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Intelligent Control Techniques for Parameter Tuning of PID Controller for LFC with Emphasis on Genetic Algorithm

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***Abstract*-** **The theme of this work is carried out to reduce the deviations involved in LFC of a developed system by via GA technique (intelligent controller) deployed PID controller. In MATLAB environment, the system is modelled and as well as simulated for conventional controller, Fuzzy, PSO and GA based PID tuning parameters. Simulation results shows that there is an improved dynamic response of the system when subjected to different step perturbations with proposed GA-PID controller.**

Index terms: Load Frequency Control, Integral Time Absolute Error, Fuzzy Logic Controller, Particle Swarm Optimization, Genetic Algorithm & PID controller.

I. INTRODUCTION

The goal of LFC during transient conditions is to maintain constant frequency, power exchanges and tackling system complex model as well as variations involved [1-3].In general case, the habitual apparent power produced by generators must be met in accordance with the load power variations. The principal task before a power system engineers is to provide good quality of power supply generated by a mixture of renewable and non-renewable sources of energy to the utility customers without any distortions.Load frequency control to be referred as by maintaining frequency within permissible limits by regulating both wattage input power generation and demand [12]. The variables (Δf and ΔP_{tie}) effects during power transient load power conditions.Automatic control is more efficient method of load frequency control because manual controls are sluggish and involve inherent human time lags. The problem of ALFC resolves into not only measuring Δf but also analysing the measured change from a reference measurement value. Keep view on this correction is initiated by using control strategy to keep the system original measured value. The risk of the interconnected system increases because of system design deals with more time varying parameters. Valid assumptions are to be incorporated in design of a system controller to enhance overall performance. Tyreus - Luyben, Cohen-Coon, Fertik, Z-N and Integral Control Methods, are considered for controlling the LFC of isolated single area system [3-5]. Integral gain of conventional controller restricts the dynamic performance of the system. An optimal control scheme based PSO which enhances the gain of controller for addressing LFC in power systems of single area or multi area type power systems. The authors [6-7] proposed the AGC by using a optimal controller for two area power system as well as compared the results.Intelligent control technique needs to be deployed to achieve further improvement in power system dynamics [8-11]. Among them GA has been used to deal complex optimization problems which uses H2/H∞ Controller [5-7].

II. MODEL INVESTIGATION & CONTROLLERS

Figure 1 shows the complete closed loop representation of power plant which comprises of governor, turbine, a generator and load with speed regulation as feedback etc., are represented by respective transfer functions.Table 1 shows the gains and time constants of the blocks for the system model shown in figure 1.

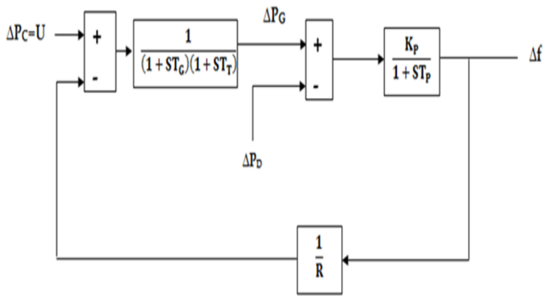

Fig.1 Single Area Thermal Power Generation Model

Table 1 Power System Parameters

Name of the Component	Gain	Time Constant
Governor	$K_G = 1$	$T_G = 0.08$
Turbine	$K_T = 1$	$T_T = 0.3$
Power System / Generator	$K_P = 120$	$T_P = 20$
Speed Regulation	$R = 2.4$	

The state space equations of the mentioned model shown in figure 1with state variables are listed below:

$$\dot{x_1} = \left(\frac{-1}{T_g}\right)x_1 + \left(\frac{K_P}{T_P}\right)x_3 - K_P\Delta P_D$$

$$\dot{x_2} = x_6$$

$$\dot{x_3} = \left(\frac{1}{T_t}\right)x_2 + \left(\frac{-1}{T_t}\right)x_3$$

$$\dot{x_4} = x_5$$

$$\dot{x_5} = \left(\frac{-K_P}{T_P T_t}\right) x_2 + \left(\frac{K_P}{T_P {T_t}^2}\right) x_3 + \left(\frac{-1}{T_g}\right) x_5 + \left(\frac{K_P}{T_P T_t}\right) x_6$$

$$\dot{x_6} = \left(\frac{k_i}{T_g}\right) x_1 + \left(\frac{k_p\ R-1}{T_g\ R}\right) x_4 + \left(\frac{k_d}{T_g}\right) x_5 + \left(\frac{-1}{T_g}\right) x_6$$

In Power system, invariably the nature of the elements is non-linear.At a particular working point linearization to be done to get a linear model from a nonlinear model. The actual conditions and practical conditions are differing in general scenario. Classical algorithms are used to design a load frequency with PID controller in terms of state space variables for the modeled system. The system dynamics are tabulated for uncontrolled, conventional, Fuzzy rule based, PSO based and GA based PID Controller in section III. The intelligent controllers implemented for the model to get hold of better tuning of gains are listed below.

PID Controller:

Almost in all control applications, PID controllers are extensively used because of its robustness and system performance. The proto type of PID controller has parameters namely K_P, K_i and K_d which are shown in the figure 2. To achieve better system performance within desirable limits; it is necessary to tune the K_P, K_i and $K_d$terms in the controller by appropriate optimization technique. Improper tuning leads to adverse effects on system performance.

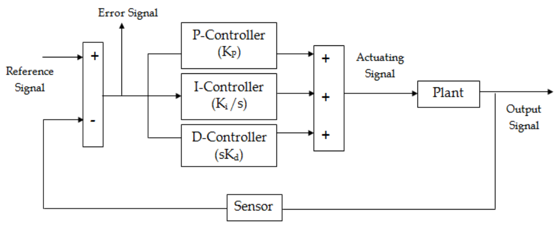

Fig.2 Proto Type PID Controller

Fuzzy Logic Controller:

The general Fuzzy based logic controller consists of fuzzification, rule based control and defuzzification shown in the figure 3. The logic is much closer to the human logics and is better as compared with classical systems. We cannot achieve satisfactory solutions from regular PID controllers due to the involvement of time varying variables while designing the system. The linguistic variables from [3] used for input e (t) and $[\dot{e(t)}]$ for the chosen model as well as for output also under fuzzification and rule based fuzzy table framed and shown in table 2 for the model shown in figure 1 based on If and Then rules. Centroid method used for defuzzification process to transform the output linguistic variable to a real value signal.

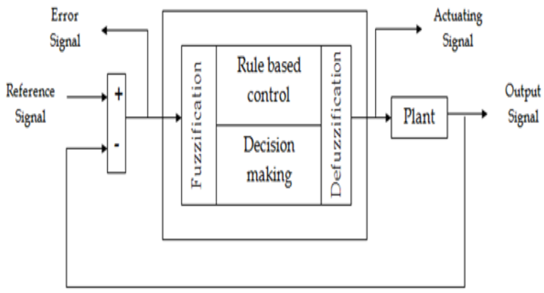

Fig.3 Fuzzy Logic Controller

Table 2: Fuzzy rule based table

de/dt \ (e)	NL (Negative Large)	NS (Negative Short)	ZZ (Zero)	PS (Positive Short)	PL (Positive Large)
NL (Negative Large)	S	S	M	M	L
NS (Negative Short)	S	M	M	L	VL
ZZ (Zero)	M	M	L	VL	VL
PS (Positive Short)	M	L	VL	VL	VVL
PL (Positive Large)	L	VL	VL	VVL	VVL

PSO Algorithm:

PSO is also one of the soft computing techniques to acquire better tuning values for parameters involved in PID controller to solve more complex engineering problems. The procedure for minimization of performance index which is integral time absolute error (ITAE) **i.e.,** ITAE= $\int t\ e(t)dt$ and frequency deviation is an error function is obtained by uniformly distributed particles, particle's position and particles velocities & weights. Figure 4 shows the flow chart of PSO algorithm.

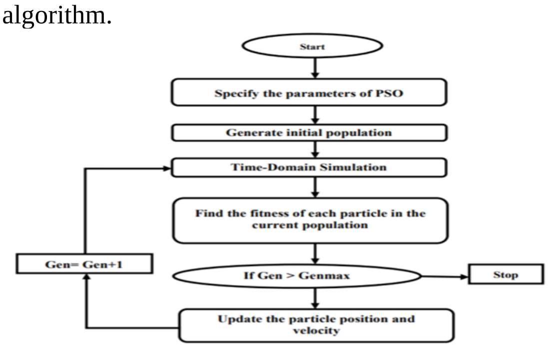

Fig.4 PSO Algorithm Flow Chart

Genetic Algorithm:

To solve more complex problems GA isused and the process involved represented by flow chart which is shown in figure 5. The procedure for minimization of performance index which is integral time absolute error (ITAE) = $\int t\ e(t)dt$ and frequency deviation is an error function is obtained by reproduction, crossover and mutation.

III. SIMULATION RESULTS:

For the modelled system, by applying step change in load perturbation (ΔP_D = 0.01, 0.02, 0.03, 0.04 & 0.05) applied to the generator for the system. The dynamic responses of the system for the above mentioned step inputs are shown in figures 6 to 10. The dynamics of the system analysed in terms of undershoot static error and settling time (mentioned in table 3) with GA based, PSO based, Fuzzy Logic PID controllers. From the responses it is observed that GA-PID controller performs better transient behaviour with minimum time that indicates the effectiveness of implemented controller with other controllers.

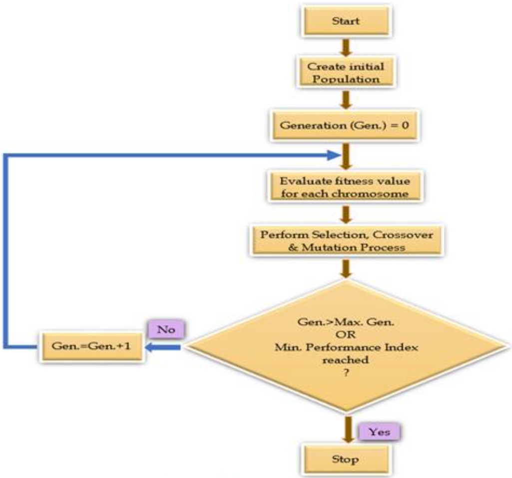

Fig. 5 Genetic Algorithm Flow Chart

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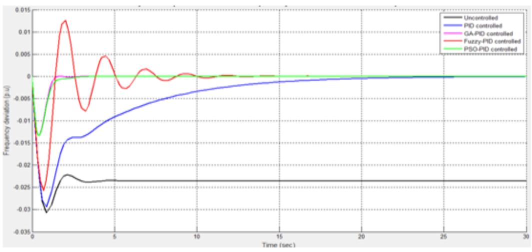

Fig.6 Dynamic Response of Isolated Thermal System with a disturbance of ΔP_D = 0.01

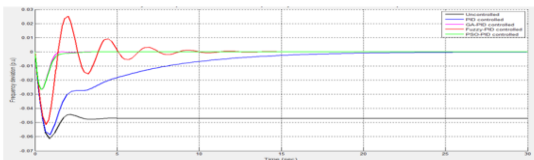

Fig.7 Dynamic Response of Isolated Thermal System with a disturbance of ΔP_D = 0.02

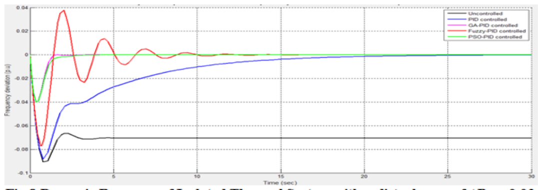

Fig.8 Dynamic Response of Isolated Thermal System with a disturbance of ΔP_D = 0.03

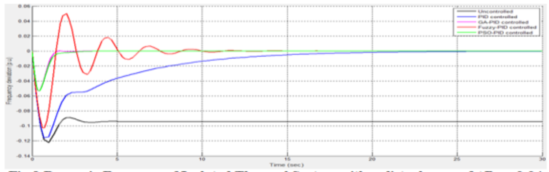

Fig.9 Dynamic Response of Isolated Thermal System with a disturbance of ΔP_D = 0.04

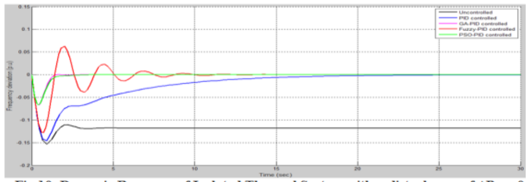

Fig.10 Dynamic Response of Isolated Thermal System with a disturbance of ΔP_D = 0.05

Table 3 Comparison of Different Controllers

Disturbance with ΔP_D=0.01			
Type of Controller	**Undershoot**	**Static Error**	**Settling Time**
Uncontrolled	-0.03069	-0.02352	4.255
PID controlled	-0.02942	0	23.780
Fuzzy-PID controlled	-0.02716	0	6.755
PSO-PID controlled	-0.01329	0	3.195
GA-PID controlled	-0.01325	0	2.744
Disturbance with ΔP_D =0.02			
Type of Controller	**Undershoot**	**Static Error**	**Settling Time**
Uncontrolled	-0.06139	-0.04697	4.439
PID controlled	-0.05855	0	24.030
Fuzzy-PID controlled	-0.05355	0	7.641
PSO-PID controlled	-0.02658	0	3.459
GA-PID controlled	-0.02638	0	3.226
Disturbance with ΔP_D =0.03			
Type of Controller	**Undershoot**	**Static Error**	**Settling Time**
Uncontrolled	-0.09076	-0.07044	4.817
PID controlled	-0.08821	0	24.860
Fuzzy-PID controlled	-0.08035	0	8.032
PSO-PID controlled	-0.04003	0	3.765
GA-PID controlled	-0.03999	0	3.507
Disturbance with ΔP_D =0.04			
Type of Controller	**Undershoot**	**Static Error**	**Settling Time**
Uncontrolled	-0.12201	-0.09405	5.045
PID controlled	-0.11560	0	25.310
Fuzzy-PID controlled	-0.10250	0	11.49
PSO-PID controlled	-0.05332	0	4.566
GA-PID controlled	-0.05228	0	4.255
Disturbance with ΔP_D =0.05			
Type of Controller	**Undershoot**	**Static Error**	**Settling Time**
Uncontrolled	-0.15340	-0.11770	5.685
PID controlled	-0.14590	0	26.451
Fuzzy-PID controlled	-0.12780	0	12.760
PSO-PID controlled	-0.06599	0	5.349
GA-PID controlled	-0.06579	0	5.021

V. CONCLUSION

A single area Load frequency control problem with PID controller is modelled and state variables are derived. Conventional controller, Fuzzy based, PSO based and GA based PID controllers are applied to the generator to get dead beat response from the system. These controllers are used to minimize the system transient behaviour pertaining to step load disturbances i.e., ΔP_D (p.u.) =0.01 to 0.05 in steps of 0.01. GA based PID tuned controller improves the system transient behaviour in contrast with other controllers implemented. The proposed GA controller is more robust in nature to minimize the system transient behaviour. There is a scope for further research to where the robustness of power system can be improved by new soft computing techniques which deals optimization of complex problems.

VI. REFERENCES

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