PARTICLE SWARM OPTIMIZATION BASED LOAD FREQUENCY CONTROL IN A SINGLE AREA POWER SYSTEM

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Abstract: *In this study, a particle swarm optimization (PSO) based on load frequency control (LFC) of a single area power system is presented. The study has been realized to control of a single area interconnected power system with PSO optimized self-tuning PID controller. The comparison between a conventional Proportional-Integral (PI) controller and the proposed PSO based controller is showed that the proposed controller can generate the best dynamic response for a step load change. For this application, MATLAB-Simulink software is used.*

1. INTRODUCTION

The dynamic behavior of many power systems and resulted in industrial loads heavily depends on disturbances and in particular on changes in the operating point [1]. Load frequency control in power systems is very important in order to supply reliable electric power with good quality. The goal of the LFC is to maintain stable system frequency which has zero steady state errors, and to provide load sharing between areas in a multi area interconnected power system. In addition, the power system should fulfill the proposed dispatch conditions. Power systems are divided into control areas connected with tie-lines. All generators are supposed to constitute a coherent group in each control area. From the experiments on the power system, it can be seen that each area needs its system frequency to be controlled [2].

Generally, ordinary LFC systems are designed with Proportional-Integral (PI) controllers. However, since the “I” control parameters are usually tuned, it is incapable of obtaining good dynamic performance for various load and system change scenarios. Many studies have been carried out in the past about the load frequency control. In literature, some control strategies have been suggested based on the conventional linear control theory [3]. These controllers may be unsuitable in some operating conditions due to the complexity of the power systems such as nonlinear load characteristics and variable operating points. According to some authors, variable structure control [4] maintains stability of system frequency. However, this method needs some information for system states, which are very difficult to know completely. Also, the growing needs of complex and huge modern power systems require optimal and flexible operation of them. The dynamic and static properties of the system must be well known to design an efficient controller. On the other hand, to handle such a complex system is quite complicated [5]. According to [6], conventional PID control schemes will not reach a high degree of control performances. Since the dynamic behavior even for a reduced mathematical model of a power system is usually nonlinear, time-variant and governed by strong cross-couplings of the input variables, special care has to be taken for the design of the controllers. For this reason, recently, a lot of artificial intelligence based robust controllers such as genetic algorithm, tabu search algorithm, fuzzy logic and neural networks are used for PID controller parameters tuning in LFC by authors

[7, 8]. Since, Particle Swarm Optimization algorithm is an optimization method that finds the best parameters for controller in the uncertainty area of controller parameters and obtained controller is an optimal controller, it has been used in almost all sectors of industry and science. One of them is the load frequency control [12].

In this study, it is used to determine the parameters of a PID controller according to the system dynamics changing with daily period. In addition, for different applications, this method does not require a certain model [3]. In the integral controller, if the integral gain, Ki, is very high, undesirable and unacceptable large overshoots will be occurred [3]. However, adjusting the maximum and minimum values of proportional (K_p) and integral (K_i) gains respectively, the outputs of the system (voltage, frequency) can be improved. In this simulation study, K_p is made equal a regulation constant “R” to obtain robustness, and it is shown that the overshoots and settling times with the proposed PSO-PID controller are better than the outputs of the other controllers.

2. 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 [9, 10]. 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 [11]. Because of these specifications, it is used for many power system areas such as AVR systems [15], Voltage/VAR control systems [16], and power factor correction systems [17, 18].

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 proceeding flight experiences. The projected position of i^{th} particle of the swarm x_i, and the velocity of this particle v_i at $(t+1)^{th}$ iteration are defined as the following two equations in this study:

$$v_{iD}^{t+1} = K.\left(v_{iD}^{t} + c_1 r_1\left(p_{iD}^{t} - x_{iD}^{t}\right) + c_2 r_2\left(g_i^{t} - x_{iD}^{t}\right)\right) \quad (1)$$

$$x_{iD}^{t+1} = x_{iD}^{t} + v_{iD}^{t+1} \quad (2)$$

where, i = 1, ..., n and n is the size of the swarm, D is dimension of the problem space, c_1 and c_2 are positive constants, r_1 and r_2 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 particle 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 best 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 x_i 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 can not be able to an optimum result of the problem, but certainly it will be an optimal one.

3. SMART HOME ARCHITECTURE

Basically, single area power system consists of a governor, a turbine and a generator with feedback of regulation constant. System also includes step load change input to the generator. This work mainly related with the controller unit of a single area power system. Simple block diagram of a single area power system with the controller is shown in Figure 1.

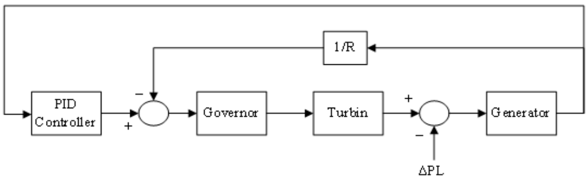

Fig. 1. A single area power system with the controllers (ΔPL = 0.01)

The framework of PSO based self-tuning PID controller is depicted as Figure 2. To find the optimum parameters (K_p, K_i, K_d) of PID controller, PSO program should search in 3-dimensional search space. In an ordinary load frequency control systems, since a regulation constant R is used as K_p parameter in PID controller, especially I (integral) controller is used in LFC systems. At the proposed system, K_p is made equal regulation constant R, and ID (integral-derivative) controller is used in LFC system. Thus, for robustness, regulation constant is tuned according to load and system changes, too. With the optimized parameters based on PSO algorithm, the proposed PID controller of the LFC can achieve optimal properties. The block diagram of a single area power system with this controller is shown in Figure 2.

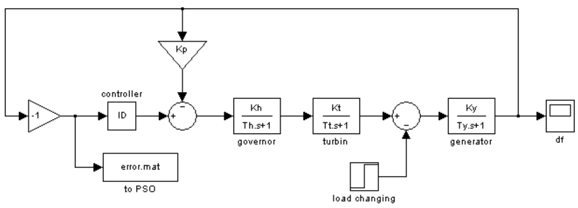

Fig. 2. A single area power system with proposed PSO-PID controllers

During the simulation study, error signal which is required for the controller is transferred to PSO software with error.mat component. All positions of particles on each dimension are clamped in limits which are specified by the user, and the velocities are clamped to the range [$v^{min.}$, $v^{max.}$] given as [13]:

$$v^{max} = k.x^{max} \quad , \quad 0.1 \le k \le 0.5 \tag{3}$$

$$v^{min.} = -v^{max} \tag{4}$$

To ensure to convergence of search, the constriction factor K in (1) is computed as follows [14],

$$K = \frac{2}{\left|2-\varphi-\sqrt{\varphi^2-4\varphi}\right|}, \varphi = c_1 + c_2 > 4 \tag{5}$$

In this simulation, the objective is to minimize the cost function. For this reason the objective function is chosen as the Integral Square Error (ISE). The ISE squares the error to remove negative error components [15].

$$ISE = \sum_{k=1}^{q} e^2(k) \tag{6}$$

PSO minimize the fitness function, the minimization objective function is transformed to be as fitness function as follows,

$$f = \frac{1}{ISE} \tag{7}$$

The ordinary single area power system parameters are given in Table 1. Simulation results for the single area power system are shown in Table 2, and Figure 3. As can be observed, the settling time and overshoots with the proposed PSO-PID controller are much shorter than that of with the conventional PI controller. Therefore, the proposed PSO-PID controller provides better performance than conventional PI controller for the single area power system.

Table 1: Parameters of the ordinary single area power system

Gains	Time Constants
K_h=1; K_t=1; K_y=120; K_i=0.65; K_p=0.45; R=2.4	T_h=80e-3; T_t=0.3; T_y=20

Table 2: System performances for conventional PI controller and proposed controller

Controllers	Settling Time (s)	Maximum Deviation (Hz)
Conventional PI	13.5	0.01966
Proposed PSO-PID	11.5	0.002662

At the simulation, the number of generations is taken 10 and the population size is taken 5. c_1 and c_2 constants are taken 2.05.

Table 3: Values of the PID parameters

	System parameters		
	Nominal	Increased by %20	Decreased by %50
K_p = R	3.3935	3.6957	4.6977
K_i	4.8989	3.7485	4.2232
K_d	1.5977	2.4893	2.6212

To show robustness of the proposed controller, all parameters of the system are increased by 20% and decreased %50 from their nominal values. These results are shown in Figure 4, Figure 5 and Table 3.

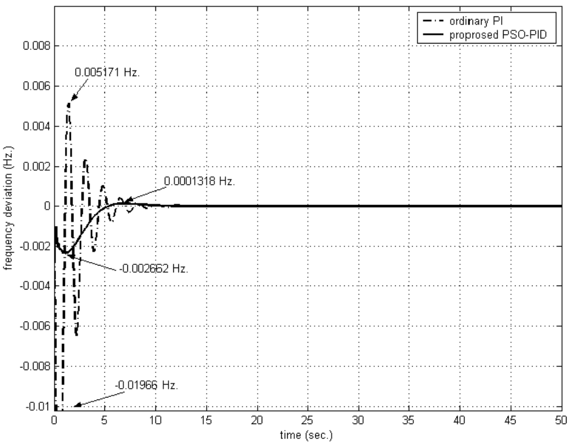

Fig. 3. Deviation of frequency of the single area power system

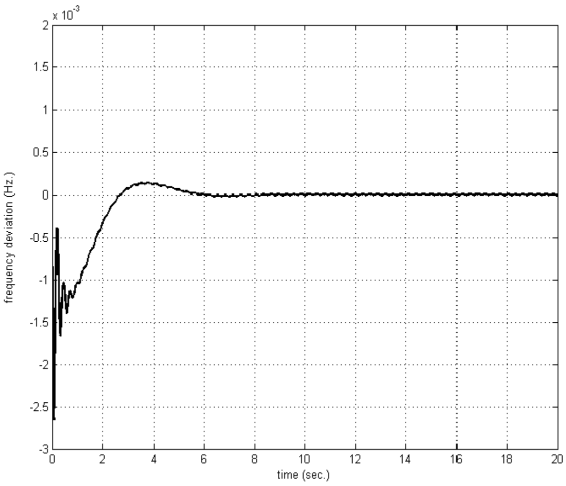

Fig. 4. Deviation of frequency in case of parameters increased by %20

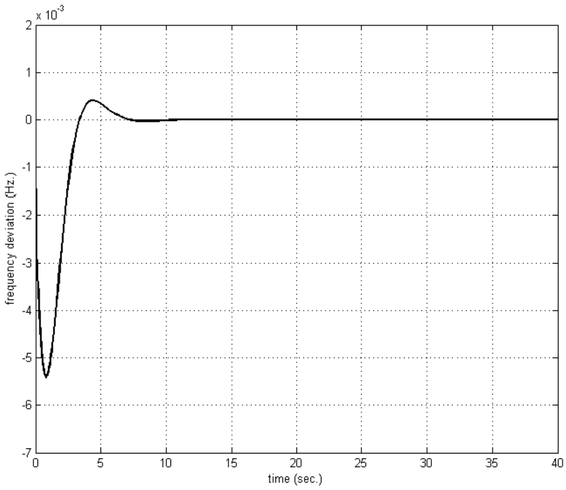

Fig. 5. Deviation of frequency in case of parameters decreased by %50

4. CONCLUSION

In this study, a new particle swarm optimized LFC has been investigated for automatic load frequency control of a single area power systems. For this purpose, first, to obtain more adaptive tuning mechanism for the PID 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-PID controller is recommended to generate good quality and reliable electric energy. In addition, the proposed controller is very simple and easy to implement since it does not require many information about system parameters. Two area power systems operation will be investigated in future. In addition, comparison of the proposed PSO-PID controller with conventional PID controllers will be subject to the future work.

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