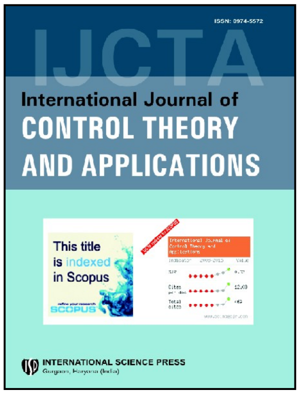

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Load Frequency Control of an Interconnected Multi Area Power System with Diverse Scenarios using Swarm based optimization Algorithm

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Abstract: In this paper load frequency control of an inter-connected multi area power system with different scenarios were studied. Here the classical PID controller tuned by particle swarm optimization algorithm (PSO) is connected in secondary control path. This paper illustrate the behavior of frequency response of the Systems with non reheat turbine, reheat turbine, mechanical governor, electrical governor, governor without dead band, and governor with dead band. All the above diverse scenarios were studied at different load variations and additionally the study was extended to parameter sensitivities also. Results are carried out in matlab and simulink environment.

Keywords: load frequency control, reheat turbine, PSO, secondary controller

1. INTRODUCTION

The power demand is randomly varies in an interconnected power system practical scenario. The variation in the active power demand of an interconnected power system leads to the variation in system frequency. Therefore a suitable control strategy is needed to make system stable by reducing frequency oscillations [1-13]. In reference [1], reinforcement learning is used to evaluate the multilayer perception neutral network (MLPNN) controller performance. Also evaluated sensitivity analysis that is subjected to wide variations in system loading, and to investigate strength of controller generator inertia. Sequential Quadratic Programming (SQP) designed a robust PID controller for ALF control of non-linear consistent power system [2]. In reference [3,7], a emotional learning method is implemented for designing a suitable controller in the secondary loop of a two-area interconnected system with the consideration of generation rate constraint (GRC). In reference [4], group of optimal Fuzzy rule is implemented for load frequency control by Fuzzy C-Means clustering technique (FCM) and it is compared with conventional controller and novel Fuzzy controller in the presence of GRC. The decentralised load frequency control (LFC) problem for multi-area power system is studied in deregulated environments and the stability analysis of the decentralised LFC for conventional environments is extended to the deregulated case and which is illustrated in [5]. In reference [8], the decentralized LFC synthesis is expressed as a multi objective optimization problem (MOP) which is solved by genetic algorithms (GAs) and it is used to design well-tuned PI controllers in multi-area power systems. In proposed work, load frequency control of an inter-connected multi area power system were studied with different scenarios. Here the classical PID controller tuned by particle swarm optimization algorithm (PSO) is connected in secondary control path.

This paper illustrate the behavior of frequency response of the Systems with non reheat turbine, reheat turbine, mechanical governor, electrical governor, governor without dead band, and governor with dead band. All the above diverse scenarios were studied at different load variations and additionally the study was extended to parameter sensitivities also. In Section 1 includes brief introduction and literature survey about automatic generation control. Section 2 provides procedure to apply search based optimum tuning technique known as PSO to automatic load frequency control. System studied was presented in section 3. Different results are provided in section 4. Section 5 provides the conclusion of the paper.

2. PSO ALGORITHM

Particle swarm optimization (PSO) is a swarm based stochastic optimization algorithm. High quality solutions is obtained from PSO with less time of calculation and characteristics of stable convergence with its algorithm when compared to other stochastic methods like genetic algorithm. At particular region, group of bird's looks randomly for food is known as search process. Food is present only at particular area but birds are not aware of food. Nearest birds location is followed by all other birds in order to find the food location. The updating process is taken place based on the following equations: Particle swarm optimization simply called as PSO algorithm is a population based algorithm for getting optimizes parameters for proper operation and control of existing systems. Kennedy and Eberhart introduced PSO in the year 1995 [ref] in which search process was introduced as a group of birds that looks for food randomly at certain region. Food is available at one area where the place is not known by the birds but birds know their distance at each step during searching process. To find the food location, all birds monitor the nearest bird which is nearer to the food place. In PSO algorithm, each bird is presented as a particle and a group or swarm is formed with all these particles. are the two vectors used to determine each particle which means position and velocity respectively of the particle at the time. For each particle, position Xi is considered. At each time to find best position, particles will fly all over the search place where their speed and position change. Routes are regulated by all particles and other's involvements at the previous moment of the flight. Equation shows the update process:

$$V_{ij}(t+1) = W.V_{ij}(t) + C_1 * rand1.(P_{best,ij}(t) - X_{ij}(t)) + C_2 * rand2.(g_{best,j}(t) - X_{ij}(t)$$

$$X_{ij}(t+1) = X_{ij}(t) + V_{ij}(t+1)$$

At the end of the iterations, the best position of the swarm will be the solution of the problem i.e., gbest values will give optimal control parameters for given classical controller. In this paper, three classical controllers are used namely I-controller, PI- controller and PID-Controller. For each case, the classical controllers presented in the system are tuned by PSO Algorithm and for the system studied in chapter 3, here PID controller structure considered only.

3. SYSTEM STUDIED

An interconnected two area thermal-thermal reheat power system is considered as system studied which is shown in figure 2. Here the secondary controller (PID) is tuned by particle swarm optimization algorithm. In this paper, the behavior of frequency response of the Systems with non reheat turbine, reheat turbine, mechanical governor, electrical governor, governor without dead band, and governor with dead band are studied and the corresponding results mentioned in chapter-4.

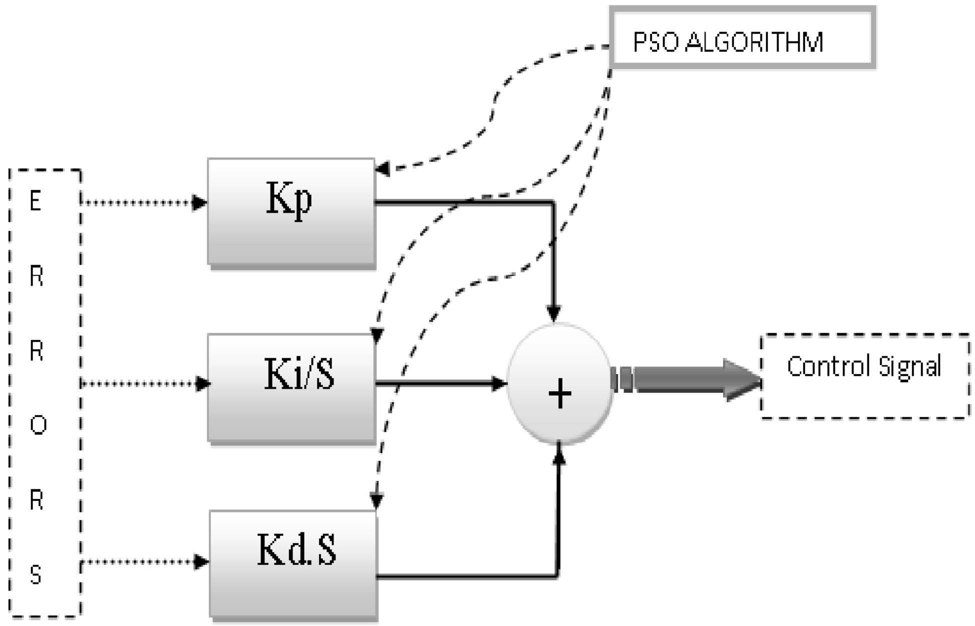

Figure 1A: PID control tuning structure using PSO

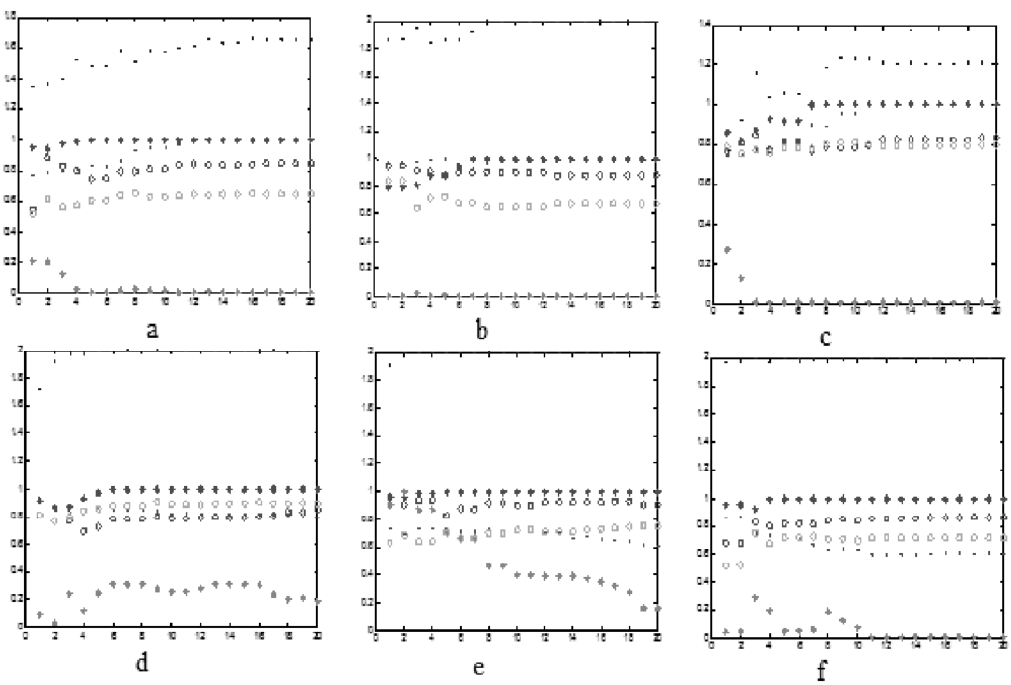

Figure 1B: a. multi area power system with non reheat turbine interconnected by normal AC tie line where the secondary controllers are tuned by PSO technique, b. a multi area power system with non reheat turbine interconnected by normal AC tie line where the secondary controllers are tuned by PSO technique with Variable load gain. (decrease), c. a multi area power system with non reheat turbine interconnected by normal AC tie line where the secondary controllers are tuned by PSO technique with Variable load time constant, d. a multi area power system with reheat turbine interconnected by normal AC tie line where the secondary controllers are tuned by PSO technique, e. a multi area power system with reheat turbine interconnected by normal AC tie line where the secondary controllers are tuned by PSO technique with Variable load gain. (increase), f.a multi area power system with reheat turbine interconnected by normal AC tie line where the secondary controllers are tuned by PSO technique with Variable load time constant (decrease).

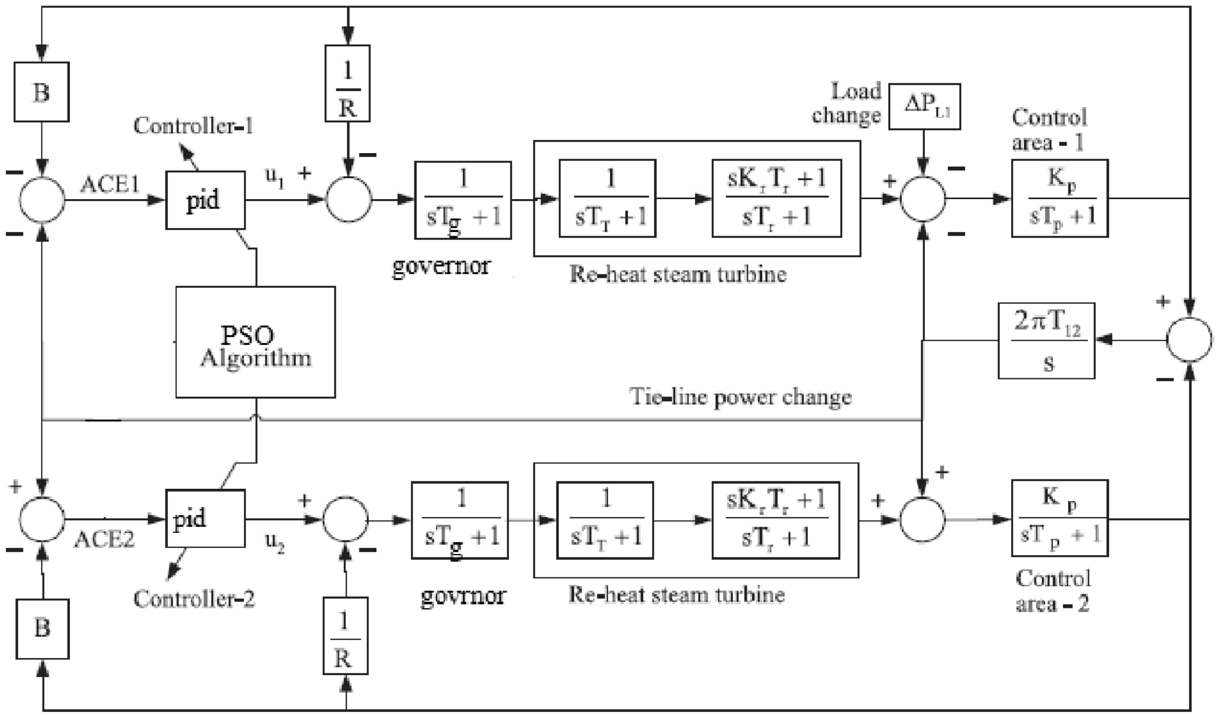

Figure 2: System studied (Block diagram of an interconnected power system with reheat turbine)

4. RESULTS

In this paper the investigations are carried out on the behavior of frequency response of the Systems with non reheat turbine; reheat turbine, mechanical governor, electrical governor, governor without dead band, and governor with dead band. With the above case studies additionally the Influence of parameter variations on system frequency were also studied and all these case studies were listed in the below with detailed explanation.

Case-1: Here the comparison was done between the interconnected power systems with no reheat turbine and reheat turbine. Initially the variations in system frequency observed for the interconnected power systems with no reheat turbine and reheat turbine without secondary control. Later the study is changed to same interconnected power systems with no reheat turbine and reheat turbine in presence of secondary control. When compared the system with non reheat turbine to without non reheat turbine at same load change, the former system will takes more time to settle compared to later system. The same result will repeat in presence of secondary controller but the transient and steady state performances may increase. In figure 3, Change in frequency responces of area-1 and area-2 in presence of non reheat and reheat turbines without secondary controller is presented. in figure 4, Change in frequency responces of area-1 and area-2 in presence of non reheat and reheat turbines with secondary controller is presented.

Case-2: In this case, the comparison was done between the interconnected power systems by considering governor dead band and without governor dead band. Initially the variations in system frequency observed for without secondary control. Later the study is changed to same interconnected power systems in presence of secondary control. When compared the system with Governor dead band to without Governor dead band at same load change, the former system will takes more time to settle compared to later system. The same result will repeat in presence of secondary controller but the transient and steady state performances may increase.

Case-3: Because of sensible loads in industry, the approximation of load parameters as constants is not a valid model. Here the sensitivity of load parameters is included in terms of random variable within certain limits

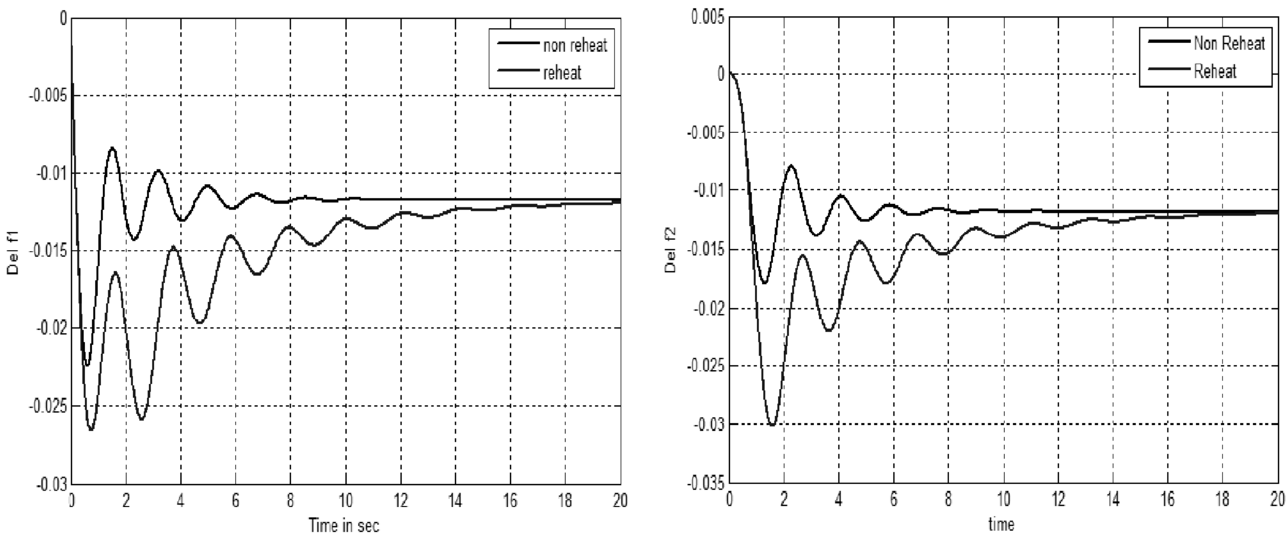

Figure 3: Change in frequency responces of area-1 and area-2 in presence of non reheat and reheat turbines without secondary controller

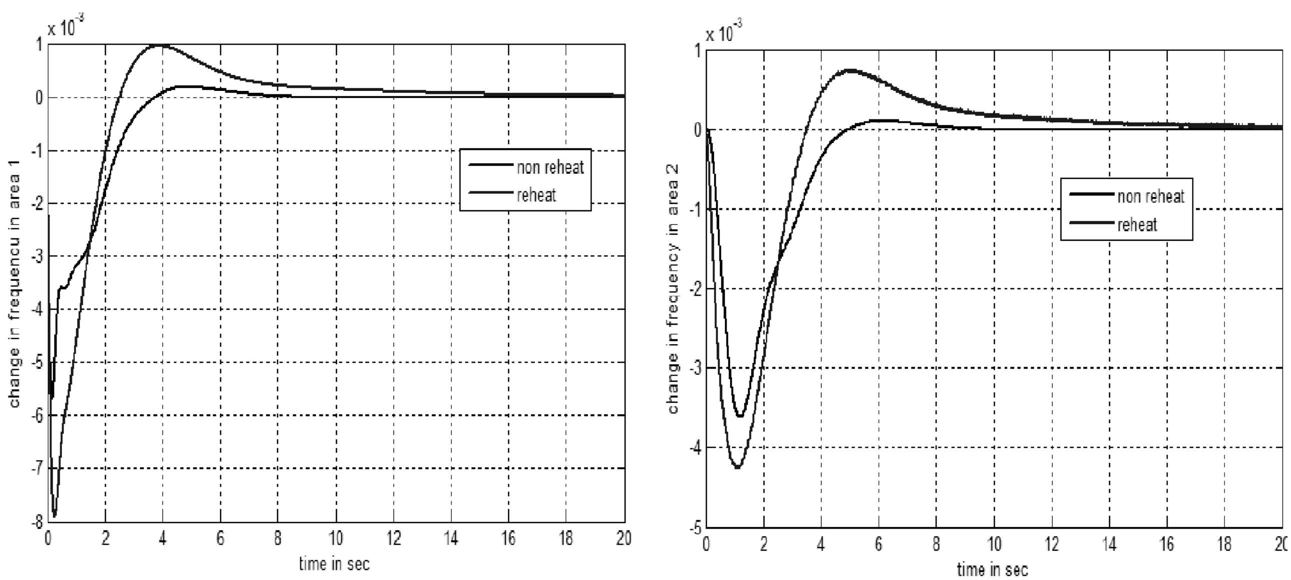

Figure 4: Change in frequency responces of area-1 and area-2 in presence of non reheat and reheat turbines with secondary controller

and the influence of these parameters is also tested at different loading conditions. In all cases, the details of tuned PID parameters are mentioned in table 1.

Case-4: Discussions: The presence of secondary controller will definitely improve the system stability if the controller parameters properly tuned. Several classical methods existed for tuning of PID controller. Here the particle swarm optimization algorithm was considered for getting optimal parameters of secondary controller. In table 1, the tuned parameter values of secondary controllers in both areas are mentioned in terms of proportional gain, integral time constant and derivative time constant. In table 2, the comparative study was presented in terms of linguistic variables for both transient and steady state parameters. In each case, the presence of secondary PID controller tuned by particle swarm optimization algorithm improves the system behavior. Finally in table 3,

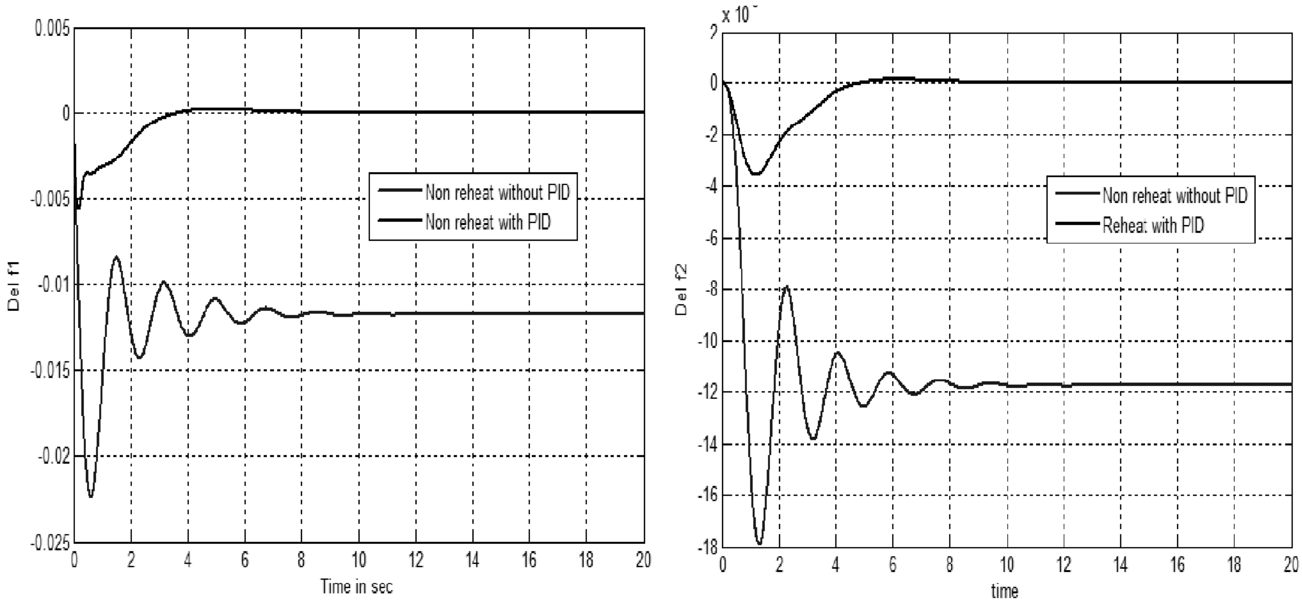

Figure 5: Change in frequency responces of area-1 and area-2 in presence of non reheat turbine without secondary controller and with secondary control

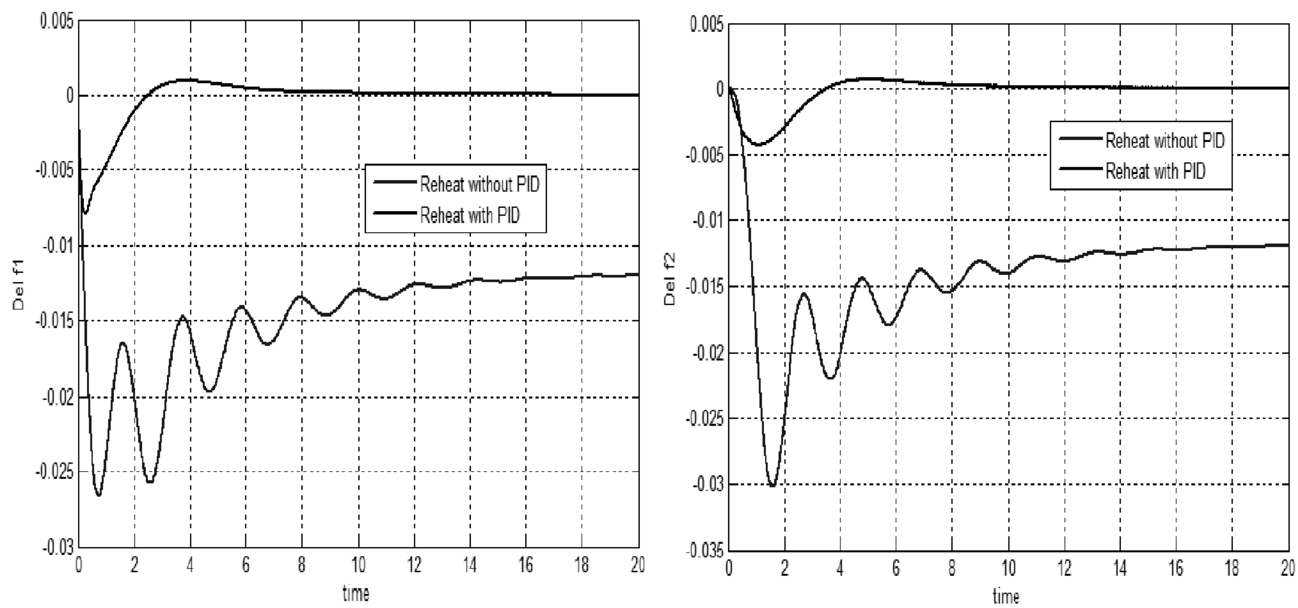

Figure 6: Change in frequency responces of area-1 and area-2 in presence of reheat turbine without secondary controller and with secondary control

the integral square error (ISE) values are presented for best particle position at the initial iteration and final iteration of the PSO algorithm. Here the tested cases are: Interconnected thermal power system with non reheat turbine with constant load parameters, interconnected thermal power system with non reheat turbine with governor dead band

Interconnected thermal power system with non reheat turbine with variable load gain parameter, organized thermal power system through non reheat turbine with variable load time constant parameter, organized thermal power system through reheat turbine with constant load parameters, interconnected thermal power system with reheat turbine with variable load gain parameter, interconnected thermal power system with reheat turbine with variable load time constant parameter etc.

Table 1
Tuned PID parameter values with PSO Technique

Scenario	*Area-1*			*Area-2*		
	Kp	*Ti*	*Td*	*Kp*	*Ti*	*Td*
Interconnected thermal power system with non reheat turbine with constant load parameters	1.6559	0.9980	0.998	0.0102	0.8422	0.6473
Interconnected thermal power system with non reheat turbine with governor dead band	0.2514	0.4998	0.999	0.0100	0.9030	0.8637
Interconnected thermal power system with non reheat turbine with variable load gain parameter (DEC)	1.9980	0.9980	0.999	0.0102	0.8840	0.6736
Interconnected thermal power system with non reheat turbine with variable load gain parameter (INC)	1.3274	0.9980	0.998	0.0104	0.6751	0.5770
Interconnected thermal power system with non reheat turbine with variable load time constant parameter (DEC)	1.2090	0.9870	0.997	0.0100	0.8351	0.7946
Interconnected thermal power system with non reheat turbine with variable load constant parameter (INC)	1.9990	0.9980	0.998	0.0102	0.9130	0.7597
Interconnected thermal power system with reheat turbine with constant load parameters	1.9980	0.7974	0.997	0.0189	0.8545	0.9965
Interconnected thermal power system with reheat turbine with variable load gain parameter (DEC)	1.9980	0.6161	0.997	0.0168	0.9074	0.7511
Interconnected thermal power system with reheat turbine with variable load gain parameter (INC)	1.9980	0.9161	0.998	0.0103	0.8298	0.7717
Interconnected thermal power system with reheat turbine with variable load time constant parameter (DEC)	1.9980	0.8648	0.998	0.01	0.8015	0.7635
Interconnected thermal power system with reheat turbine with variable load constant parameter (INC)	1.9980	0.6090	0.998	0.01	0.8608	0.7143

Table 2
Steady state and transient parameters with and without secondary controller

Scenario	*Without PSO tuned PID*			*With PSO tuned PID*		
	Peak	e_{ss}	*Ts*	*Peak*	e_{ss}	*Ts*
Interconnected thermal power system with non reheat turbine with constant load parameters	Medium	Medium	Medium	Low	zero	low
Interconnected thermal power system with non reheat turbine with governor dead band	Medium	Medium	High	Low	zero	low
Interconnected thermal power system with reheat turbine with constant load parameters	High	High	High	Low	zero	low
Interconnected thermal power system with reheat turbine with variable load gain parameter (DEC)	Medium	High	Medium	Low	zero	low
Interconnected thermal power system with reheat turbine with variable load constant parameter (INC)	Medium	High	Medium	Low	zero	low

Table 3
ISE values at Best particle position for initial and final iteration

Case	*Initial ISE*	*Final ISE*
Interconnected thermal power system with non reheat turbine with constant load parameters	0.0077869	0.0064293
Interconnected thermal power system with non reheat turbine with governor dead band	0.0065467	0.0049194
Interconnected thermal power system with non reheat turbine with variable load gain parameter (DEC)	0.0054027	0.0043522
Interconnected thermal power system with non reheat turbine with variable load gain parameter (INC)	0.0109930	0.0090484
Interconnected thermal power system with non reheat turbine with variable load time constant parameter (DEC)	0.012650	0.010388
Interconnected thermal power system with non reheat turbine with variable load constant parameter (INC)	0.006453	0.0044017
Interconnected thermal power system with reheat turbine with constant load parameters	0.013632	0.011147
Interconnected thermal power system with reheat turbine with variable load gain parameter (DEC)	0.010454	0.0095771
Interconnected thermal power system with reheat turbine with variable load gain parameter (INC)	0.013718	0.01297
Interconnected thermal power system with reheat turbine with variable load time constant parameter (DEC)	0.014643	0.013821
Interconnected thermal power system with reheat turbine with variable load constant parameter (INC)	0.0099297	0.0095801

5. CONCLUSION

In this paper, Load Frequency Control of an Interconnected Multi Area Power System with Diverse Scenarios using Swarm based optimization Algorithm was studied. Based on the simulation results, following conclusions were made.

- The presence of reheat turbine in the power system will improve the efficiency but when random load changes occur, the system needs more time to settled down when compared to system with non reheat turbine.
- The frequency oscillations were comparatively large for the system with governor dead band.
- The proper secondary controller minimizes the errors and improves the system in all cases.
- The parameter variations will influence the system behavior and which is large for the system without secondary controller and small for the system with secondary controller.

REFERENCES

[1] Lalit Chandra Saikia, Sukumar Mishra, Nidul Sinha, J. Nanda “Automatic generation control of a multi area hydrothermal system using reinforced learning neural network controller” *Electrical Power and Energy Systems* 33 (2011) 1101–1108.

[2] A. Khodabakhshian, M. Ezatabadi Pour, R. Hooshmand “Design of a robust load frequency control using sequential quadratic programming technique” *Electrical Power and Energy Systems* 40 (2012) 1–8.

[3] Reza Farhangi, Mehrdad Boroushaki, Seyed Hamid Hosseini “Load–frequency control of interconnected power system using emotional learning-based intelligent controller” *Electrical Power and Energy Systems* 36 (2012) 76–83.

[4] K.R. Sudha, Y. Butchi Raju, A. Chandra Sekhar "Fuzzy C-Means clustering for robust decentralized load frequency control of interconnected power system with Generation Rate Constraint" *Electrical Power and Energy Systems* 37 (2012) 58–66.

[5] Wen Tana, Hongxia Zhang, Mei Yu "Decentralized load frequency control in deregulated environments" *Electrical Power and Energy Systems* 41 (2012) 16–26.

[6] Rajeeb Dey, Sandip Ghosh, G. Ray, A. Rakshit "H" load frequency control of interconnected power systems with communication delays" *Electrical Power and Energy Systems* 42 (2012) 672–684.

[7] R. Hooshmand, M. Moazzami "Optimal design of adaptive under frequency load shedding using artificial neural networks in isolated power system" *Electrical Power and Energy Systems* 42 (2012) 220–228.

[8] Fatemeh Daneshfar, Hassan Bevrani "Multi objective design of load frequency control using genetic algorithms" *Electrical Power and Energy Systems* 42 (2012) 257–263.

[9] K.P. Singh Parmar, S. Majhi, D.P. Kothari "Load frequency control of a realistic power system with multi-source power generation" *Electrical Power and Energy Systems* 42 (2012) 426–433.

[10] Wen Tan, Hong Zhou "Robust analysis of decentralized load frequency control for multi-area power systems" Electrical Power and Energy Systems 43 (2012) 996–1005.

[11] T. Hussein "A Genetic Algorithm for Optimum Design of PID Controller in Load Frequency Control" World Academy of Science, Engineering and Technology 70 2012.

[12] Hao Huang, Fangxing Li "Sensitivity Analysis of Load-Damping Characteristic in Power System Frequency Regulation" *IEEE transactions on power systems*, vol. 28, no. 2, may 2013.

[13] Bethala Prasad, Ch. Durga Prasad and G.Pavan Kumar "Effect of Load Parameters Variation on AGC of Two Area Thermal Power System In the Presence of Integral and PSO-PID Controllers" I-manager's *Journal on Instrumentation and Control Engineering*, 3(2), Feb-Apr 2015, Print ISSN 2321-113X, E-ISSN 2321-1148, pp. 16-23.

[14] R.Durga Kalyan, G.Pavan Kumar and Ch. Durga Prasad "Effect of Load Variations on AGC of an Interconnected Hydro-Thermal Power System in Presence of Conventional PI and FL Controllers" in 2014 IEEE international conference on Advanced communication, control and computing technologies ICACCCT-2014.