academicJournals

Vol. 5(3), pp. 44-49, September, 2013
DOI 10.5897/JEEER12.107
ISSN 1993–8225 ©2013 Academic Journals
http://www.academicjournals.org/JEEER

Journal of Electrical and Electronics Engineering Research

Full Length Research Paper

Effect of generation rate constraint on load frequency control of multi area interconnected thermal systems

Naresh Kumari* and A. N. Jha

Department of Electrical, Electronics and Communication Engineering, ITM University, Gurgaon (Haryana), India.

Accepted 29 August, 2013

This paper deals with automatic generation control (AGC) of two unequal interconnected thermal areas considering the reheat turbines for thermal areas and appropriate Generation Rate Constraint (GRC). The response with GRC is compared with the analysis done without the Generation Rate Constraint. Although the frequency deviation is less with suitable controllers when the GRC is not considered, it is not the actual frequency deviation. When GRC is considered the actual frequency deviation can be found and then accordingly the controller is tuned. Particle swarm optimization (PSO) technique is used to simultaneously optimize the integral gains (KI), speed regulation parameter (Ri) and frequency bias (Bi) parameter. Most of the literature for AGC used classical approach based on integral squared error (ISE) technique, etc. for optimal selection of controller parameters. This is a trial and error method; extremely time consuming when several parameters have to be optimized simultaneously. The computational intelligence based technique like PSO is a more efficient and fast technique for optimization of different gains in load frequency control. MATLAB/SIMULINK is used as a simulation tool.

Key words: Area control error, automatic generation control, particle swarm optimization, generation rate constraint

INTRODUCTION

The main task of power system is to maintain the balance between power demand and power generation, to provide users with reliable, high-quality electric power. Changes in the power demand affect the frequency of the power system as well as the tie-line power flow between control areas (Saadat, 1999). Therefore, the main objectives of the Load Frequency Control (LFC) are to keep the system frequency at the scheduled value, and regulate the generator units based primarily on area control error (ACE), making the area control error tends to zero under the continuous adjustment of active power, so that the generation of entire system and load power well match (Elgerd, 1983; Nanda et al., 2006).

Many times the interconnected power systems do not include the effect of restrictions on the rate of change of power generation. The different power sources have different rates of power generation. Any power source when instructed to increase/ decrease its power from a specified value need to follow a ramp rate (Panda et al., 2009). We need to emphasize here that the power output cannot be changed from one value to another instantaneously. The ramp rate limit for power output change is termed as Generation Rate Constraint (GRC) and depends on the type of the power source (Mallesham et al., 2012). In thermal power plants the steam flow rate change from the governor is not instantaneous and also it is kept within the permissible limits, otherwise the steam turbine will be subjected to a high temperature difference between the face of the blades towards the steam inflow and the other face which is not towards the injected

---

*Corresponding author. E-mail: nareshkumari@itmindia.edu.

steam. This high temperature difference can lead to the breakdown of turbine. This phenomenon leads to the consideration of GRC while designing the model of thermal power plant. In the present work the Automatic Generation Control of two interconnected thermal power plants has been compared with and without GRC. The PI controller used in both the cases is tuned with computationally intelligent technique called Particle Swarm Optimization.

Traditionally, the area control error (ACE), which is the combination of area frequency bias times frequency deviation and net power interchange error or net tie-line flow error is used as the input of the load frequency controller whose objective is to control the ACE and the interconnection frequency deviation. The load frequency controllers used in the industry are proportional-integral (PI) type and are tuned online based on trial-and-error approaches (Saikia et al., 2010). Several optimization techniques have been proposed to tune the control parameters using simulation of the entire system rather than just the control area being studied (Venayagamoorthy and Harley, 2002; Saikia et al., 2008). Some of them simply assume that all subsystems are identical, which is not the case of actual power systems (Tyagi and Srivastava, 2006). Subsequently, a number of decentralized load frequency controllers were developed to eliminate the above drawback (Patel et al., 2008).

The controller used here is a PI controller tuned by a robust control design algorithm called Particle Swarm Optimization (PSO) to achieve the robust performance details.

In order to obtain the optimal controller parameters with regards to controller structure constraints, Particle Swarm Optimization (PSO) is a powerful probabilistic search technique and is used to find the control parameters of the PI load frequency controller (Naik et al., 2005).

MODELLING OF AGC FOR TWO-AREA POWER SYSTEM

The system considered in this study consist two thermal system control areas connected by a tie-line and the transfer function models using MATLAB simulink without GRC (Nanda et al., 2006) and with GRC are as shown in Figures 1 and 2, respectively. The Generation rate constraint (GRC) is realized by differentiating outputs from both the power sources, thereafter a saturation limiter is used to decide the upper and lower limit of the rate (Haddin et al., 2011; Kundur, 1994). The signal is further integrated to get back to the original signal.

The areas taken for investigation are of 2000 and 4000 MW. The turbine used is single reheat turbine. The suitable Generation Rate Constraint is taken into account and generally it is found to be 3%/min (Hari et al., 1991; Liu et al., 2010). The other parameters of the system are given in Table 1 (Nanda et al., 2009). GRC for the kth subsystem is 0.0005 p.u. MW/s.

Equation of objective function (ISE) used is given below:

$$ISE = \int(\Delta f1^2 + \Delta f2^{\ 2} + \Delta Ptie^{\ 2})dt$$

A step load perturbation of 1% of nominal loading has been considered in Area-1. The effect on frequency is observed on both areas. The gains of both areas are optimized using PSO technique to have the minimum frequency deviation.

The frequency deviations after the use of PI controller and optimizing the gains in both the areas are shown in Figures 3 and 4 with the 1% load change in Area-1. Then same load change is done in Area-2 and Δf1 and Δf2 is observed with same gains and shown in Figures 5 and 6. The comparison is done with frequency deviation without GRC, which is less but not the actual frequency deviation in practical cases, hence GRC is to be considered and accordingly the controller is designed and tuned for frequency control.

Table 1. Nominal parameters of thermal systems investigated.

f=60 Hz
Tg1=Tg2=0.8 s
Ptie max=200 MW
Tr1=Tr2=10 s, T12=0.544
Kr1=Kr2=0.5
Tt1=Tt2=0.3
Kp1=Kp2=120 Hz/puMW
Tp1=Tp2=20 s, a=-0.5; a12=-0.5

RESULT AND DISCUSSION

The interconnected power system with two different thermal power plants as described has been considered for studies. The dynamic responses have been obtained with 1% load change in one area at a time, which also affects the frequency of other systems. For the automatic generation control the computationally intelligent technique - Particle Swarm Optimization has been applied for optimizing the values of Kp, Ki ,Ri and Bi of various areas. The analysis and comparison has been done with and without considering the GRC.

The objective function (ISE) of system shown in Figures 1 and 2 is given to the PSO technique. The population size of the swarm is taken as 50 and maximum number of iterations is limited to 50. The values assigned to c1, c2 are 2 each and w_{max}=0.7, w_{min}=0.3. The eight variables obtained after optimizing the PI controller, frequency bias and speed regulation parameter of each area simultaneously are provided in Table 2. The dynamic responses have been shown in Figures 3 to 6. The performance index variation using PSO method has been shown in Figure 7.

OVERVIEW OF PARTICLE SWARM OPTIMIZATION (PSO)

PSO is a population-based optimization method first proposed by Eberhart and Colleagues. Some of the attractive features of PSO include the ease of implementation and the fact that no gradient information is required. It can be used to solve a wide array of different

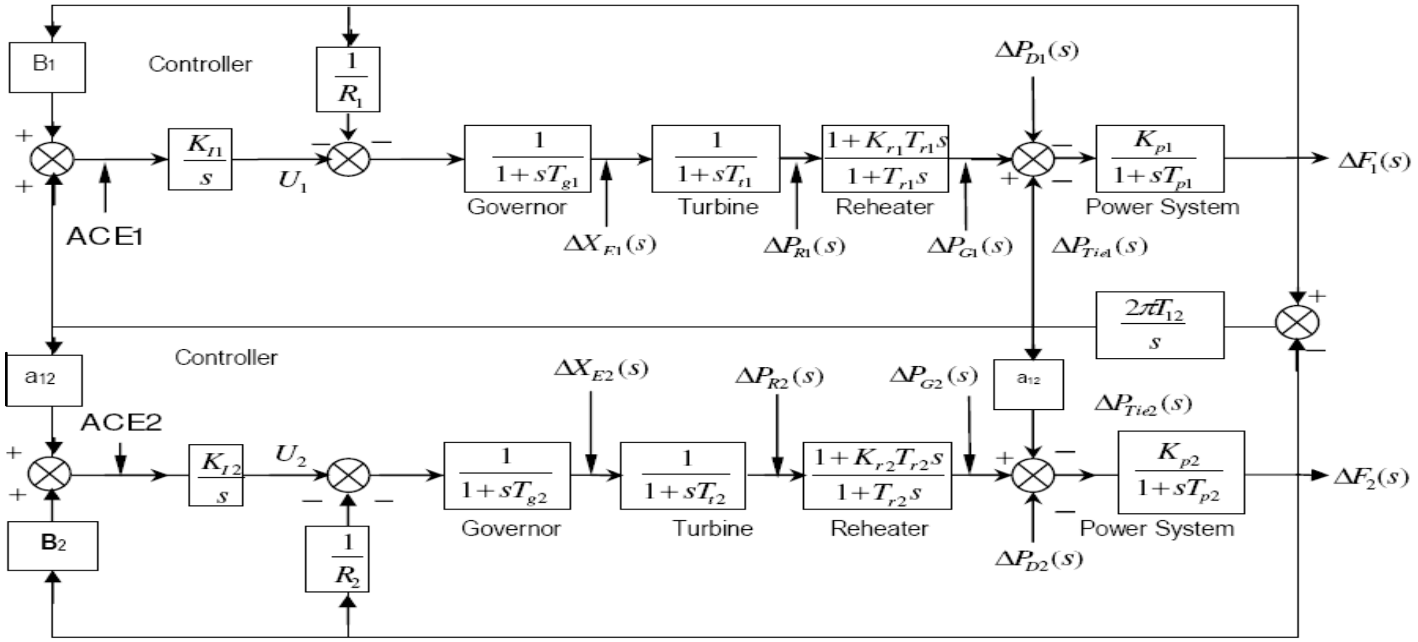

Figure 1. Transfer function model of two area interconnected reheat thermal system without GRC.

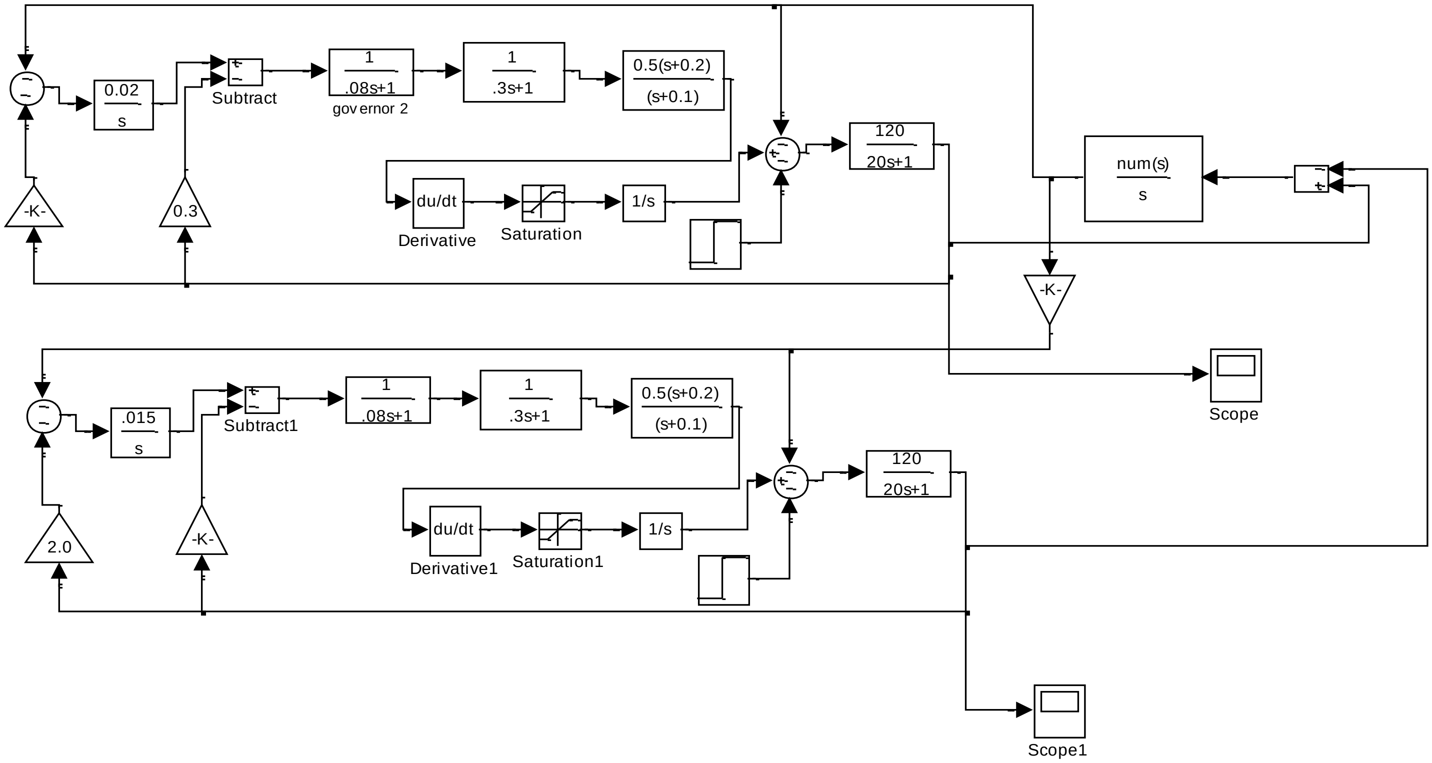

Figure 2. Transfer function model of two area interconnected reheat thermal system with GRC.

optimization problems. Particle swarm optimization (PSO) is a stochastic optimization technique based on a collection of population (swarm) and inspired by social behavior of the movement of bird or fish to find food sources (Figure 8).

To find the optimal solution, every bird, or in this case

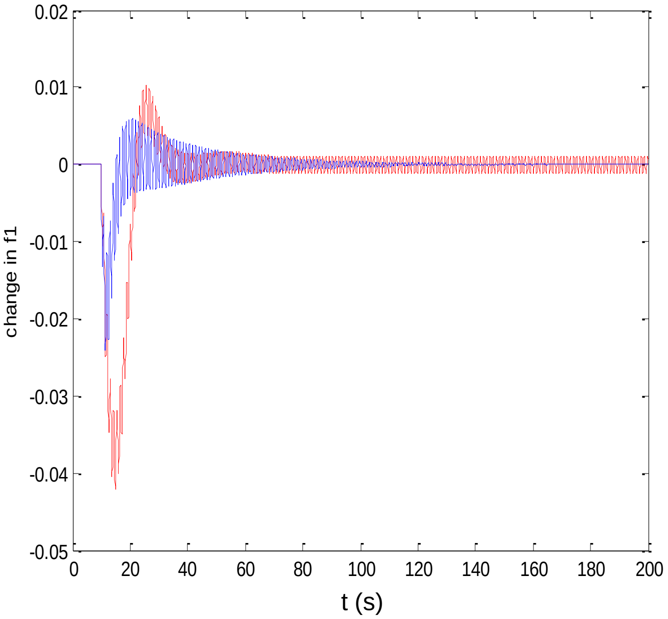

Figure 3. Change in f1 for 1% change in load of Area 1.

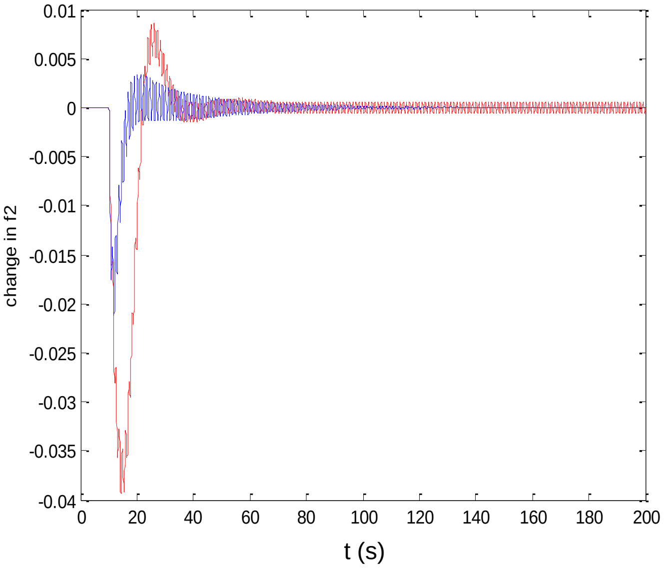

Figure 4. Change in f2 for 1% change in load of Area 1.

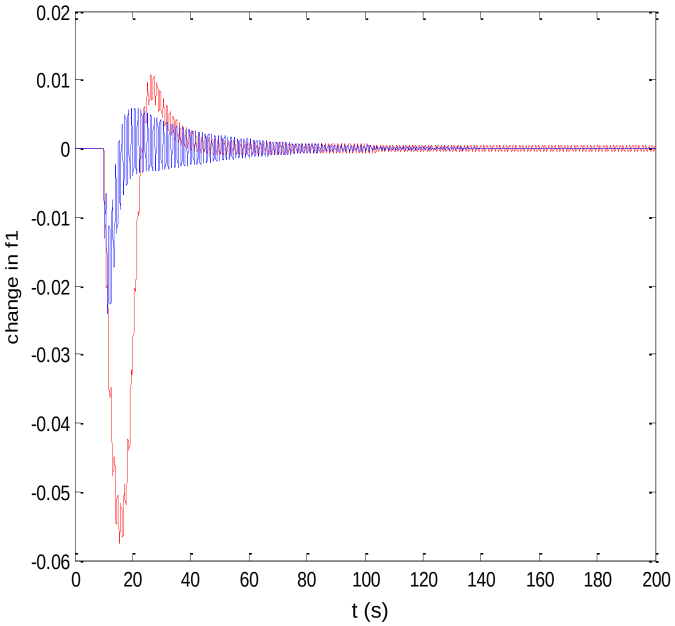

Figure 5. Change in f1 for 1 % change in load of area 2.

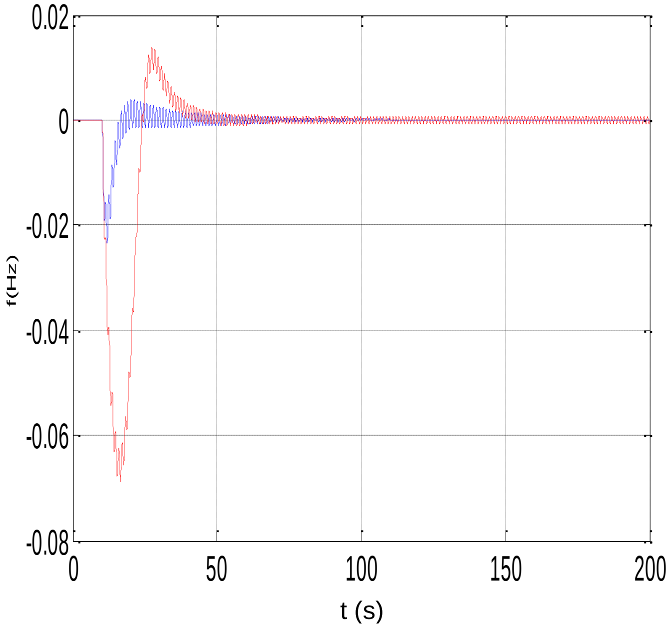

Figure 6. Change in f2 for 1% change in load of area 2.

the particle, set the search direction based on two factors, namely previous best experience (pbest) and the best experience of all the birds that exist in this population (gbest). PSO model consists of a set of particles initialized with a population of candidate solutions at random (Naik et al., 2005). Particles moving through space with a d-dimensional problem to seek new solutions, with fitness f, can be calculated as a determined measuring quality. Each particle has a position represented by the vector-position xi (i is the index of the particle) and speed (velocity) is represented by the vector velocity vi. Each particle has so far resulted in the best position (pbest) in vector xik, and the value of the j-th dimension is xijk. Vector best position among the compounds (swarm) so far (gbest) is stored in a vector xl, and the value of the j-th dimension is xjl. During this time of iteration (t), the particles update the speed of the previous speed with the new speed determined. The new position is determined by the sum of the previous position and the new velocity.

Table 2. Optimized values of system variables using PSO technique.

Interconnected areas	Optimum parameters	Controller and system parameters optimized by PSO
Thermal Power System -I	Kp1	0.011
	Ki1	0.020
	B1	2.100
	R1	0.300
Thermal Power System -II	Kp2	0.012
	Ki2	0.015
	B2	2.020
	R2	0.850

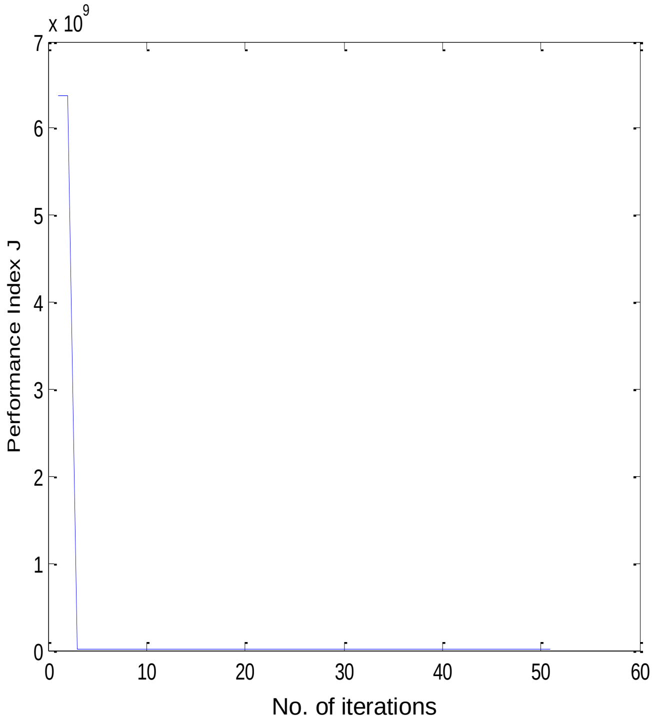

Figure 7. Performance Index using PSO technique.

Conclusion

The frequency change occurs in both areas due to load fluctuation in one area at a time. The PI controller is effective for controlling this frequency change along with suitable frequency bias feedback gain (Bi) and governor speed regulation parameter (Ri). The transfer function models for the two unequal interconnected thermal power plants have been developed with and without considering the GRC. The frequency control is done with PI control for this interconnected system. The powerful computationally intelligent PSO technique has been applied for optimization of various controller gains and system parameters. The simulation studies on the systems have been done in MATLAB/SIMULINK, which show that the effective PI controller for minimizing the frequency deviation can be designed when GRC is taken into consideration. Further, the PSO technique used for optimization of Kp, Ki, Bi and Ri is very efficient and powerful computationally intelligent technique.

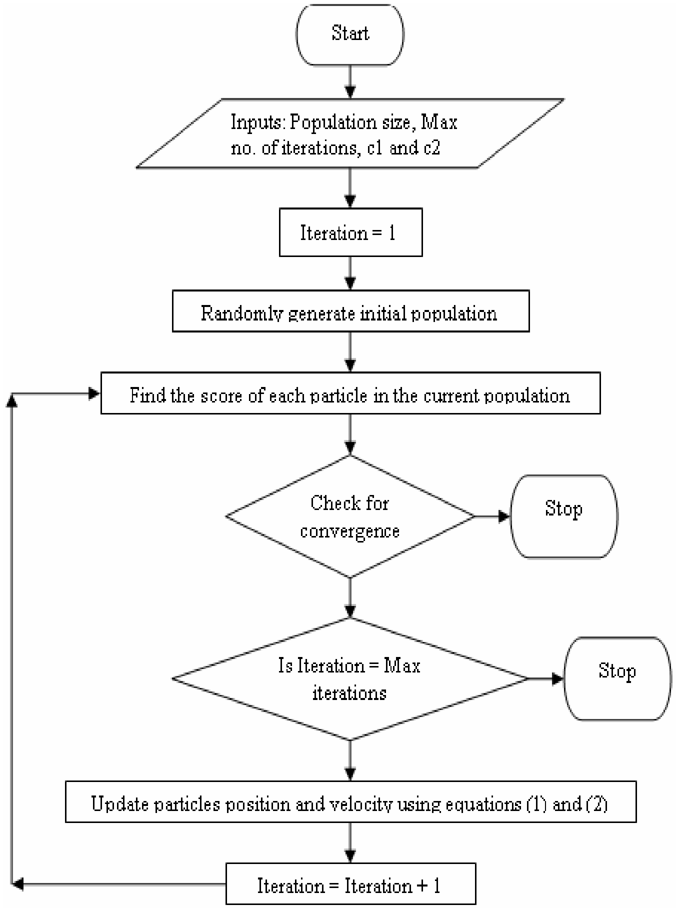

Figure 8. Flow chart for Particle Swarm Optimization.

Nomenclature

i:	Subscript referred to area (1, 2).
*:	Superscript denotes optimum value.
P_{ri}:	Rated power of area (MW).
Hi:	Inertia constant of area (s).
ΔP_{Di}:	Incremental load change in area (p.u.).
Di:	ΔP Di / Δfi (p.u./Hz).
ΔPgi:	Incremental generation change in area (p.u.).
Ri:	Governor speed regulation parameter of area. (Hz/p.u.MW).
Tgi:	Steam governor time constant of area (s).
Kri:	Steam turbine reheat constant of area.
Tri:	Steam turbine reheat time constant of area (s).
Tti:	Steam turbine time constant of area (s).
Bi:	Frequency bias of area.

f: Nominal system frequency (Hz).
Kpi: 1/ Di (Hz/p.u.).
Kii: Gain of integral controller in area.
Bi: Bi frequency response characteristics of area (i)
T: Simulation time (s)
Δfi: Incremental change in frequency of area (Hz).
ΔPgi: Incremental generation of area (p.u.).
ΔPtie: 1-2 Incremental change in tie power of tie 1–2(p.u.).

REFERENCES

Elgerd OI (1983). Electric energy systems theory: An introduction. 2nd ed., New Delhi: Tata McGraw-Hill.

Haddin M, Soebagio, Soeprijanto A, Purnomo M (2011). Gain Coordination of AVR-PSS and AGC based on Particle Swarm Optimization to improve the dynamic stability of the power system. Int. J. Acad. Res. 3(3):462.

Hari L, Kothari ML, Nanda J (1991). Optimum selection of speed regulation parameters for automatic generation control in discrete mode considering generation rate constraints. IEE Proc. 138(5):401–406.

Kundur P (1994). Power system stability and control. Tata McGraw-Hill, New Delhi, India, pp. 410-478.

Liu X, Zhan X, Qian D (2010). Load Frequency Control Considering Generation Rate Constraints. Proceedings of the 8th World Congress on Intelligent Control and Automation.

Mallesham G, Mishra S, Jha AN (2012). Automatic Generation Control of Microgrid using Artificial Intelligence Techniques. IEEE Power and Energy Society General Meeting, 2012.

Naik S, ChandraSekhar K, Vaisakh K (2005). Adaptive PSO based optimal fuzzy controller design for AGC equipped with SMES. J. Theor. Appl. Inf. Technol. 7(1):008-017.

Nanda J, Mangla A,Suri S (2006). Some new findings on automatic generation control of an interconnected hydrothermal system with conventional controllers. IEEE Trans. Energy Convers. 21(1):187–194.

Nanda J, Mishra S, Saikia LC (2009). Maiden Application of Bacterial Foraging-Based Optimization Technique in Multiarea Automatic Generation Control. IEEE Trans. Power Syst. 24(2).

Panda G, Panda S, Ardil C (2009). Automatic Generation Control of Interconnected Power System with Generation Rate Constraints by Hybrid Neuro Fuzzy Approach. World Academy of Science, Engineering and Technology, p. 52.

Patel RN, Sinha SK, Prasad R (2008). Design of a Robust Controller for AGC with Combined Intelligence Techniques. World Academy of Science, Engineering and Technology 21:687-693.

Saadat H (1999). Power System Analysis. McGraw-Hill.

Saikia LC, Mishra S, Sinha N, Nanda J (2008). Automatic generation control of a multi area hydrothermal system using reinforced learning neural network controller. Electr. Power Energy Syst. 33:1101-1108.

Saikia LC, Nanda J, Mishra S (2010). Performance comparison of several classical controllers in AGC for multi-area interconnected thermal system. Electric. Power Energy Syst. AUPEC. 22:1-6.

Tyagi B, Srivastava SC (2006). A Decentralized Automatic Generation Control Scheme for Competitive Electricity Markets. IEEE Trans. Power Syst. 21(1):312-320.

Venayagamoorthy GK, Harley RG (2002). Two Separate Continually Online-Trained Neuro-controllers for Excitation and Turbine Control of a Turbo generator. IEEE Trans. Ind. Appl. 38(3):887-893.