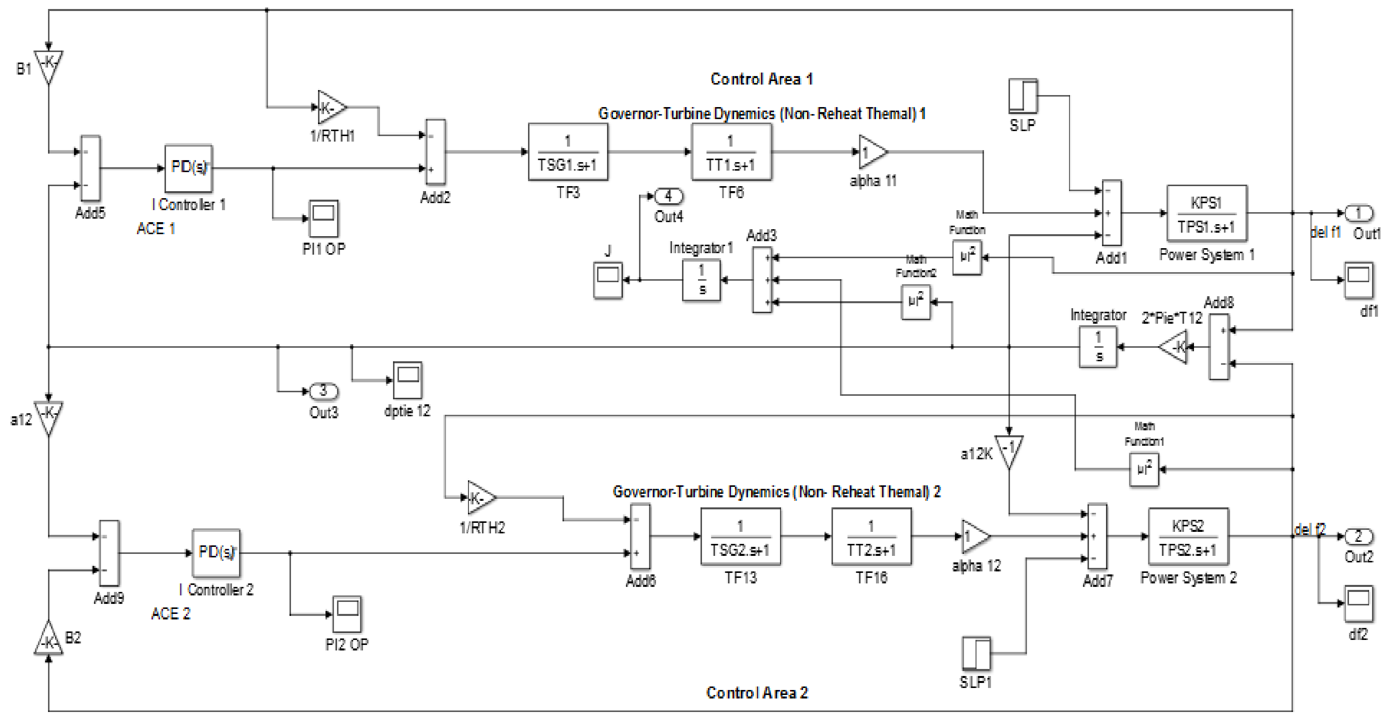

Fig.4. Transfer Function of PID controller.

PSO Optimization Technique

The PSO is optimization tools and it's providing a population based search technique and this every one called particles and this particles change their position with time. In a PSO system; particles fly around in a multidimensional search/solution space. When each particles during the fly adjust their position on the basis of their own experience and the experience of their neighboring particle is defined by the set of particle neighboring the particles & their past experience. The particles fly for searching space with a velocity which is dynamically adjust according to own flying experience.

Let, a- A particle's co-ordinate position.

d -Their speed (velocity) in a search space.

Each particle is treated as a volume less particle and represented as a volume less particle and represented as $a_i = a_{i1}, a_{i2}, \ldots..a_{ix}$ in the x- dimensional space. The previous position of ith particle is represented as

$a_{besti} = (a_{besti1,}a_{besti2} \dots \dots a_{bestix})$. The index of the best particles among all the particles is treated as globel best particle and represented as h_{bestx}. The velocity of ith particle is represented as $d_i = d_{i1}, d_{i2}, \dots \dots d_{ix}$.

$$(d)_{ix}^{(t+1)} = d_{ix}^{t} * y + c_1 * rand(\quad) * (a_{bestix}^{t} - a_{ix}^{t}) + c_2 * Rand(\quad) * (h_{bestx}^{t} - a_{id}^{t}) \quad (1)$$

a = position of particles.
d = velocity of particles.
x = dimension of particles.
h = global best

$$a_{ix}^{(t+1)} = a_{ix}^{t} + d_{ix}^{(t+1)} \quad (2)$$

The modified velocity & position of each particles can be calculated using the recent value of velocity and the distance from position best to global best and this condition shown in following position; In the above equation, c_1 &c_2 are accredited as the acceleration coefficient that pull each particles towards the position best and global best. The value of Rand( ) & rand( ) both are the random numbers are accurate between 0 & 1.

rand ( )* ($a_{bestix}^{t} - a_{ix}^{t}$) = Cognitive component
Rand ( )* ($h_{bestix}^{t} - h_{ix}^{t}$) = Social component
w = Inertia weight factor

The low value of c_1&$c_2$recognize particles to roam far from the target regions and before being tugged back and the high values result in sudden movement towards c_1& $c_2$are usual set to be $c_1 = 1.8$ &c_2 = 1.7 in this project. The value of inertia weight factor w = 1 and the damping ratio of inertia weight$w_{damp} = 0.99$. The value of w and $w_{damp}$are used in I, PI, PD and PID Controller for Fuzzy-Tuned Controller this values are 1.5 & 2.0.

Simulation Results and Discussion

In this work, different control strategies for secondary control are implemented through MATLAB Simulink model. Integral Controller (I), Proportional (P) Controller, Proportional-Integral (PI) Controller, Proportional-Integral-Derivative (PID) Controller and Fuzzy-Tuned Controller are used and their results are compared.

Case-I

Firstly, we apply Integral-Controller gains K_{I1} and K_{I2}in PID controller in Simulink model of two unequal area interconnected model and result waveform is shown in Fig 5(a), Fig 5(b), Fig 5(c) and also analysis; the response of settling time and overshoot time of LFC of area1 & area2 and as well as studies about tie-line power and compare their response to each other.Frequency deviation in area-1. In case of Integral controller the value of overshoot time of area1 = 8.4 and the value of overshoot time of area-2 = 3.352, Best Cost = 0.00052836.

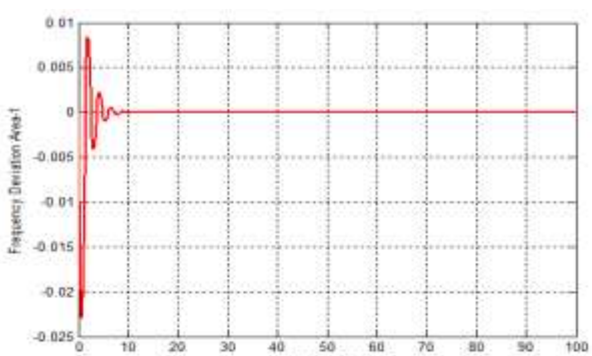

Fig 5(a).Frequency deviation in area-1 of thermal power system with integral controller.

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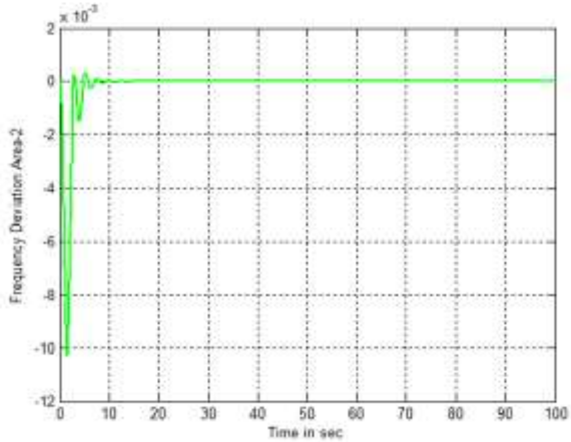

Fig 5(b).Frequency deviation in area-2 of thermal power system with integral controller.

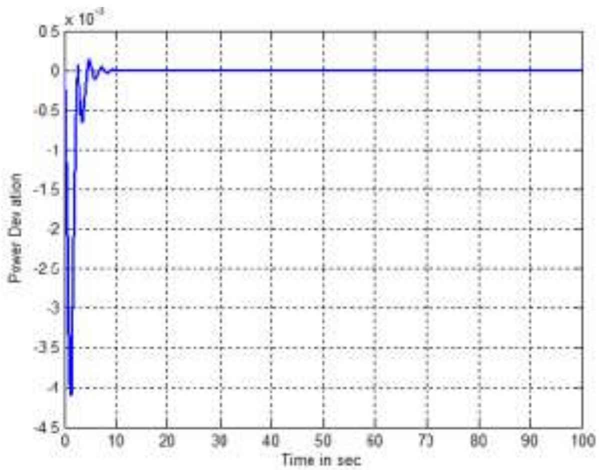

Fig 5(c).Tie line power deviation in two area thermal power system with I controller.

Case-II

Secondly, we apply Proportional-Controller gain K_{p1} and K_{p2} in PID controller in Simulink model of two unequal area interconnected model and result waveform is shown in Fig 6(a), Fig 6(b) and Fig 6(c) and also analysis; the response of settling time and overshoot time of LFC of area1 & area2 and as well as studies about tie line power and their response compared. In caseof proportional controller the value of overshoot time (df1) = 5.412.

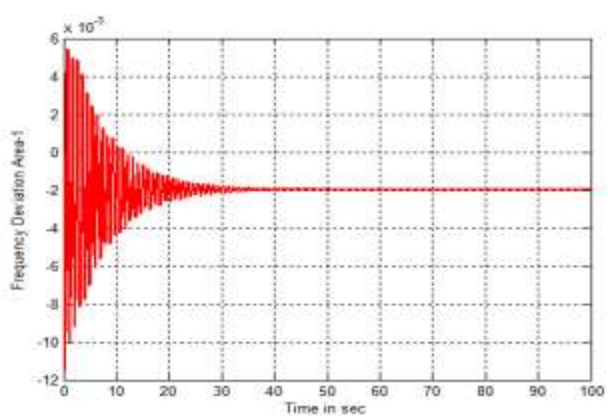

Fig 6(a).Frequency deviation in area-1 of thermal power system with P controller.

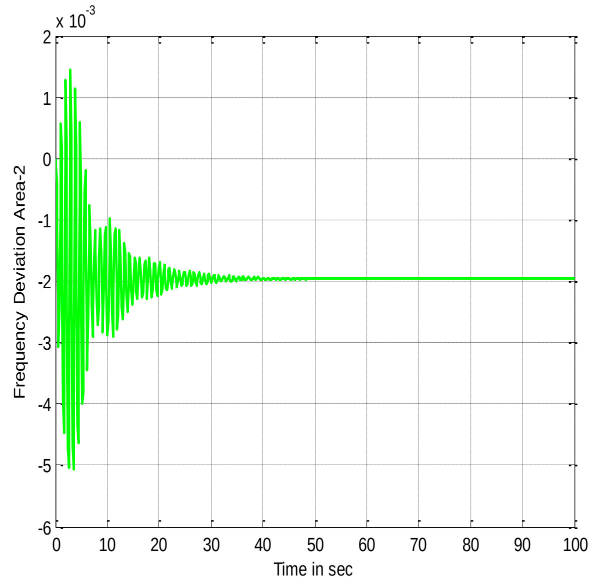

Fig 6(b).frequency deviation in area-2 of thermal power system with P controller.

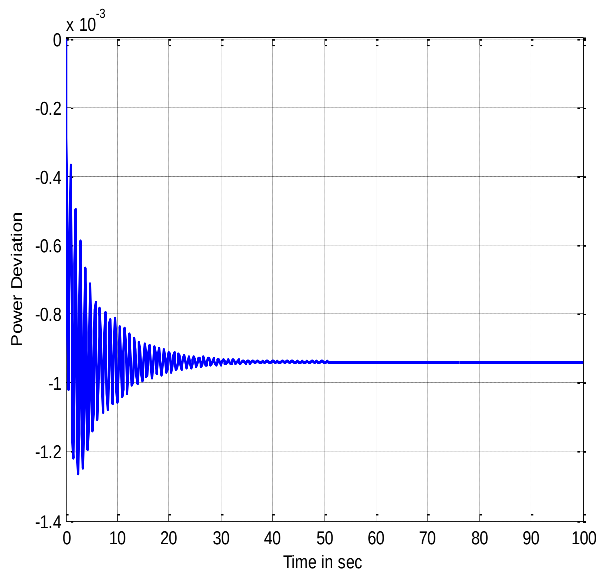

Fig 6(c).Tie-line power deviation in two area thermal power system with P controller

Area1	B1	K_{I1}	K_{P1}	R1	F1 settling time	P tie-line settling time
Fuzzy-PID	**0.4312**	**1.5000**	**1.5000**	**2.40**	**11.5**	**17**
I	**0.4312**	**0.8210**	**0.0000**	**2.40**	**15**	**13**
P	**0.4312**	**0.0000**	**4.6057**	**2.40**	**69**	**55**
PI	**0.4312**	**1.0362**	**2.6680**	**2.40**	**19**	**30**
PID	**0.4312**	**5.0000**	**5.0000**	**2.40**	**15.5**	**16**

TABLE-1

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Area2	B2	K_{I2}	K_{P2}	R2	F2 settling time	P tie-line settling time
Fuzzy-PID	0.500	1.4923	1.50	2.80	9.5	18
I	0.500	-0.0020	0.00	2.80	14	13
P	0.500	0.0000	5.00	2.80	66	55
PI	0.500	0.2941	5.00	2.80	30	30
PID	0.500	-0.0363	5.00	2.80	15	16

TABLE-2

Case III

Then, we apply Proportional-Integral-Controller gains K_{P1}, K_{P2} *and* K_{I1}, K_{I2} in Simulink model. The gains of PI controller is optimized, and overshoot time of area-1 =5.65, overshoot time of area-2 = 1.78 and Tie-line power deviation response is obtained, shown in fig 7(a), 7(b) and 7(c) and Table-1 & Table-2 is represent the response of this controller. The overshoot time of frequency deviation in area-1 = 5.65, overshoot time of frequency deviation in area-2 = 1.78 and overshoot time of tie-line frequency deviation = 0, Best Cost = 0.00013922.

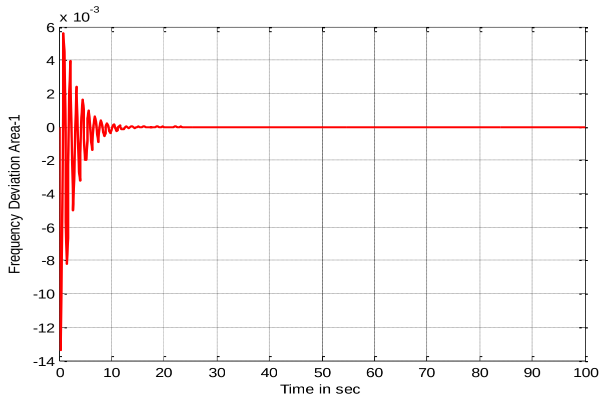

Fig 7(a).frequency deviation in area-1 of thermal power system with PI controller.

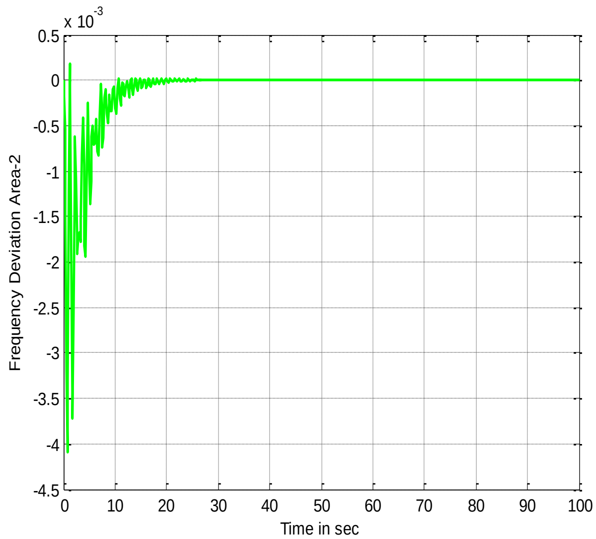

Fig 7(b).frequency deviation in area-2 of thermal power system with PI controller.

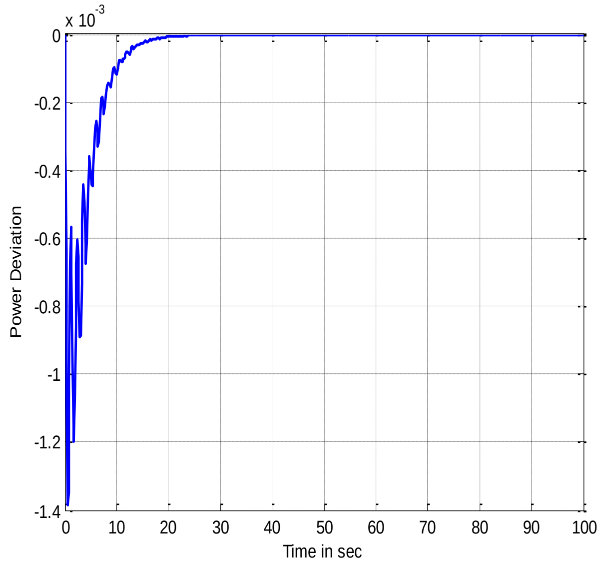

Fig 7(c).Tie-line power deviation in two area thermal power system with PI controller.

Case IV

After PID controller, we apply Proportional-Integral-Derivative - controller $K_{I1}, K_{I2}, K_{P1}, K_{P2}$ & K_{D1}, K_{D2} in Simulink model. The gains of PID controller is optimized, frequency deviation in area-1, frequency deviation in area-2 and Tie-line power deviation response is obtained, shown in fig 8(a), 8(b), 8(c) and Table-1 & Table-2 the response of this controller. The overshoot time of frequency deviation in area-1 = 3.410,overshoot time of frequency deviation in area-2 = 7.62& overshoot time of tie-line frequency deviation =3.85, $K_{D1} = 5.00$, $K_{D2} = 5.00$, Best Cost =6.5136e-06.

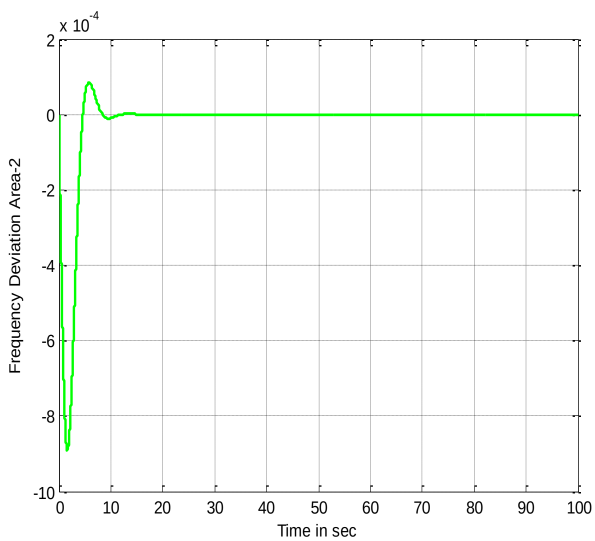

Fig 8(b).frequency deviation in area-2 thermal power system with PID controller.

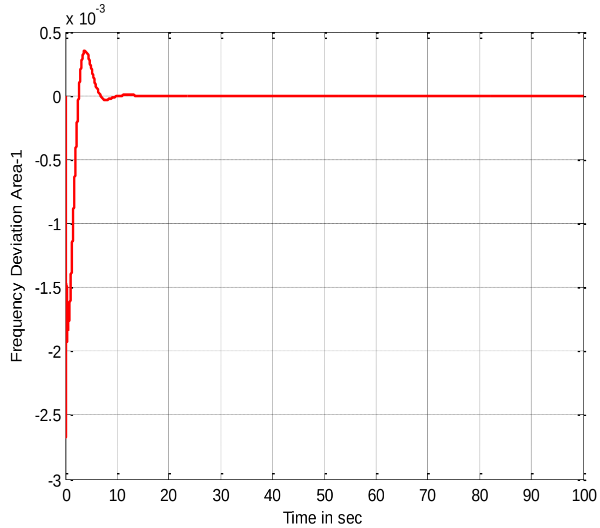

Fig 8(a).frequency deviation in area-1 thermal power system with PID controller.

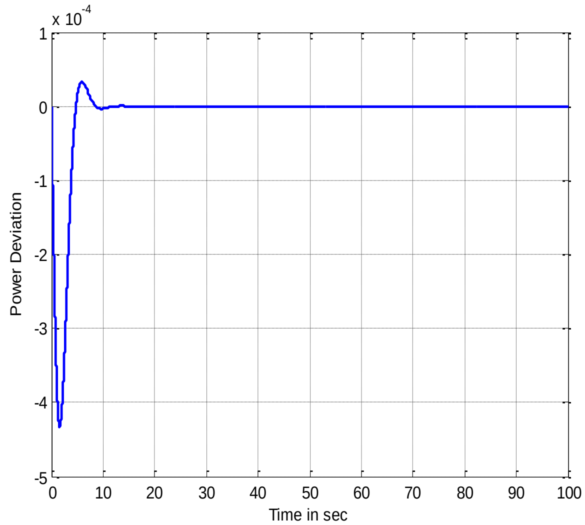

Fig 8(c).Tie-line frequency deviation intwo area thermal power system with PID Controller.

Case V

In the last we apply, In Fuzzy-PID-Controller we use maximum no of iteration = 50, lower & upper bound of variables = 0 to 1.5. Fuzzy-PID Controller and this controller is optimized and the response shown in Fig 9(a), Fig 9(b) & Fig 9(c) and Table-1 & Table-2. After optimization Fuzzy-Tuned Controller (Fuzzy-PID Controller) the result of

$\alpha 1 = 1.500,\ \alpha 2 = 1.500\ \&\ \beta 1 = 1.4926,$

$\beta 2 = 1.500.$

The overshoot time of frequency deviation in area-1 = 1.53 ,overshoot time of frequency deviation in area-2 = 0 and overshoot time of tie-line frequency deviation = 2.82, Best Cost = 0.00018912.

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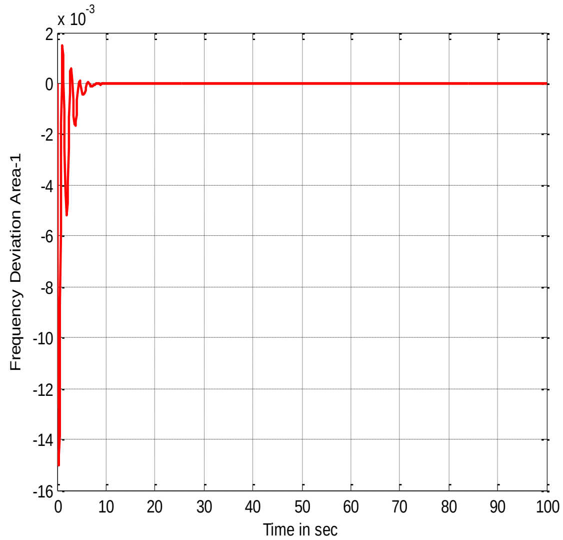

Fig.9(a).frequency deviation in area-1 thermal power system with Fuzzy- PID controller.

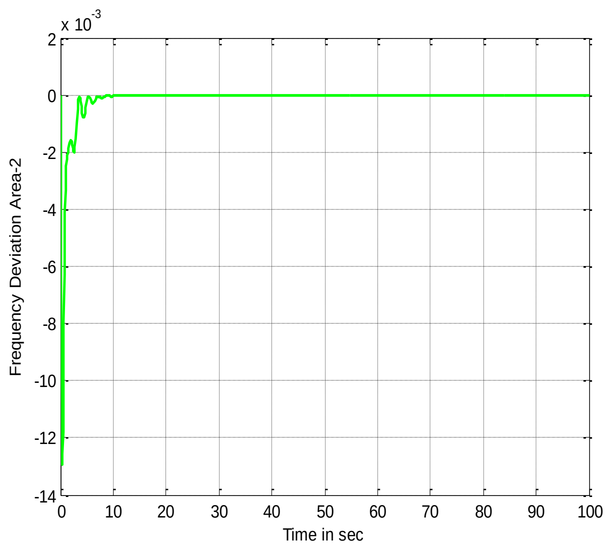

Fig.9(b).frequency deviation in area-2 thermal power system with Fuzzy- PID controller.

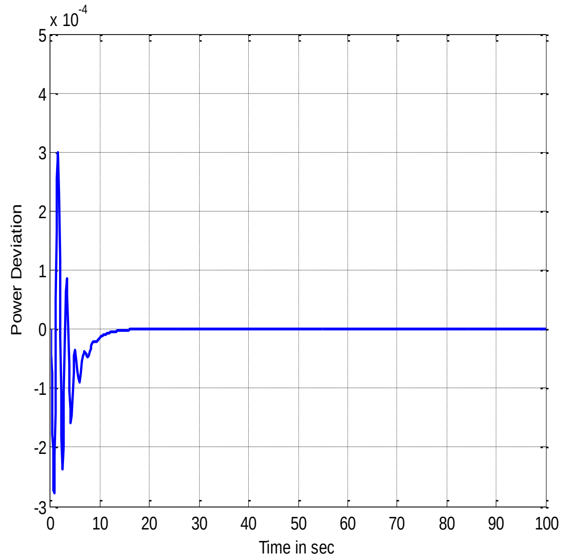

Fig.9(a) Tie-line frequency deviation in two area thermal power system with Fuzzy-PID Controller.

Appendix

KPS1 = 68.9655;KPS2 = 50;TPS1=11.49;TPS2=10;TSG1=0.06;TSG2=0.07;TT1=0.3;TT2=0.2;T12=0.0433;RTH1=2.4;RTH2=2.8;B1=0.4312;B2=0.5;a12=-1.

Conclusion

1.Particle Swarm Optimization Techanique for simultaneous optimization of controller gains has been applied for the two unequal area interconnected in automatic genertion control.

2. The optimum value of controller gains for conventional controller & soft controller and their values are: (i) Best Cost (I Controller) = 0.00052836, (ii) Best Cost (P Controller) = 0.0010586, (iii) Best Cost (PI Controller) = 0.00013922, (iv) Best Cost (PID Controller) = 6.5138 $\times 10^{-6}$ (v) Best Cost (Fuzzy-PID Controller) = 0.0001889. According to this cost function PID Controller provides optimum cost better than other controller.

3. Settling time of frequency deviation in area-1 for different controller shown in Table-1. According to this Table-1 Fuzzy-PID Controller (Df1=11.5) provides better settling time to other controller.

4. Settling time of frequency deviation in area-2 for different controller shown in Table-1. According to this Table-2 Fuzzy-PID Controller (Df2=9.5) provides better settling time to other controller.

5. Settling time of Tie-line frequency deviation in this power system for different controller shown in Table-1 & Table-2. According to this Table-1 & Table-2 Integral Controller (Df12=13) provides better settling time to other controller

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