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Tuning of PID Controller in Multi Area Interconnected Power System Using Particle Swarm Optimization

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Abstract: *This paper addresses the dynamic performance of Load Frequency Control (LFC) of four area interconnected power system. In this, area-1 consists of thermal plant, area-2 consists of thermal with reheat system, area-3 consists of hydro plant and area-4 consists of gas power plant. The proposed system is the combination of most complicated system like hydro plant, gas plant and thermal plant with reheat turbine are interconnected which increases the nonlinearity of the system. All the four areas are equipped with PID controller and the parameters of these PID controllers are optimized using Particle Swarm Optimization (PSO). The objective function taken into consideration is Integral Square Error (ISE). The performance of controller is simulated in MATLAB/SIMULINK software. The existing LFC systems assist the frequency and tie line power deviations to settle quickly with zero steady state error.*

Keywords: *Load Frequency Control (LFC), Particle Swarm Optimization (PSO), Area Control Error (ACE), PID controller.*

I. Introduction

Power systems are extremely large and complex electrical networks consisting of generation networks, transmission networks and distribution networks along with loads which are being spread all over the network over a large geographical region[1]. In the power system, the system load keeps varying from time to time according to the requirements of the consumers. Accordingly to the requirements of the consumers properly designed controllers are required for the regulation of the system variations in order to maintain the stability of the power system.

The fast development of the industries has further lead to the increased complexity of the power system. Frequency is very much depends on active power and the voltage is very much depends on the reactive power. The active power and frequency control is referred as Load Frequency Control (LFC). Load Frequency Control (LFC) in a multi-area interconnected power system has four principal objectives when operating in either the normal or preventive operating states:

- Matching total system generation to total system load
- Regulating system electrical frequency error to zero
- Distributing system generation amongst control areas so that net area tie flows match net area ties flow schedules[2]

A typical large – scale power system is composed of several areas of generating units interconnected together and power is exchanged between the utilities. The problem of an interconnected power system is the control of electric energy with nominal system frequency, voltage profile and tie-line power interchanges within their prescribe limits.

There are several methods available for Load Frequency Control in an interconnected power system. The first proposed control approach is integral control action to minimize the Area Control Error (ACE). The main drawback of this controller is that the dynamic performance of the system is limited by its integral gain. Regardless of the potential of present control techniques with different structure, PID type controller is extensively used for solution of LFC problem. PID type controller is not only used for their simplicities, but PID controllers have some attractive features like more reliable, having a quick operation and more efficient. It has an ability of changing the dynamics of the system and this thing is more useful for designing a power system.

In traditional a method, such as trial and error method and Cohen-Coon, PID controller is tuned therefore, they are not able to provide fine robust performance. To attain best gains for PID controller, Genetic Algorithm (GA) or Particle Swarm Optimization (PSO) methods were used [3]. According to current study it has found that Genetic Algorithm (GA) has various drawbacks such as the parameters being optimized are very much correlated. They need to run several times to obtain best optimal solution. Also the premature convergence of Genetic Algorithm degrades its performance and reduces its search capability resulting in sub-optimal solutions. To overcome this problem of sub- optimal convergence, powerful computational intelligent evolutionary technique such as Particle Swarm Optimization (PSO) is proposed to optimize the PID gains of controller for the Load Frequency Control (LFC) problem in power systems.

The aim of this study is to observe the load frequency control and inter area tie-power control problem for a multi-area power system taking into consideration the uncertainties in the parameters of system. An optimal control scheme based particle swarm optimization (PSO) Algorithm method is used for tuning the parameters of this PID controller. The proposed controller is simulated for a four-area power system. In four-area power system area-1 consists of thermal plant, area-2 consists of thermal with reheat, area-3 consists of hydro plant and area-4 consists of gas plant. To show effectiveness of proposed method a comparative study is made between Trial and error method and Particle Swarm Optimization (PSO) method.

II. PID Controller

The block diagram of Proportional Integrative Derivative (PID) controller is shown in Fig.1.The PID controller improves the transient response so as to decrease inaccuracy amplitude with every oscillation and then output is ultimately settled to a final required value. Improved margin of stability is ensuring with PID controllers. The arithmetical equation for the PID controller is given as

$$Y(t) = K_p e(t) + K_i \int_0^t e(t)dt + K_d \frac{d}{dt} e(t) \qquad (1)$$

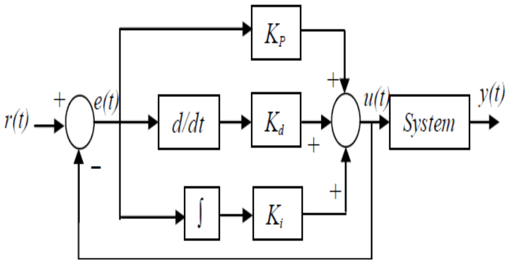

Figure 1: Block diagram of a PID controller

Where y (t) is the controller output and u (t) is the error signal. K_P, K_I and K_D are proportional, integral and derivative gains of the controller [3]. The proportional control (K_P) results in reduce of rise time but also results in oscillatory performance. The derivative control (K_D) reduces the oscillations by providing appropriate damping which results in improved transient performance with stability. The (K_I) integral control reduces the steady state error to zero. The goal is to get a good load disturbance response by optimally selecting PID controller parameters. The effect of the controller parameters K_P, K_I and K_D can be summarized as in Table 1. Usually, the control parameters have been obtained by trial and error approach, which consumes more amount of time in optimizing the choice of gains. To reduce the difficulty in tuning PID parameters, Evolutionary computation techniques can be used to solve an extensive range of realistic problems together with optimization and design of PID gains.

Table 1: Effect of Controller Parameters

Response	**Rise Time**	**Over-Shoot**	**Settling Time**	**Steady State Error**
K_P	Decrease	Increase	Minor Change	Decrease
K_I	Decrease	Increase	Increase	remove
K_D	Minor Change	Decrease	Decrease	Minor Change

III. System under Study

A multi-area interconnected power system is taken for LFC analysis. In multi-area power system area-1 consists of thermal plant, area-2 consists of thermal with reheat, area-3 consists of hydro plant and area-4 consists of gas plant. For an interconnected system, each area connected to others via tie line which is the basis for power exchange between them. When there is change in power in one area, which will be meeting by the raise in generation in every associated area with modify in the tie line power and a decrease in frequency. But in normal functioning state of the power system that is the demand of each area will be satisfied at a normal frequency and each area will absorb its own load changes. For each area there will be area control error (ACE) and this area control error (ACE) is reduced to zero by every individual area. The ACE of each area is the linear combination of the frequency and tie line error, i.e. ACE = Frequency error + Tie line error. The transfer function models of thermal, thermal with reheat; hydro and gas plants are described below.

3.1 Modelling of hydro plant

There are certain assumptions in representation of the hydraulic turbine and water column in stability study. The hydraulic resistance is negligible. The penstock pipe is assumed inelastic and water is incompressible. Also the speed of the water is considered to be varying directly with the gate opening and with the square root of the net head and the turbine output power is almost proportional to the product of head and volume flow [4].

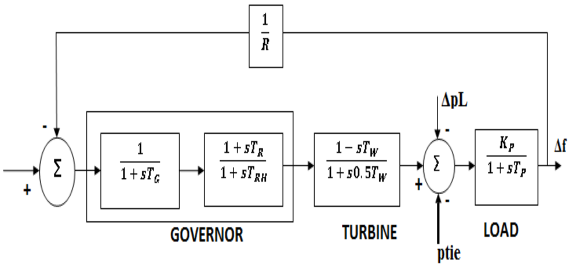

Figure 2: Block diagram of a hydro plant

Hydro plant is designed in the same way as thermal plants. The input to the hydro turbine is water instead of steam. Initial droop characteristics owing to decrease the pressure on turbine on opening the gate valve has to be compensated. Hydro turbines have irregular response due to water inertia; a change in gate position produces an initial turbine power change which is reverse to that required. For stable control performance, a large transient (temporary) droop with a long resettling time is therefore required in the forms of transient droop compensation as shown in Fig.2. The compensation limits gate movement until water flow power output has time to catch up. The result is governor exhibits a high droop for quick speed deviations and low droop in steady state.

3.2 Modelling of gas plant

A gas turbine power plant usually consists of valve positioned, speed governor, fuel system, combustor and gas turbine. The load-frequency model of gas turbine plant is shown in Fig. 3. The system frequency deviation and governor speed regulation parameters are represented by Δf in pu and R_G in Hz/p.u MW respectively. The transfer function representation of valve positioned is shown in Fig. 3, where, c_g is the valve positioned of gas turbine, b_g is the valve positioned constant of gas turbine.

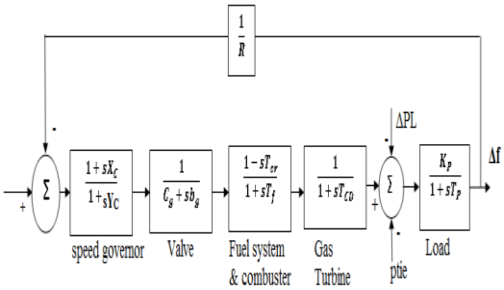

Figure 3: Block diagram of a gas plant

The speed governing system is represented by a lead-lag compensator as shown in Fig. 3, where, XC is the gas turbine speed governor lead time constant in sec, YC is the gas turbine speed governor lag time constant in sec. The fuel system and combustor is represented by a transfer function with appropriate time constants as shown in Fig. 3, where, T_F is the fuel time constant of gas turbine in sec and T_{CR} is the combustion reaction time delay of gas turbine in sec. The gas turbine is represented by a transfer function, consisting of a single time constant i.e. the gas turbine compressor discharge volume–time constant (T_{CD}) in sec [5].

3.3 Modelling of thermal plant

The transfer function modeling of thermal plant is described below. Thermal plant contains Speed governor, turbine and generator [4].

3.3.1. Speed Governing System

The command signal ΔP_C initiate a sequence of events-the pilot valve move upwards, high pressure oil flow on to the top of the main piston moving it downwards; the steam valve opening accordingly increase, the turbine generator speed increases, i.e. the frequency go up which is modeled mathematically.

$$\Delta Y_E(s) = \left[\Delta P_c(s) - \frac{1}{R}\Delta f(s)\right] * \left(\frac{K_{sg}}{1 + sT_{sg}}\right) \qquad (2)$$

3.3.2. Turbine model

The dynamic response of steam turbine is related to changes in steam valve opening ΔY_E in terms of changes in power output. Typically the time constant T_t lies in the range 0.2 to 2.5 sec.

3.3.3. Generator Load Model

The increment in power input to the generator load system is related to frequency change as

$$\Delta F(s) = [\Delta P_G(s) - \Delta P_D(s)] * \left(\frac{K_{ps}}{1 + T_{ps}}\right) \qquad (3)$$

A complete block diagram of an isolated power system comprising turbine, generator, governor and load is easily obtained by combining the blocks and complete block diagram of thermal plant without reheat is shown in Fig. 4.

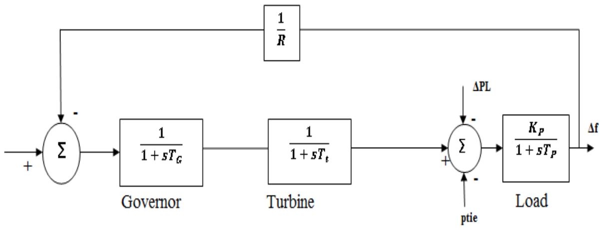

Figure 4: Block diagram of a thermal plant

Reheat block is modelled as second-order units, because they have diverse stages due to high and low steam pressure [6] [7]. The transfer function of reheat is represented as

$$G_R(s) = \frac{K_r T_r s+1}{T_r s+1} \qquad (4)$$

Where K_r represents low pressure reheat time and T_r represents high pressure reheat time. The block diagram of thermal plant with reheat is shown in Fig.5.

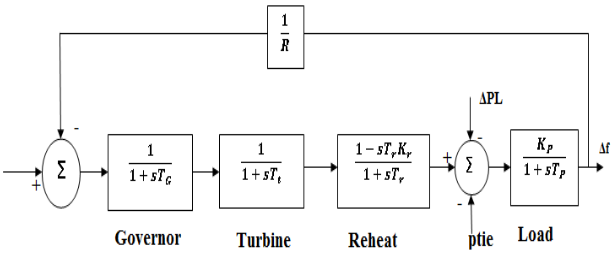

Figure 5: Block diagram of a thermal plant with reheat

The data of thermal, hydro, gas plant used in simulation studies is represented in Table 2 and the data taken from ref [8][9].

Table 2: system data

Parameters	values
Steam turbine without reheat:	
Speed governor time constant(T_g)	0.08s
Turbine time constant (T_T)	0.3s
Speed governor regulation parameter (R_{TH})	2.4HZ/pu MW
Steam turbine with reheat:	
Speed governor time constant(T_g)	0.08s
Turbine time constant (T_T)	0.3s
Speed governor regulation parameter (R_{TH})	2.4HZ/pu MW
Low pressure reheat time (K_r)	0.5sec
High pressure reheat time(T_r)	10sec
Hydro turbine:	
Speed governor time constant (T_{RS})	4.9s
Transient droop time constant (T_{RH})	28.749s
Main servo time constant (T_{GH})	0.2s
Water time constant (T_W)	1.1s
Speed governor regulation (R_{HY})	2.4HZ/pu MW
Gas turbine:	

Speed governor lead time constants (X_G) lag time constants (Y_G)	0.6s 1.1s
Valve position constants (b_g) (c_g)	0.049s 1
Fuel time constants (T_F)	0.239s
Combustion reaction time delay (T_{CR})	0.01s
Compressor discharge volume time constant (T_{CD})	0.2s
Speed governor regulation parameter (R_G)	2.4HZ/pu MW
Power system:	
Frequency bias constants (B1,B2,B3,B4)	0.425puMW/Hz
a=2*pi*T12=2*pi*T23 =2*pi*T34=2*pi*T41	0.545
load model gain (K_{ps})	120HZ/pu MW
load time constant (T_{ps})	20s
Frequency	50HZ

IV. Defining Objective Function

The conventional load frequency control (LFC) is based up on tie-line bias control, each area tends to reduce area control error (ACE) to zero. The control error of each area consists of a linear combination of frequency and tie-line error. The error input to the controllers are the individual area control errors (ACE) given by

$$ACEi = \Delta Ptie, i + Bi\Delta Fi \qquad (5)$$

Where, i represent number of areas. Control input to the power system is obtained by use of PID controller together with the area control errors ACE_i.

$$U_i = K_{P,i} ACE_i + K_{I,i} \int ACE_i \, dt + K_{D,i} \frac{d(ACE_i)}{dt} \qquad (6)$$

Now a performance index can be defined by adding the sum of squares of cumulative errors in ACE, hence based on area control error a performance index J can be defined as:

$$J = ISE = \int \sum_{i=0}^{4} (ACE_i)^2 \, dt \qquad (7)$$

Based on this performance index J optimization Problem can be sated as:
Minimize J
Subjected to:

$$K_{P,i}^{min} \leq K_{P,i} \leq K_{P,i}^{max}$$
$$K_{I,i}^{min} \leq K_{I,i} \leq K_{I,i}^{max}$$
$$K_{D,i}^{min} \leq K_{D,i} \leq K_{D,i}^{max} \qquad i=1, 2,3\&4$$

Where $K_{P,i}$, $K_{I,i}$ and $K_{D,i}$ are PID controller parameters of ith area.

V. Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO) is an evolutionary computational method developed by Kennedy and Eberhart in 1995. It is developed from swarm intelligence and is based on the study of bird and fish flock group performance. The Particle swarm optimization algorithm is a multi-agent similar search method which maintains a group of particles and each particle represents a possible solution in the swarm. All particles fly throughout a multidimensional search space where each particle adjusts its position according to its personal knowledge and neighbour's experience [10] [11].

Each particle keeps pathway of its coordinate in the solution space which are coupled with the best solution (fitness) that have achieve so far by that particle. This value is called personal best, p_{best}. Another best value that is tracked by the PSO is the best value obtained so far by any particle in the neighbourhood of that particle. This value is called ***gbest***. The basic concept of PSO lies in accelerating each particle toward its pbest and the gbest locations, with a random weighted acceleration at every time step as shown in Fig.6

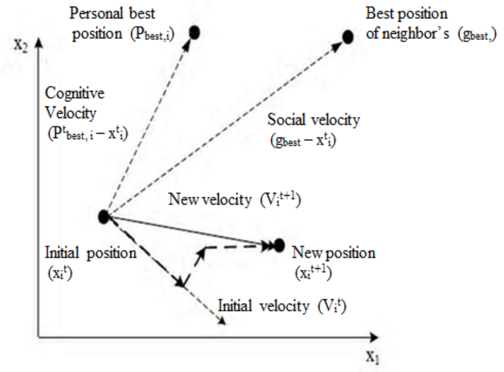

Figure 6: Concept of searching mechanism of PSO

After finding the p_{best} and g_{best}, the particle updates its velocity and positions with following equations

$$V_{ij}^{t+1} = WV_{ij}^t + C_1 r_{1j}^t \left[P_{best,i}^t - X_{ij}^t\right] + C_2 r_{2j}^t \left[G_{best,i} - X_{ij}^t\right] \quad (8)$$

$$X_{ij}^{t+1} = X_{ij}^t + V_{ij}^{t+1} \quad (9)$$

Where V_{ij}^{t+1} and X_{ij}^{t+1} are the velocity and position of i^th^ particle in dimension j at time t+1. C_1 and C_2 are two position constants call acceleration constants. r_1 and r_2 are two different random numbers in the range 0 to1. The inertia weight *w* keeps the movement inertial for the particle. It describes weight of the earlier velocity to the existing velocity, which means make the algorithm have the tendency to expand the search space and have the capability to explore the new district, and there is the function to adjust the rate of velocity of particle. Linear variety of the '*w'* is

$$W = \frac{\text{MAXITER} - \text{ITER}}{\text{MAXITER}} \quad (10)$$

Where, w represents the inertia weighting factor.
ITER= current number of iteration,
MAXITER = maximum number of iterations.

There are three terms in velocity equation

1. $W^*V^t_{ij}$ is called inertia element that provide a memory of the earlier journey direction that means movement in the instantaneous past.
2. $C_1\, r^t_{1j}\, [P^t_{best,i} - X^t_{ij}]$ is called cognitive element. This element looks like an individual memory of the position that was best for the particle.
3. $C_2\, r^t_{2j}\, [G_{best,i} - X^t_{ij}]$ is called social element. The effect of this element is each particle fly in the direction of the best position found by the neighbourhood particles.

5.1 Algorithm of PSO method

Step-1: Initialize the parameters of the particle swarm optimization (PSO).

- Number of particles(ig)
- Maximum number of iterations
    - Population size

Step-2: Initialize the maximum and minimum gain limits of PID controller.

Step-3: Find the maximum and minimum velocities for all particles using following equations

VelxM (ig) =1/R*(xmax (ig)-xmin (ig))
Velxm (ig) =-velxM (ig)

Step-4: Evaluate the initial population by simulating the LFC block module with each particle and calculate the performance index (ISE).

Step- 5: Initialize the local minimum (P_{best}) for each population.

Step-6: Find the best particle (G_{best}) in the initial population matrix based on the minimum performance index.

Step-7: Iter=1

Step-8: Update the velocity of the particle using the equation (7).

Step-9: Create new particles from the updated velocity.

Step-10: If any of the new particles violate the search space limit then choose the particle and generate the new values within the search space.

Step-11: Evaluate the performance index for each new particle.

Step-12: Update the position for each particle using equation (8). Update the P_{best} for each particle based on comparison between new particle performance index and old p_{best} performance index.

Step-13: update G_{best} and its performance index.

Step-14: Iter=Iter+1.
Step-15: If Iter<=Max Iter go to step-8, otherwise go to next step.
Step-16: Print the global best PID controller gain values and its performance index value.

VI. Simulation Results

A multi-area interconnected power system is taken for LFC analysis. In multi-area power system area-1 consists of thermal plant, area-2 consists of thermal with reheat, area-3 consists of hydro plant and area-4 consists of gas plant. Simulation model of the proposed system with PSO-PID controller is shown in Figures 7. The MATLAB code based on PSO algorithm has been run in MATALB environment.

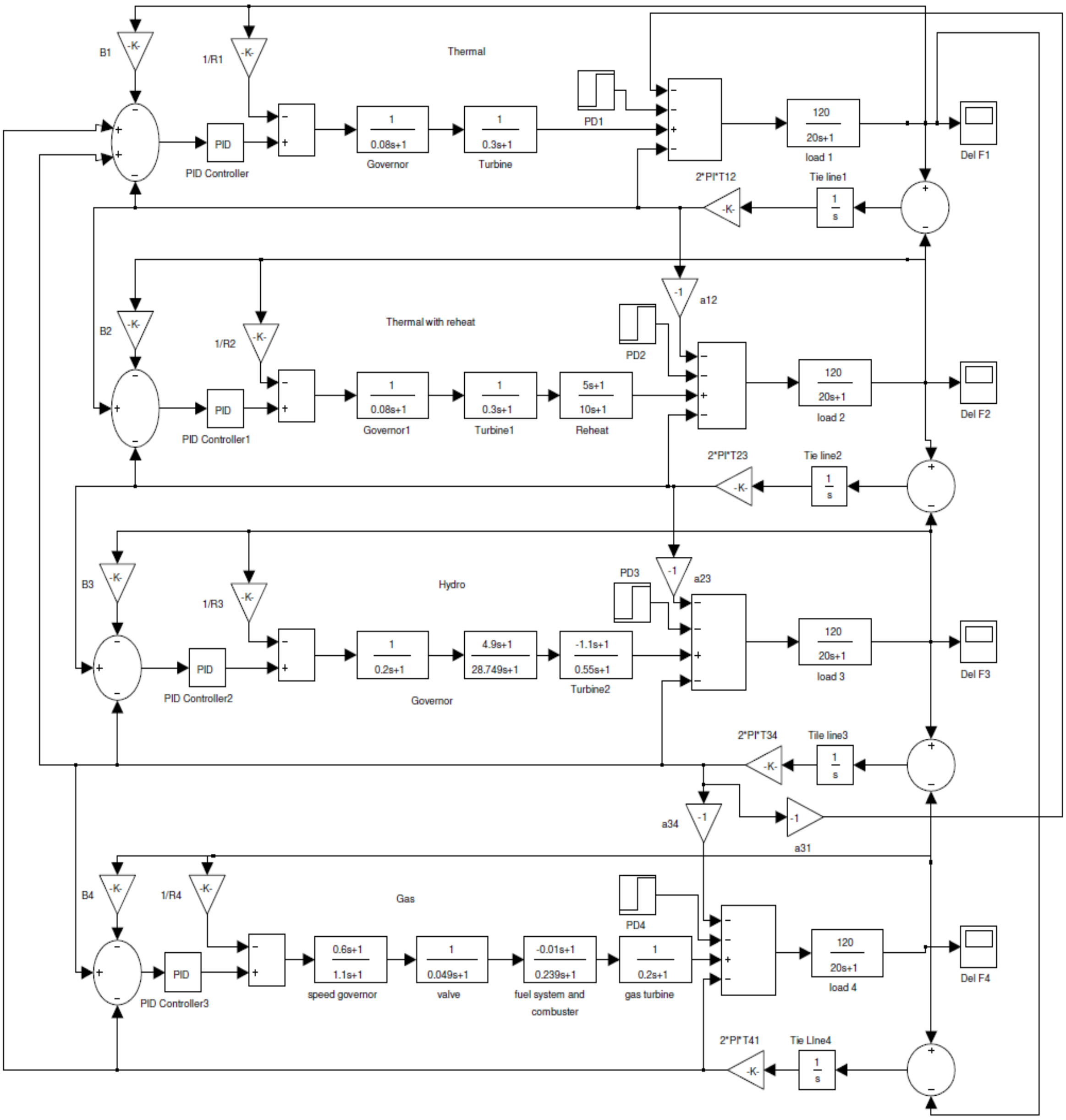

Figure.7 Simulation module of four area interconnected power system

PSO parameters taken for optimizations are: Population size=80, Maximum number of iterations=50, *c1*=1.8; *c2*=1.7 and simulation time=50s.

Case-1: Step change in area-1(Thermal)

Simulation is carried out with 1% step load perturbation in area-1. The optimized controller gains obtained when 1% step load perturbation in area-1 is shown in Table 3.

Table 3: Optimized values of PID controller parameters there is step change in area-1

Method	**Area**	**K_P**	**K_I**	**K_D**
Trial and error method	1	1.3293	1.177	1.468
	2	1.7827	0.6026	0.5737
	3	0.7291	1.199	0.2785
	4	0.9030	1.3018	1.1853
PSO method	1	2	1.9230	1.0871
	2	0.7757	0.9721	1.1196
	3	0.4942	0.4942	0.100
	4	1.2288	0.8755	1.3039

The dynamic responses of a four area interconnected power system with 1% step load perturbation in area-1 are shown in the figures 8-15. Figures 8-11 represents the responses of frequency deviation in area-1, area-2, area-3, area-4 respectively when there is a 1% step load perturbation in area-1(Thermal area). Figures 12-15 represents the responses of tie-lines (Tie-12, Tie-23, Tie-34 and Tie-41) power deviation, respectively when there is a 1% step load perturbation in area-1. It was observed that in PSO method number of oscillations and settling time reduces compared with trial and error method. The minimized value of performance index J by PSO method is $1.9473*10^{-5}$.

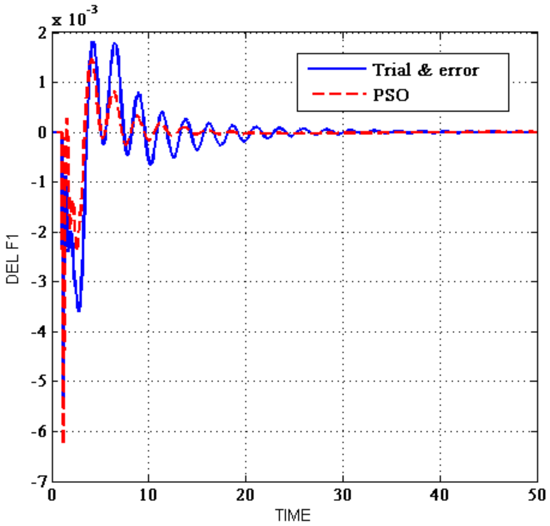

Figure.8 Frequency deviation in area-1 due to step change in area-1

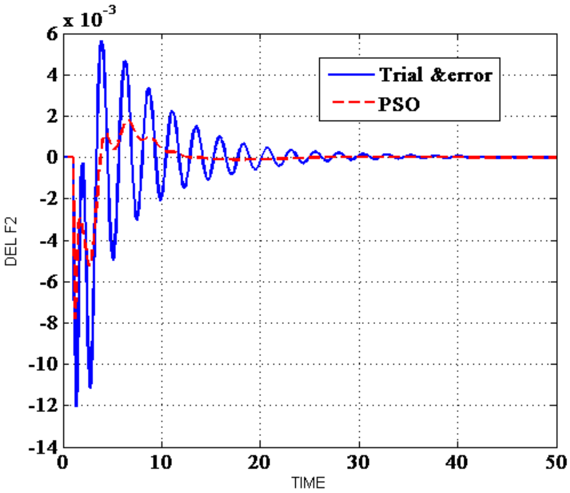

Figure.9 Frequency deviation in area-2 due to step change in area-1

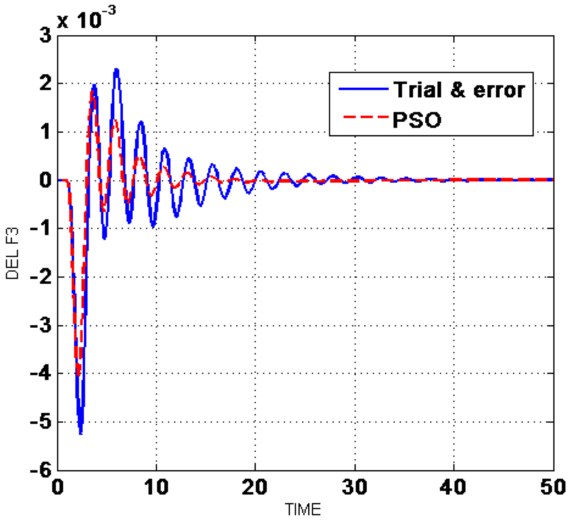

Figure.10 Frequency deviation in area-3 due to step change in area-1

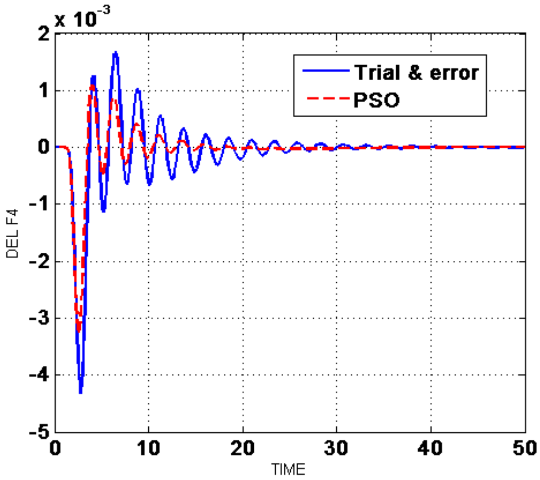

Figure.11 Frequency deviation in area-4 due to step change in area-1

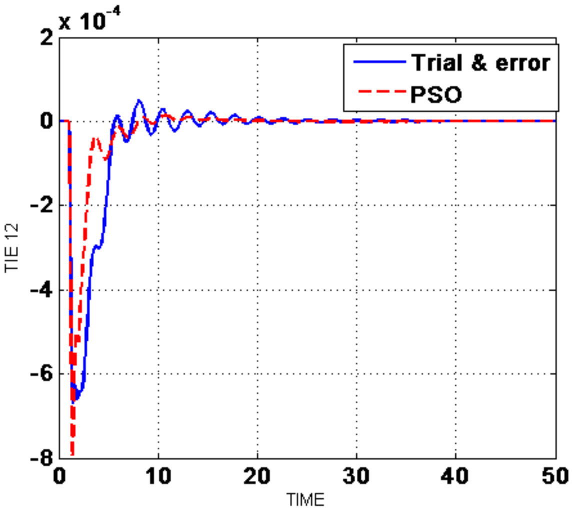

Figure.12 Tie line12 power deviation due to step change in area-1

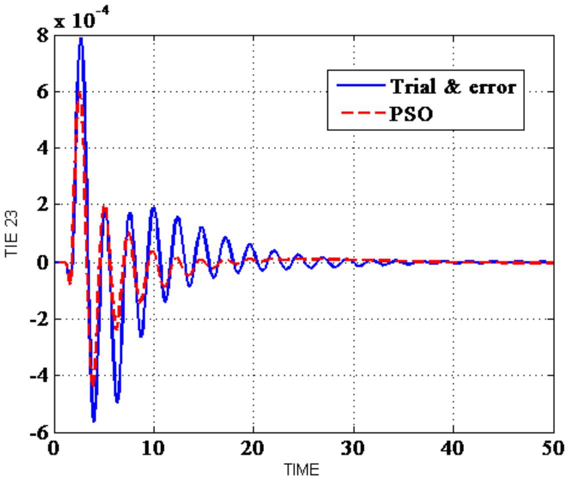

Figure.13 Tie line23 power deviation due to step change in area-1

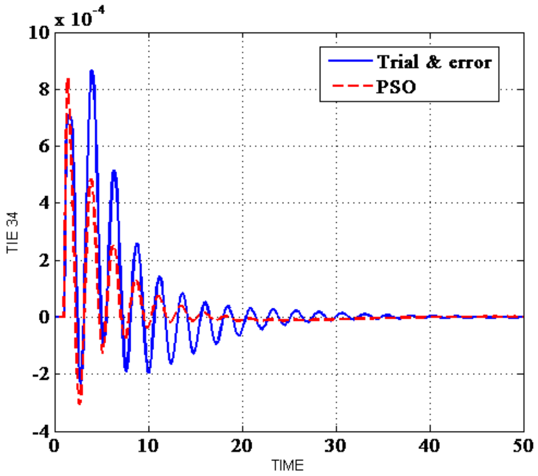

Figure.14 Tie line34 power deviation due to step change in area-1

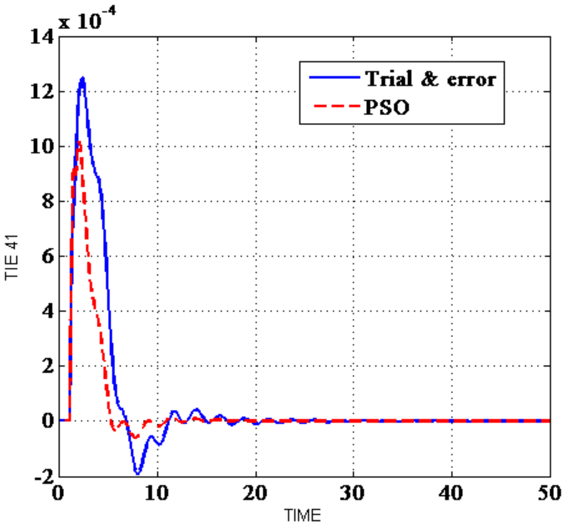

Figure.15 Tie line41 power deviation due to step change in area-1

Case-2: Step change in area-2(Thermal with reheat)
Simulation is carried out with 1% step load perturbation in area-2. The optimized controller gains obtained when 1% step load perturbation in area-2 is shown in Table 4.

Table 4: Optimized values of PID controller parameters when step change in area-2

Method	Area	K_P	K_I	K_D
Trial and error method	1	1.3293	1.177	1.468
	2	1.7827	0.6026	0.5737
	3	0.7291	1.199	0.2785
	4	0.9030	1.3018	1.1853
PSO method	1	0.7667	0.9894	1.5516
	2	1.8878	1.2459	1.6560
	3	0.2613	0.8655	0.100
	4	1.0574	0.953	1.4942

The dynamic responses of a four area interconnected power system with 1% step load perturbation in area-2 are shown in the figures 16-23. Figures 16-19 represents the responses of frequency deviation in area-1, area-2, area-3, area-4 respectively when there is a 1% step load perturbation in area-2(Thermal with reheat area). Figures 20-23 represents the responses of tie-lines (Tie-12, Tie-23, Tie-34 and Tie-41) power deviation, respectively when there is a 1% step load perturbation in area-2. It was observed that in PSO method number of oscillations and settling time reduces compared with trial and error method. The minimized value of performance index J by PSO method is $6.05*10^{-5}$.

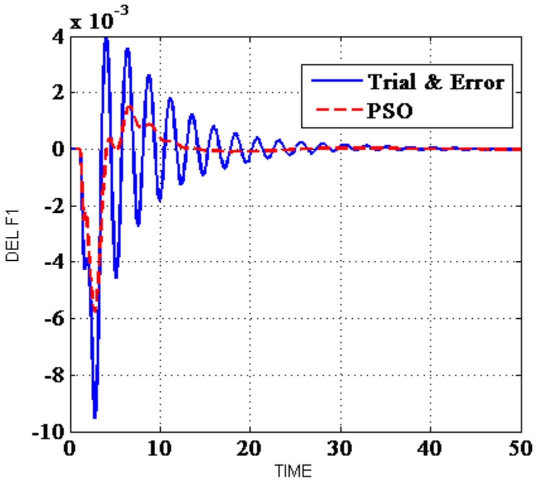

Figure.16 Frequency deviation in area-1 due to step change in area-2

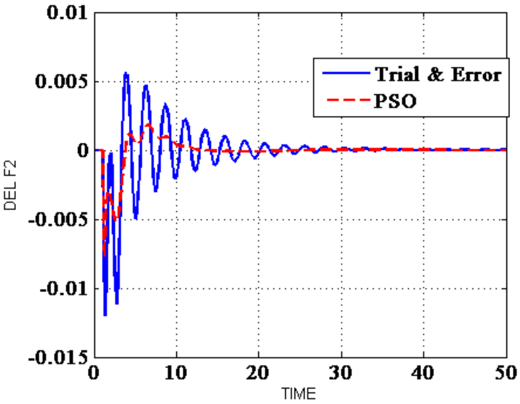

Figure.17 Frequency deviation in area-2 due to step change in area-2

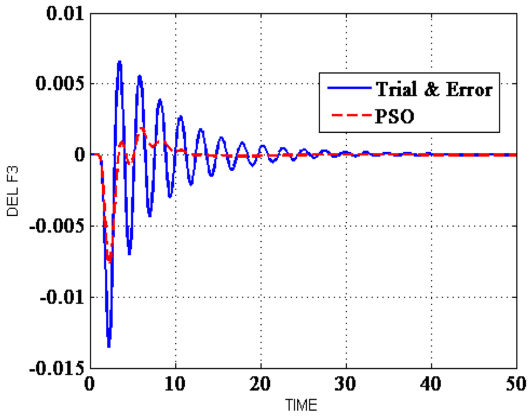

Figure.18 Frequency deviation in area-3 due to step change in area-2

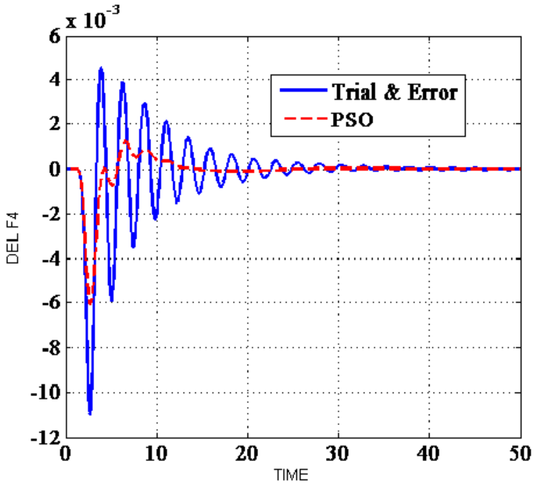

Figure.19 Frequency deviation in area-4 due to step change in area-2

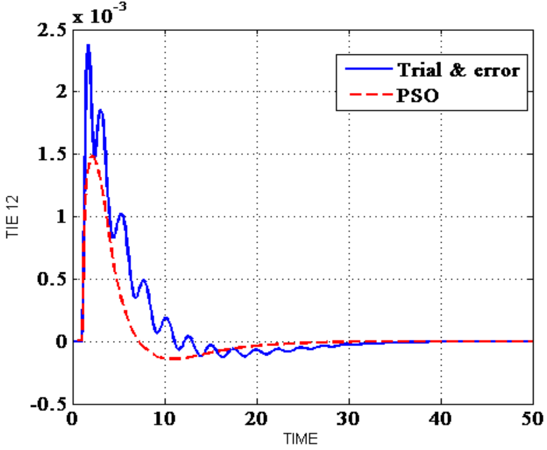

Figure.20 Tie line12 power deviation due to step change in area-2

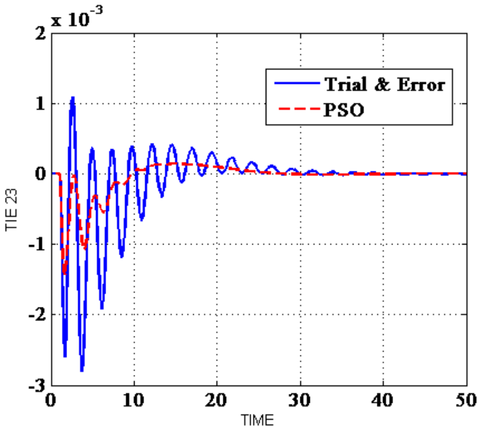

Figure.21 Tie line23 power deviation due to step change in area-2

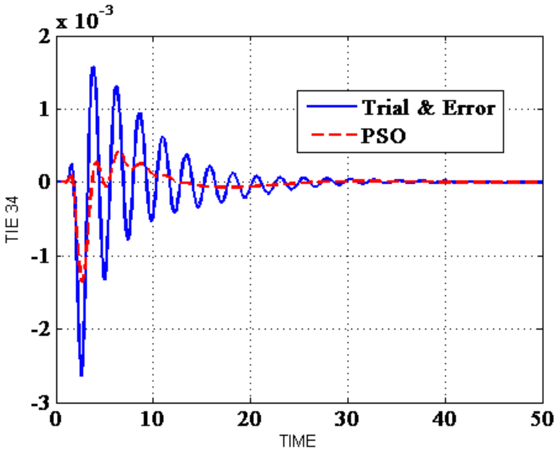

Figure.22 Tie line34 power deviation due to step change in area-2

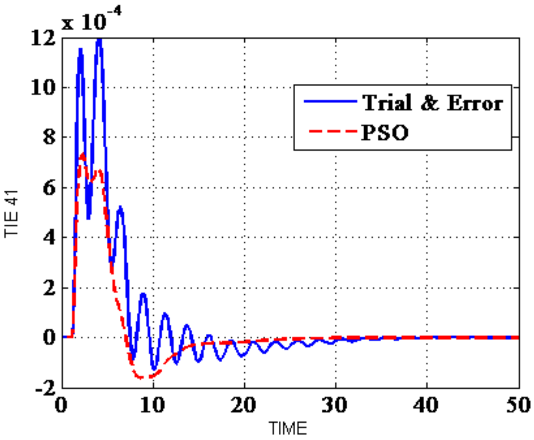

Figure.23 Tie line41 power deviation due to step change in area-2

Case-3: Step change in area-3(Hydro)
Simulation is carried out with 1% step load perturbation in area-3. The optimized controller gains obtained when 1% step load perturbation in area-3 is shown in Table 5.

Table 5: Optimized values of PID controller parameters there is step change in area-3

Method	Area	K_P	K_I	K_D
Trial and error method	1	1.3293	1.177	1.468
	2	1.7827	0.6026	0.5737
	3	0.7291	1.199	0.2785
	4	0.9030	1.3018	1.1853
PSO method	1	1.2514	1.2502	0.8175
	2	1.2238	0.8900	1.1240
	3	0.2477	1.0170	0.100
	4	0.8798	0.9641	1.3909

The dynamic responses of a four area interconnected power system with 1% step load perturbation in area-3 are shown in the figures 24-31. Figures 24-27 represents the responses of frequency deviation in area-1, area-2, area-3, area-4 respectively when there is a 1% step load perturbation in area-3(Hydro). Figures 28-31 represents the responses of tie-lines (Tie-12, Tie-23, Tie-34 and Tie-41) power deviation, respectively when there is a 1% step load perturbation in area-3. It was observed that in PSO method number of oscillations and settling time reduces compared with trial and error method. The minimized value of performance index J by PSO method is $9.6616*10^{-4}$.

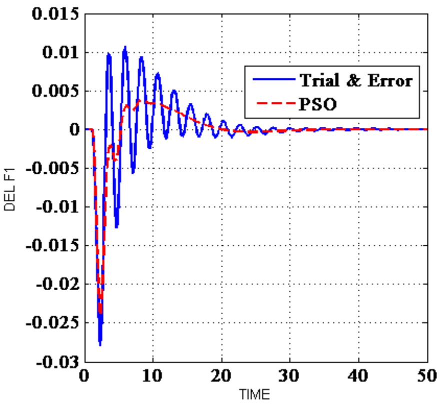

Figure.24 Frequency deviation in area-1 due to step change in area-3

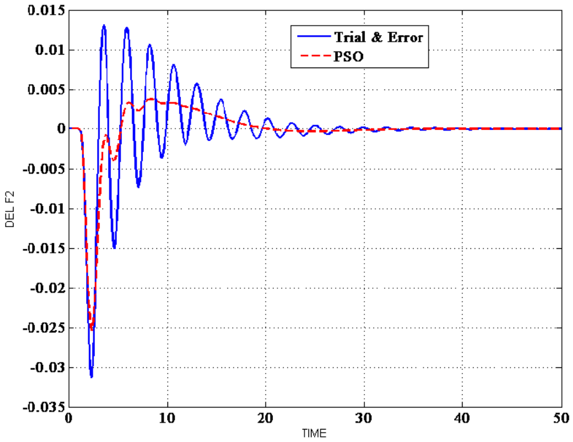

Figure.25 Frequency deviation in area-2 due to step change in area-3

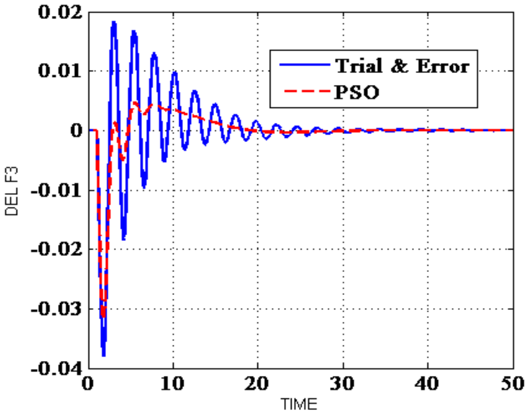

Figure.26 Frequency deviation in area-3 due to step change in area-3

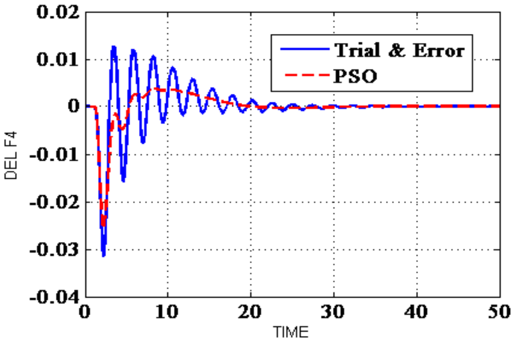

Figure.28 Frequency deviation in area-4 due to step change in area-3

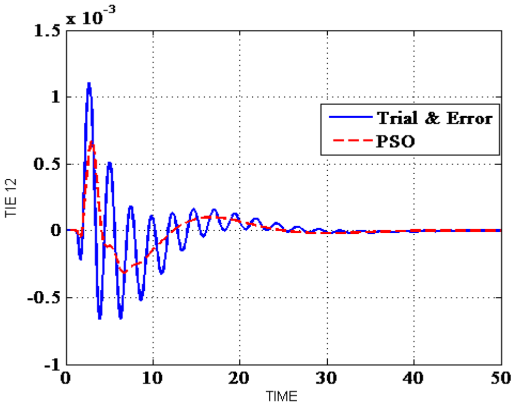

Figure.28 Tie line12 power deviation due to step change in area-3

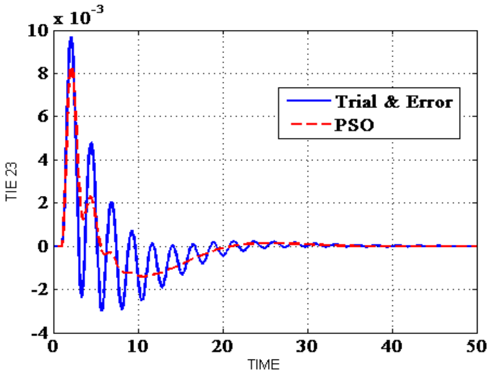

Figure.29 Tie line23 power deviation due to step change in area-3

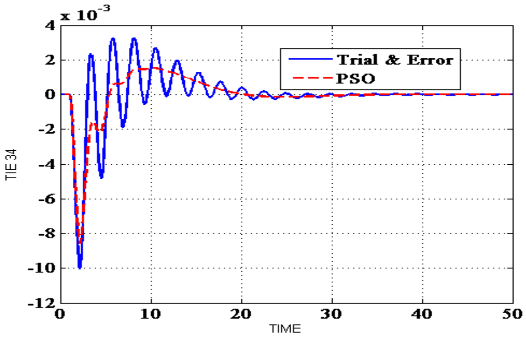

Figure.30 Tie line34 power deviation due to step change in area-3

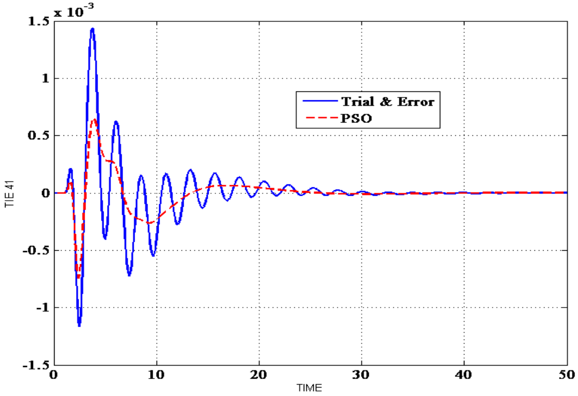

Figure.31 Tie line41 power deviation due to step change in area-3

Case-4: Step change in area-4(Gas)

Simulation is carried out with 1% step load perturbation in area-4. The optimized controller gains obtained when 1% step load perturbation in area-3 is shown in Table 6.

Table 6: Optimized values of PID controller parameters there is step change in area-4

Method	**Area**	**K_P**	**K_I**	**K_D**
Trial and error method	1	1.3293	1.177	1.468
	2	1.7827	0.6026	0.5737
	3	0.7291	1.199	0.2785
	4	0.9030	1.3018	1.1853
PSO method	1	1.1089	1.0737	1.5724
	2	1.0615	1.0897	1.3511
	3	0.1426	1.0310	0.2216
	4	1.7337	1.3300	1.7227

The dynamic responses of a four area interconnected power system with 1% step load perturbation in area-4 are shown in the figures 32-39. Figures 32-35 represents the responses of frequency deviation in area-1, area-2, area-3, area-4 respectively when there is a 1% step load perturbation in area-4(Gas). Figures 36-39 represents the responses of tie-lines (Tie-12, Tie-23, Tie-34 and Tie-41) power deviation, respectively when there is a 1% step load perturbation in area-4. It was observed that in PSO method number of oscillations and settling time reduces compared with trial and error method. The minimized value of performance index J by PSO method is $2.7956*10^{-5}$.

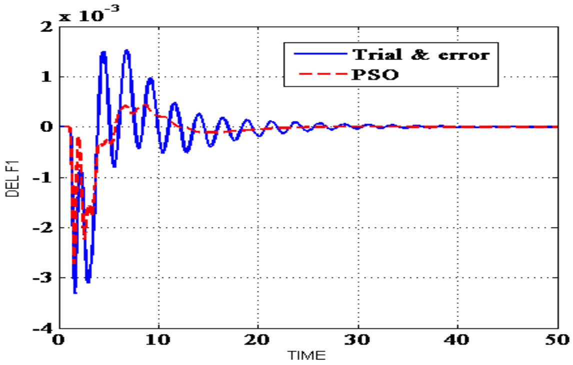

Figure.32 Frequency deviation in area-1 due to step change in area-4

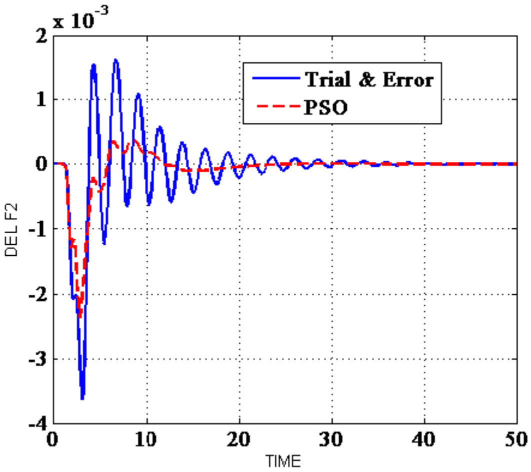

Figure.33 Frequency deviation in area-2 due to step change in area-4

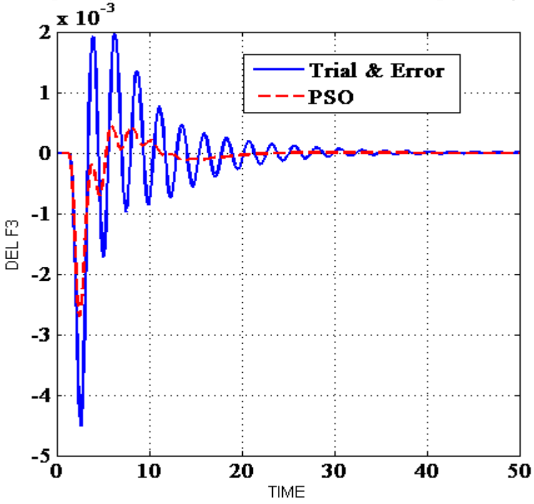

Figure.34 Frequency deviation in area-3 due to step change in area-4

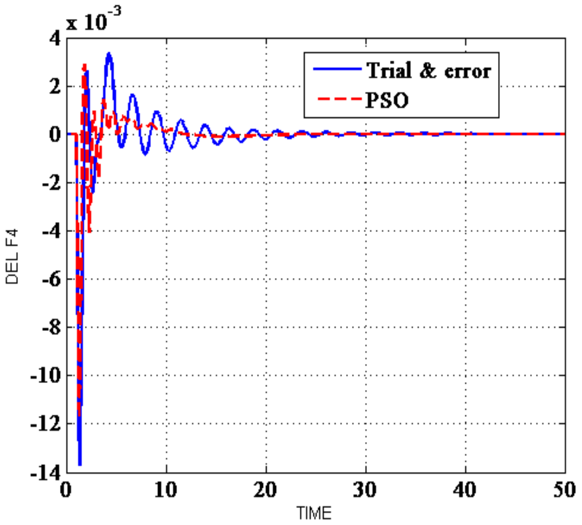

Figure.35 Frequency deviation in area-4 due to step change in area-4

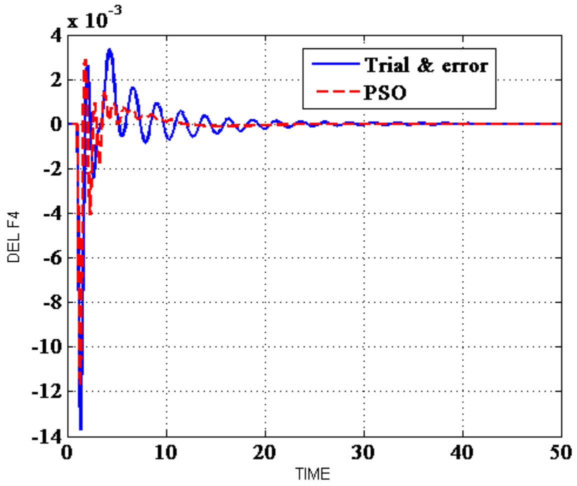

Figure.36 Tie line12 power deviation due to step change in area-4

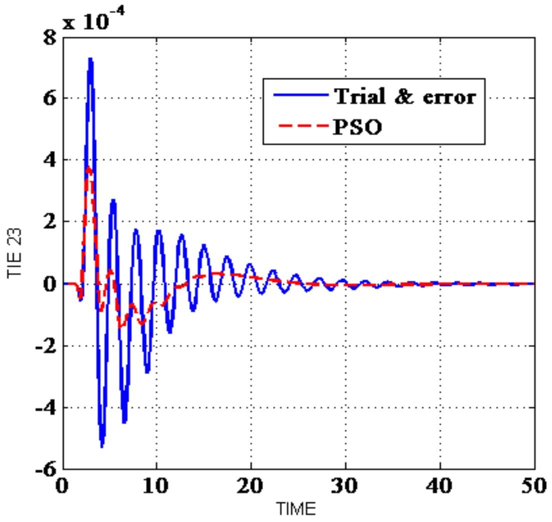

Figure.37 Tie line23 power deviation due to step change in area-4

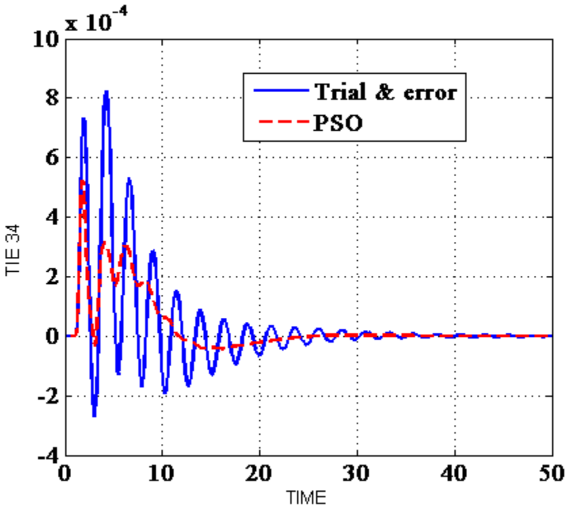

Figure.38 Tie line34 power deviation due to step change in area-4

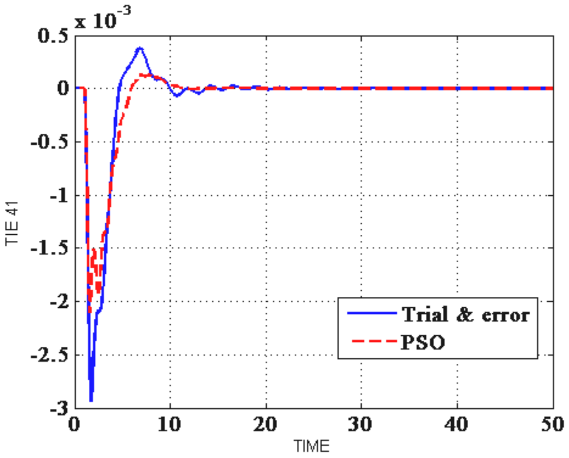

Figure.39 Tie line41 power deviation due to step change in area-4

It is observed from above cases that frequency deviations and tie lines power deviation settles quickly with zero steady state error in PSO-PID method. The transient response specifications of trial & error method and PSO-PID method are shown in Table: 7.

Table: 7 Transient response specifications

METHOD	Settling Time	Oscillations
Trial & error	32sec	10
PSO-PID	20sec	4

From transient response specifications it was observed that settling time reduced to 20sec in PSO-PID method but in Trial & error method settling time is 32sec. Compared with Trial & error method number of oscillations also reduced in PSO-PID method.

VII. Conclusion

In this paper, PSO based PID controller tuning has been proposed for a four area interconnected power system with area-1 consists of thermal plant, area-2 consists of thermal with reheat, area-3 consists of hydro plant and area-4 consists of gas plant. Simulation results proved that the tuning of PID controller using PSO optimization technique gives tremendous transient and steady state performance for frequency and tie line power deviation compared to trial and error method. Frequency deviations settled quickly and the dynamic responses are less oscillatory with low amplitude of peak over shoots using Particle swarm optimization method (PSO). The tie line power deviation settles with zero steady state errors. The dynamic responses satisfy the LFC requirements. Hence the PSO based PID controller tuning is efficient to handle the LFC problem.

References

[1]. Yao Zang, “Load Frequency Control of Multiple-Area Power Systems” Tsinghua University July, 2007 Master of science in Electrical Engineering.

[2]. B.Prakash Ayyappan, U. Thiruppathi, G. Balaganapathi, “Load Frequency Control of An Interconnected Power System Using Thyristor Controlled Phase Shifter (TCPS)” International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181 Vol. 2 Issue 6, June – 2013.

[3]. A.Sharif, K.Sabahi, M.Aliyari Shoorehdeli, M.A.Nekoui, M.Teshnehlab, “Load Frequency Control in Interconnected power System Using Multi-objective PID Controller”, 2008 IEEE Conference on Soft Computing in Industrial Applications (SMCia/08), June 25-27, 2008, Muroran, Japan.

[4]. Elgerd OI. Electric energy system theory: an introduction. 2nd ed. New York: McGraw Hill; 1983.

[5]. Soon Kiat Yee, JovicaV.Milanovic, F.M.Michael Hughes, “Overview and comparative Analysis of Gas Turbine Models for System Stability Studies”, IEEE Transactions on Power Systems, Vol.23, No.1, 2008, pp. 108-118.

[6]. P. Kundur, Power System Stability and Control, 1st ed., New York: McGraw-Hill, 1993.

[7]. D. P. Kothari, I.J. Nagrath, “Power System Engineering”, Tata McGraw Hill, second edition.

[8]. K. S. S. Ramakrishna, Pawan Sharma, T. S. Bhatti, “Automatic generation control of interconnected power system with diverse sources of power generation”, International Journal of Engineering, Science and Technology Vol. 2, No. 5, 2010, pp. 51-65.

[9]. Surya Prakash and Sunil Kumar Sinha, “Performance Evaluation of Hybrid Intelligent Controllers in Load Frequency Control of Multi Area Interconnected Power Systems , World Academy of Science, Engineering and Technology Vol: 7, 2013-05-26.

[10]. Yamille del Valle, Ganesh Kumar Venayagamoorthy, Salman Mohagheghi, Jean-Carlos Hernandez, and Ronald G. Harley, “Particle Swarm Optimization: Basic Concepts, Variants and Applications in Power Systems”, IEEE transactions on evolutionary computation, vol. 12, no. 2, april 2008.

[11]. Qinghai Bai College of Computer Science and Technology Inner Mongolia University for Nationalities Tongliao 028043, China, “Analysis of Particle Swarm Optimization Algorithm”, Computer and Information Science February-2010, vol.3.