LOAD FREQUENCY CONTROL IN TWO AREA THERMAL POWER SYSTEM USING OPTIMIZED CONTROLLER

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***Abstract*—**In this paper, particle swarm optimization based optimal proportional-plus-integral controller is designed for load frequency control of a two area thermal power system. The design is determined an optimization problem and a minimizing the error function is derived for increasing the performance of convergence to the solution. To optimize the parameters of the PI controller,fuzzy logic technique and the particle swarm optimization algorithm are used. The results show that the PSO based PI is provided better performance than Fuzzy based PI for dynamic responses of the power system.

Keywords- *Automatic Generation Control (AGC), Two-area thermal power system, Particle Swarm Optimization (PSO) algorithm.*

1.Introduction

In Interconnected power system, a nominal system frequency depends on a balance between produced and consumed real power. A real power inequality in which occurs anywhere of the system is perceived in a whole network as a frequency deviation. Nevertheless, if it is taken into consideration that the properly working of industrial loads connecting to the power system depends on quality of electric energy, this balance is had to keep for holding the steady-state frequency error between acceptable values. The balance of real power in an interconnected power system is provided by the amount of produced power is less than the demanded one, the speed and also frequency of the generator decrease, and vice versa. For bringing frequency deviation to desired level back is provided control of the turbines which turn the generators. For this purpose, the PI-controller is classically used, and by tuning the controller gains, the steady-state error of the system frequency is minimized[1].

However, due to the complexity of the power system such as nonlinear load characteristics and variable operating points, the PI-controllers tuning with conventional methods may be unsuitable in some operating conditions. In literature, some different control strategies have been suggested based on the digital, self_tuning, adaptive, variable structure systems and intelligent/soft computing control.Recently, different PSO based controllers are commonly used in literature as a self-tuning control strategy for load frequency control.

In this study, a standard PSO algorithm is used to optimizing the PI- controller gains for load frequency control of a two area thermal power system[3]. To obtain the best convergence performance, new error function is derived by using tie-line power and frequency deviations of the control areas. it is used to determine the parameters of a PI controller according to the system dynamics changing with daily period. In this study, it is used to determine the parameters of a PI controller according to the system dynamics changing with daily period. In the integral controller, if the integral gain, ki, is very high, undesirable and unacceptable large overshoots will be occurred. However, adjusting the maximum and minimum values of proportional (kp) and integral (ki) gains. Settling times with the proposed PSO-PI controller are better than the outputs of the other controllers.

2. Two area control

A two area system consists of two single area systems, connected through a power line called tie-line, is shown in the figure-1. Each area feeds its user pool, and the tie line allows electric power to flow between the areas. Information about the local area is found in the tie line power fluctuations. Therefore, the tie-line power is sensed, and the resulting tie-line power signal is fed back into both areas. It is conveniently assumed that each control area can be represented by an equivalent turbine, generator and governor system. Symbol used with suffix 1 refer to area 1 and those with suffix 2 refer to area 2.

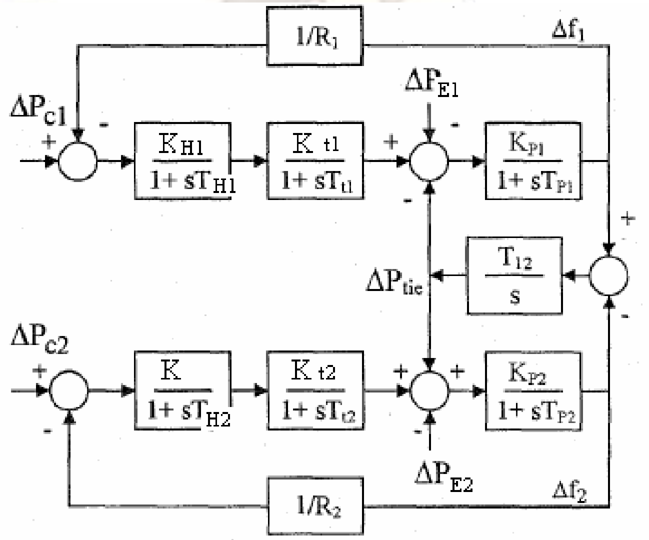

Figure-1. Basic block diagram of conventional two area system.

In an isolated control area case the incremental power was accounted for by the rate of increase of stored kinetic energy and increase in area load caused by increase in frequency.

Since a tie line transports power in or out of an area, this fact must be accounted for in the incremental power balance equation of each area [7].

The control system that is used in this paper is composed of a two area interconnected thermal power system. All areas include governor dead-band for system nonlinearity. At the simulation,

it is assumed that there is a load demanding in area-1. The linearized model of the controlled system is depicted in Fig.1,and system parameters are also given in Appendix.

In the above model, u1 and u2 are the control inputs from the controllers. ΔP_{L1} is step load changes of %1 of the nominal loading in area-1. Δ_{f1} and Δ_{f2} are frequency deviations of the control areas and ΔP_{tie} is the changing of the tie-line power. The governor dead-band is defined as the total magnitude of a sustained speed change within which there is no change in valve position. To represent the governor dead-band in the areas is used describing function approach. The governor dead-band nonlinearity tends to produce a continuous sinusoidal oscillation of natural period of about To= 2 s. This approach is used to liberalize the governor dead-band in terms of change and rate of change in the speed [5, 6]. The nonlinearity of the hysteresis is defined as,

y □ □*F(x,x1_)*

there, x is taken as a sinusoidal oscillation with f0 = 0.5 Hz.

x = Asinw0t

Since the dead-band nonlinearity tends to give continuously sinusoidal oscillation, such an assumption is quite realistic. - 1 -

When 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 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 its nominal 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 reasonability uniform frequency. Modern power system network consists of a number

1of utilities interconnected together and power is exchanged between utilities over tie lines by which they are connected. Automatic generation control (AGC) plays a very important role in power system as its main role is to maintain the system frequency

and tie line flow at their scheduled values during normal period.

3.Fuzzy Logic Controller

The Fuzzy logic control consists of three main stages, namely the fuzzification interface, the inference rules engine and the defuzzification interface [3]. For Load Frequency Control the process operator is assumed to respond to variables error (*e*) and change of error (*ce*).

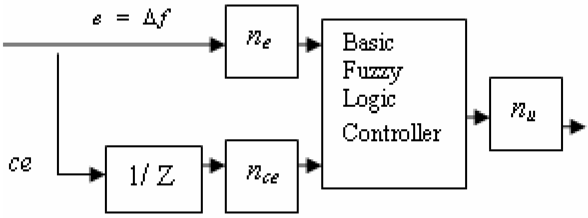

Figure-2. Block diagram of a fuzzy logic controller.

The variable error is equal to the real power system frequency deviation (). The frequency deviation is the difference between the nominal or scheduled power system frequency and the real power system frequency Taking the scaling gains into account, the global function of the FLC output signal can be written as

$\Delta PC=F[n_c e(k),n_{ce} ce(k)]$

Where, n_e and n_{ce} are the error and the change of error scaling gains, respectively, and F is a fuzzy nonlinear function. FLC is dependant to its inputs scaling gains [9]. The block diagram of FLC is shown in Figure-3. Output control gain is n_u and z is the maximum membership degree [3].

A label set corresponding to linguistic variables of the input control signals, *e (k) and* ce (k), with a sampling time of 0.01 sec is as follows:

L(*e, ce*) = { NB, NM, ZE, PM, PB},

Where, NB = Negative Big, NM = Negative Medium,

ZE = Zero, PM = Positive Medium, PB= Positive Big

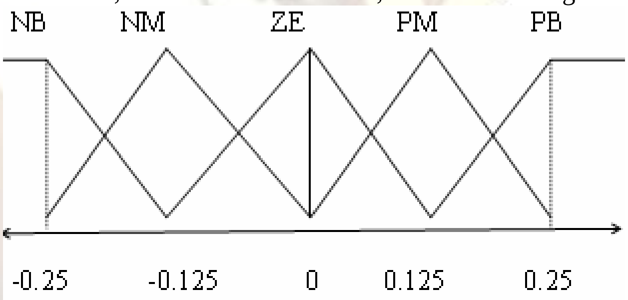

Figure-3. Membership function for the control input variables.

Fuzzy logic controller has been used in both the thermal-thermal and hydro-thermal interconnected areas. Attempt has been made to examine with five number of triangular membership function (MFs) which provides better dynamic response with the range on input (error in frequency deviation and change in frequency deviation) i.e. universe of discourse is -0.25 to 0.25. The numbers of rules are 25. The dynamic response are obtained and compared to those obtained with conventional integral controllers. Further, several inputs have been tried out and dynamic responses are examined in order to decide suitable inputs to the fuzzy logic controller (FLC) [10]. The membership functions (MFs) for the input variables are shown in Figure-3.

Table-1. Fuzzy inference rule for fuzzy logic controller.

Input	e(k)					
ce(k)		NB	NM	ZE	PM	PB
	NB	NB	NB	NM	NM	ZE
	NM	NB	NB	NM	ZE	ZE
	ZE	NM	NM	ZE	PM	PM
	PM	ZE	PM	PM	PB	PB
	PB	ZE	ZE	PM	PB	PB

4. Particle swarm optimization

Particle swarm optimization(PSO) is a population(swarm)based stochastic optimization algorithm which is first introduced by Kennedy and Eberhart in 1995.It can be obtained high quality solutions within shorter calculation time and stable convergence characteristics with PSO algorithm than other stochastic methods such as genetic algorithm. Because of these specifications, it is used for many power system areas such as AVR systems, Voltage/var control systems and power factor correction systems.

Particle swarm optimization uses particles which represent potential solutions of the problem. Each particles fly in search space at a certain velocity which can be adjusted in light of certain velocity which can be adjusted in light of proceeding flight experiences. The projected position of i^{th} particle of the swarm Xi, and the velocity of this particle vi at $(t+1)^{th}$ iteration are defined as the following two equations in this study:

$$V^i_{t+1} = wV^i_t + c1r1(P^i_t - X^i_t) + c2r2(P^g_t - X^i_t) \quad (1)$$

$$X^i_{t+1} = X^i_t + V^i_{t+1} \quad (2)$$

Where, i=1,….,n and n is the size of the swarm, D is dimension of the problem space,c1 and c2 are positive constants,r1 and r2 are random numbers which are uniformly distributed in [0,1],t determines the iteration number, p_i represents the best previous position(the position giving the best fitness value) of the i^{th} particle , and g represents the best among all the particles in the swarm. The algorithm of PSO can be depicted as follows:

1. Initialize a population of particles with random positions and velocities on D-dimensions in the problem space,
2. Evaluate desired optimization fitness function in D variables for each particle,
3. Compare particle's fitness evaluation with its previous position. If current value is better ,then set best previous position equal to the current value, and p_i equals to the current location Xi in D-dimensional space,
4. Identify the particle in the neighborhood with the best fitness so far, and assign its index to the variable g,
5. Change velocity and position of the particle according to equation (1) and (2),
6. Loop to step 2 until a criterion is met or end of iterations.

At the end of the iterations, the best position of the swarm will be the solution of the problem.It is not possible to get an optimum result of the problem always, but the obtained solution will be an optimal one. it cannot be able to an optimum result of the problem, but certainly it will be an optimal one[4].

5.Design of PSO-PI Controller

There are six steps for PSO-PI Controller follows;

1. The algorithm parameters like number of generation, population, inertia weight and constants are initialized.
2. The values of the parameters Kp and Ki initialized randomly.
3. The fitness function of each particle in each generation is calculated.
4. The local best of each particle and the global best of each particle are calculated.
5. The posion, Velocity, Local best and global best is each generation is updated.
6. Repeat the steps 3 to 5 until the maximum iteration reached or the best solution is found.

6.Simulink Model PSO-PI Controller

Fig-4. shows the simulink model of the plant with PSO algorithm based PI controller.

The PSO algorithm is used to search an optimal parameter set containing K_p and K_i. The parameters used for tuning the PSO algorithm and simulink models are tabulated in table below and Fig-5 represents the corresponding flow chart.LFC block indicates the two area thermal power plant. This is general simulink model for PSO-PI controller.

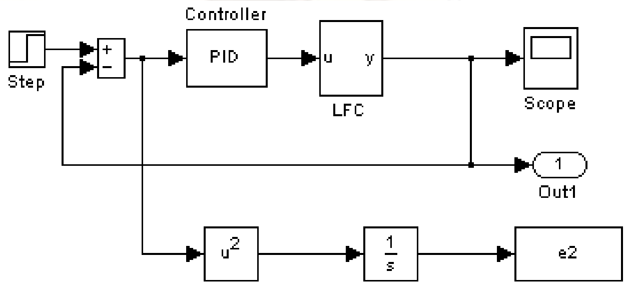

Figure-4 Simulink model of PSO-PI Controller.

PSO algorithm, which is tailored for optimizing difficult numerical functions and based on metaphor of human social interaction, is capable of mimicking the ability of human societies to process knowledge [11]. It has roots in two main component methodologies: artificial life (such as bird flocking, fish schooling and swarming) and, evolutionary computation. Its key concept is that potential solutions are flown through hyperspace and are accelerated towards better or more optimum solutions. Its paradigm can be implemented in simple form of computer codes and is computationally inexpensive in terms of both memory requirements and speed.

It lies somewhere in between evolutionary programming and the genetic algorithms.

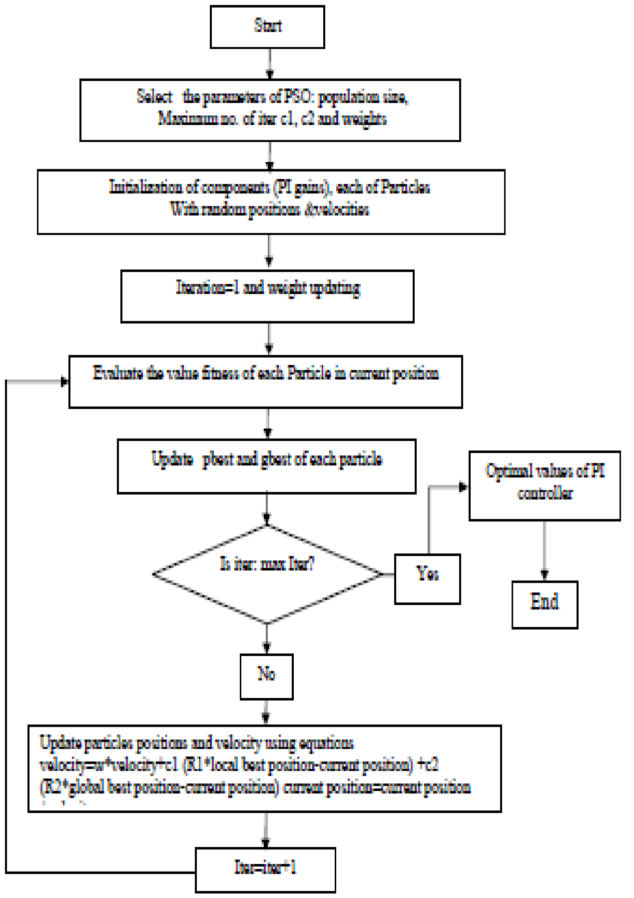

Figure-5.Flowchart for PSO based PI

7.Simulation and Results

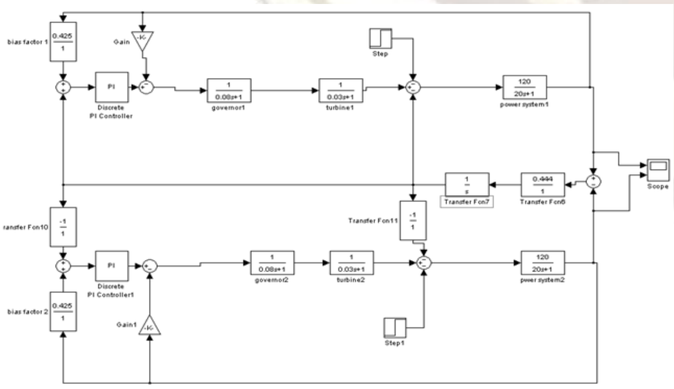

Figure-6.Simulation model of load frequency control in two area thermal power system using conventional PI controller

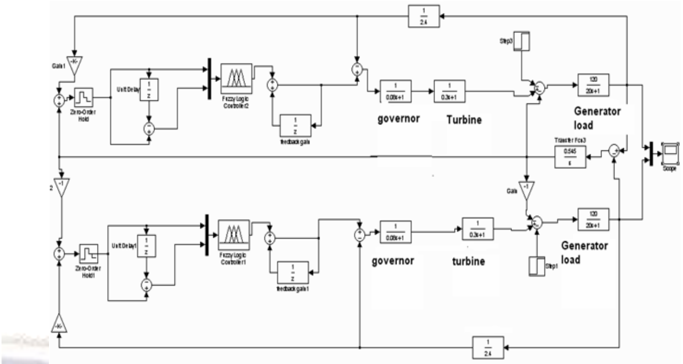

Figure-7 Simulink model of two area thermal power system with Fuzzy PI controller.

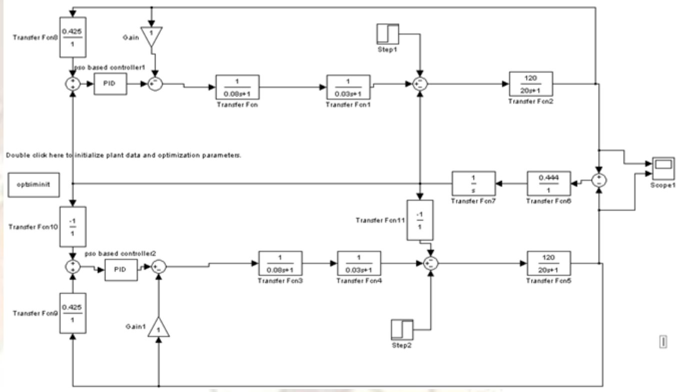

Figure-8 Simulink model of two area thermal power system with PSO-PI controller.

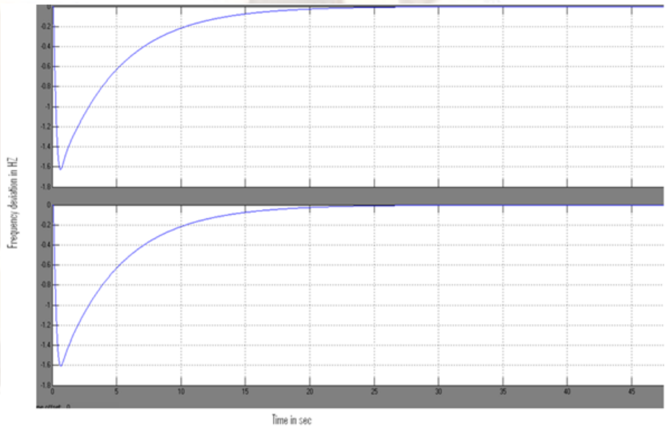

Figure-9 Response of two area thermal power plant with conventional PI controller

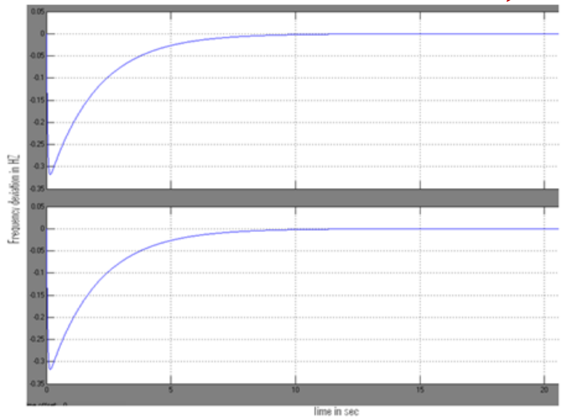

Figure-10 Response of two area thermal power plant with Fuzzy PI controller

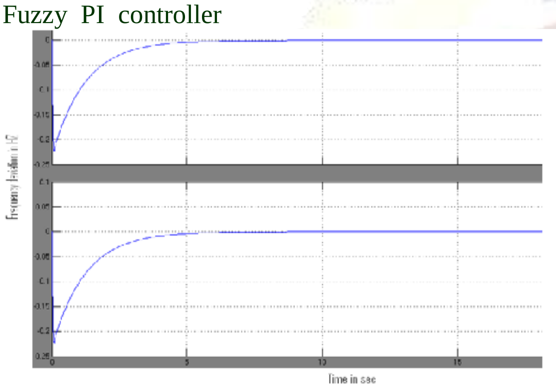

Figure-11 Response of two area thermal power plant with PSO-PI controller

8. Comparison of Results

Table-2: Results Comparison

CONTROLLER	KP	KI	FREQUENCY DEVIATION IN HZ	AREA CONTROL ERROR IN MW	SETTLING TIME IN SEC
CONVENTIONAL PI	-0.45	-0.29	-1.6	-0.0001695	15
FUZZY BASED PI	-0.9	-0.5	-0.31	-8.992e-007	8
PSO BASED PI	-0.84	-0.72	-0.22	-1.093e-006	5

9. Conclusion

In this study, a new particle swarm optimized LFC has been investigated for automatic load frequency control of a two area thermal power system. For this purpose, first, to obtain more adaptive tuning mechanism for the PI controller parameters and sensitivity of the system is increased. It has been shown that the proposed control algorithm is effective and provides significant improvement in system performance. Therefore, the proposed PSO-PI controller is recommended to generate good quality and reliable electrical energy. In addition ,the proposed controller is very simple and easy to implement since it does not require many information about system parameters. Four area power system operation will be investigated in future.

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