PSO Tuned PID Controller for Single-Area Multi- Source LFC System

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***Abstract* -** This paper presents Particle Swarm Optimization (PSO) algorithm based tuning of integral controller for Load Frequency Control (LFC) of a Single Area multi-source power system integrated with thermal, hydro, gas and wind power plants. The gain parameter of the Integral (I) controller are tuned with PSO algorithm for a step load perturbations (SLP) applied to the LFC test system. Minimization of Integral Absolute Error (IAE) is taken as the objective function for LFC system. The superiority of the proposed approach has been proved by comparing the results with the uncontrolled converter for the same system configurations. In this proposed work, the MATLAB tool is used for designing the linearised circuit and the simulated results are measured through various performance measures such as, maximum peak, settling time and steady state error. The simulation studies were performed in both single-area single-source LFC system and single-area multi-source LFC system. The output results are compared with uncontrolled The output results evidently proves that the proposed PSO tuned integral controller provide better results and overcome the instability occurred in the uncontrolled LFC system while subjected to SLP.

Keywords: Load Frequency Control, Integral Controller, Particle Swarm Optimization Algorithm, Single-area multi-source LFC system.

1. INTRODUCTION

The main objective of LFC is to make zero steady state errors in frequency variations of the control areas. It also reduces damping of frequency oscillations and decreases overshoot and undershoot of the disturbance so as to improve the power system stability.

Load frequency control (LFC) technique is used to maintain the balance between load and generation in a power system. The sudden variation of Power demand (ΔP_d) in the power system adversely affects the system frequency and creates frequency error and thereby affects the real power. Hence, LFC is necessary to keep the frequency within a specific tolerance limit in each generating area to stabilize the grid power[1].

A multi-source power system is the interconnection of various power generating sources integrated together in each area. In most of the works the multi-source power system integrated with thermal, hydro and gas are considered[2] . Very few of the recent research articles started to incorporate wind energy in multi-source power system[3]. In this research article such wind generation incorporated multi-source system is considering as a test system for analysis.

Integration of wind energy generation to a multi- source system may create instability in the output frequency of the system and this may lead to instability. Hence a prominent controller has to be designed to overcome this problem. In this paper a basic integral controller is preferred due to its simplicity and reliability in application. Tuning the gain parameter of the integral controller is a challenging task. The trial and error method is one of the conventional approach normally used to predict the gain value of integral controller. However, it is not accurate and time consuming.

Many of the heuristic algorithms are preferred nowadays for optimal tuning of the gain parameters of integral controller. One of such prominent swarm intelligence approach named Particle Swarm Optimization Algorithm (PSO) is chosen in this paper for effective tuning of controller parameter.

The objective function plays a vital role in optimization problems. Normally, minimization of integrated absolute error (IAE), or integrated time absolute error (ITAE), or the integral of squared-error (ISE), or the integrated of time-weighted-squared-error (ITSE) are used as conventional objective functions for optimal tuning of controllers. For the fast response and to obtain less settling time the IAE is chosen in this research work.

The output performances of single-area LFC system with PSO tuned integral controller is compared with the non-controller system to prove its superiority. The output results evidently prove that the PSO tuned integral controller produces better results with good transient responses such as less settling time, minimum peak and oscillations.

2. DESCRIPTION OF LFC SYSTEM

2.1 SINGLE-AREA THERMAL LFC SYSTEM

Basically, single area power system of load frequency control consists of a governor, a turbine, and a generator with feedback of regulation constant. When the system load is increased suddenly then the electrical power exceeds to the input mechanical power. This inadequacy of power at the load side is met by the kinetic energy generated by the turbine. Due to this reason the energy that is stored in the machine is reduced and it slow down[4]. The governor then

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sends signal for supplying more volumes of water, steam or gas to increase the speed of the prime mover to compensate reduction in speed. Normally, the optimization of any physical system needs a linearized model. The linearized model of single area LFC system is shown in Fig-1

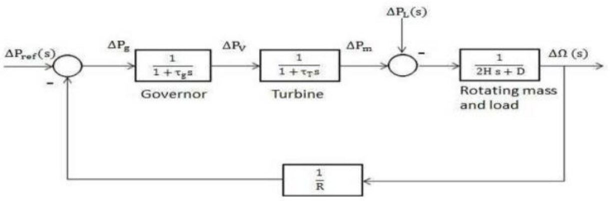

Fig-**1:** BLOCK DIAGRAM OF SINGLE AREA LINEARIZED LFC

2.1 SINGLE-AREA MULTI-SOURCE LFC SYSTEM

A small load change causes a transient frequency change in the power system. The LFC technique maintains the frequency to keep the system function properly. In the power system described in this paper, the power is generated from some conventional non-renewable sources like thermal, hydro, gas as well as a non-conventional renewable source i.e. wind [6]. Each power source contributes to the total generated power in the hybrid power system. Fig.2 shows the model of the hybrid power system and all the system parameters are defined in the Appendix A.

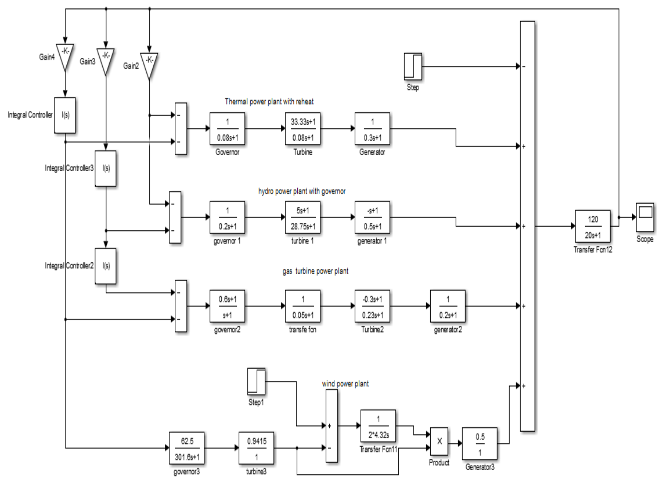

Fig-2:block diagram of single area multi source LFC system

3. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization is an computation technique developed by Kennedy and Eber hart in 1995 (Kennedy and Eber hart 1995; Eber hart and Kennedy, 1995; Eber hart, Simpson, and Dobbins 1996). Thus, at the time of the writing of this paper, PSO been around for just over five years. It seems like an appropriate time to step back and look at where we are, how we got here, and where we think we may be going. The original algorithm is presented first. Particle swarm optimization uses particles which represents the potential solutions of the problem[5]. The projected position of ith 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:

$$V_{iD}^{t+1}=K.(\ V_{iD}^{t}+c_1r_1(P_{iD}^{t}-X_{iD}^{t})+c_2r_2(g_i^{t}-x_{iD}^{t})) \qquad -(1)$$

$$X_{iD}^{t+1}=X_{iD}^{t}+V_{iD}^{t+1} \qquad -(2)$$

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 Each particles fly in search space at a certain velocity which can be adjusted in light of proceeding flight experiences.The algorithm of PSO can be depicted as follows:

1. Initialize a population of particles with random position and velocities on the D-dimensions in the problem space,

2. Evaluate desired optimization fitness function in the D variables for each particle,

3. Compare particle's fitness evaluation with the best previous position. If current value is better then the set best previous position equal to the current value, and pi equals to the current location xi in D-dimensional space,

4. Identify the particle in the neighborhood with best fitness so far, and assign its index to the variable g,

5. Change velocity and position of the particle according to Eqn. (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 particle swarm will be the solution of the problem.

5. RESULTS AND DISCUSSIONS:

The analyses in this research work are carried out with MATLAB R2014a software package. At first, the simulink model of the multi-source single-area LFC test system shown in Fig-2 with the corresponding system configurations given in Appendix is created using a MATLAB simulation tool. The transient response analysis is then carried out on the system by applying a step load increase (ΔP_L) of 1% to the LFC test system. The resultant output response of the system over the simulation period of 20s is shown in Fig-3. Some of the most significant specifications of the system response such as settling time, maximum peak and steady state error are measured at the output to analyse the system performances. These output measures are tabulated in Table.

The Fig-3 clearly illustrates that, the output response of the non-controller system is became instable. Hence it will lead the system towards instability and affects the operation of system. Hence a secondary controller is designed for the system with optimal control parameters for improving the results. The tuned integral controller parameters of thermal, hydro, gas power generating systems are $K_{I\,THERMAL}$=0.11588, $K_{I\,HYDRO}$=0.78535 , $K_{I\,GAS}$=0.46717 respectively. It is also clear from the table and Fig-3. that the output performance the multi-source single-area LFC system are significantly enhanced with minimum steady state error, settling time and peak by PSO tuned integral controller compared to other optimization methodologies.

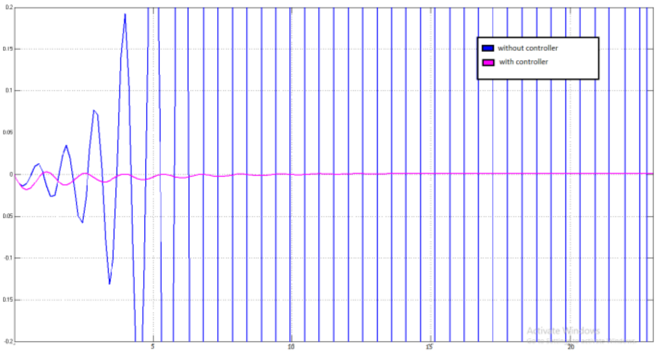

Fig-3:comparison of results

Transient measuring parameters	Without controller	PSO tuned INTEGRAL controller
Settling time (s)	Instable	26.756
Maximum peak (Hz)	Instable	0.018191
Rise time (s)	Instable	0.0012876
Steady state error (Hz)	Instable	3.7081e-05

7. CONCLUSION

In this research thesis, an off-line tuning of integral controller for power system was carried out by appropriate intelligent tuning methodology named PSO to identify the changing dynamics of the power grid at all times and to provides appropriate control actions. An integral absolute error of the frequency deviation is taken as the objective function to improve the system response in terms of settling time and overshoots. Simulation results emphasis that the proposed PSO tuned integral controller produces better output response compared to the non-controller system response by minimizing the output oscillations, settling time and peak overshoot. Hence, it is clear that the proposed PSO tuned integral controller prevent the system from instability during load perturbations by providing proper control actions.

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APPENDIX A

Nomenclature and Values of the Simulink Model Variables

f (Nominal system frequency), Δ (Small deviation of a state variable), Δf (Incremental frequency deviation), ΔP_d (Incremental load change), ΔP_g (Incremental generation change), ΔP_{gt} (Incremental generation change in thermal power), ΔP_{gh} (Incremental generation change in hydro power), ΔP_{gg} (Incremental generation change in gas power), ΔP_{gw} (Incremental generation change in wind power), ACE (Area control error), R (Droop characteristics of the governor for thermal and hydro power generators (Primary Loop)) = 2.4, R_g (Droop characteristics of the governor for gas power generators (Primary Loop)) = 10, β (Frequency bias constant for ACE (Secondary Loop) = 0.425, T_p (Power system time constant) = 20 s, K_p (Power system gain) = 120.

Thermal: T_{gt} (Thermal governor time constant) = 0.08 s, T_t (Thermal turbine time constant) = 0.3 s, K_{rt} (Reheat turbine gain) = 10/3, T_{rt} (Reheat turbine time constant) = 10 s.

Hydro: T_w (Water time constant) = 1 s, T_{gh} (Hydro governor time constant) = 0.2 s, T_1 (Hydro governor time constant for transient droop compensation) = 5 s, T_2 (Hydro governor time constant) = 28.75 s.

Gas: X (Gas governor constant) = 0.6, Y (Gas governor constant) = 1, a (Valve position constant) = 1, b (Valve position constant) = 0.05, c (Valve position constant) = 1, T_{cr} (Compressor process time constant) = 0.3 s, T_f (Fuel time constant) = 0.23 s, T_{cd} (Time delay associated with compressor discharge system) = 0.2 s.