Application of PSO Technique in Multiarea Automatic Generation Control

Mohan Kashyap, Anu Chaudhary and Satish Kansal

Abstract This paper proposes particle swarm optimization (PSO) technique to optimize the gains of an integral controller for automatic generation control (AGC) of a three unequal area thermal power system. Every control area takes into consideration dynamics of the thermal systems. Load frequency of interconnected multiarea thermal power system is also controlled for obtaining a better steady-state response of system. Further, results of PSO technique are compared with the bacterial-foraging (BF) technique that reveals superior performance of PSO technique over BF technique.

Keywords Particle swarm optimization · Integral controller · Three-area thermal power system

1 Introduction

One of the essential requirements for obtaining a continuous and healthy operation in the multiarea power system is automatic generation control [1, 2]. In large interconnected power systems, the frequency remains changing that leads to serious stability problems. Various factors like sudden changes in demand of power, different load characteristics, and various faults also increase such types of problems [3]. For obtaining a satisfactory operation, a balance between fixed frequency and

Mohan Kashyap (✉)
IKG Punjab Technical University, Jalandhar, Punjab, India
e-mail: mohan_kashyap80@rediff.com

Anu Chaudhary
Geeta Institute of Management and Technology, Kurukshetra, Haryana, India
e-mail: chaudharyanubattan60@gmail.com

Satish Kansal
Baba Hira Singh Bhattal Institute of Engineering and Technology, Lehragaga, Sangrur, Punjab, India
e-mail: kansal.bhsb@gmail.com

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the active power is required [2]. In power system, power demand change or change in power generation results in change of system frequency. Modern power systems are interconnected to one another and power exchange takes place through tie-lines. For obtaining interconnected operation of power system, the desired operating level of system is characterized by voltage profile, load flow configuration, and the nominal frequency. This can be obtained by controlling the generated real and reactive powers [2, 4]. AGC plays an important role in power system by controlling the frequency of system and tie-line power flow under normal operating conditions and during small fluctuations.

Various classical approaches utilized for optimizing the value of integral gains are found to be time consuming. Also some new techniques like genetic algorithm, neural network, and fuzzy systems are nowadays utilized for obtaining optimum value of integral gains [5, 6]. In this paper, automatic generation control of a three-area thermal power system is achieved using integral controller. As the values of integral gains (K_{i1}, K_{i2}, K_{i3}) are needed to be optimized for obtaining the better steady-state response, PSO has been applied and proved to be a powerful and intelligent technique for optimizing the value of integral gains. It is a powerful optimization tool based on population-based approach. In this technique, particles fly in a multidimensional space. The direction of particle is defined by its history experience and the set of particles neighboring the particle. The convergence speed of PSO is very fast and it is easy to use [7–15].

2 System Investigated

Three-area interconnected system consists of three interconnected control areas. There is flow of tie-line power as per the changes in the load demand due to the interconnection made between the control areas. Thus the overall stability of the system is maintained at a balanced condition in spite of the constant variations in the load and load changes. Three unequal area of different MW capacity are considered. Integral controllers are used to improve system performance. The nominal parameters of system model are taken from Ref. [16]. Per unit values of the parameters of unequal areas are taken to be same on respective MW capacity bases. Therefore, while modeling interconnected areas of different capacities, quantities $a_{12} = -P_{r1}/P_{r2},$ $a_{23} = -P_{r2}/P_{r3}$ and $a_{13} = -P_{r1}/P_{r3}$ are taken into consideration [16]. State-space approach has been used for modeling the system. Then PSO is applied to get optimum values of the integral gains. The MATLAB simulation model of three-area system is shown in Fig. 1.

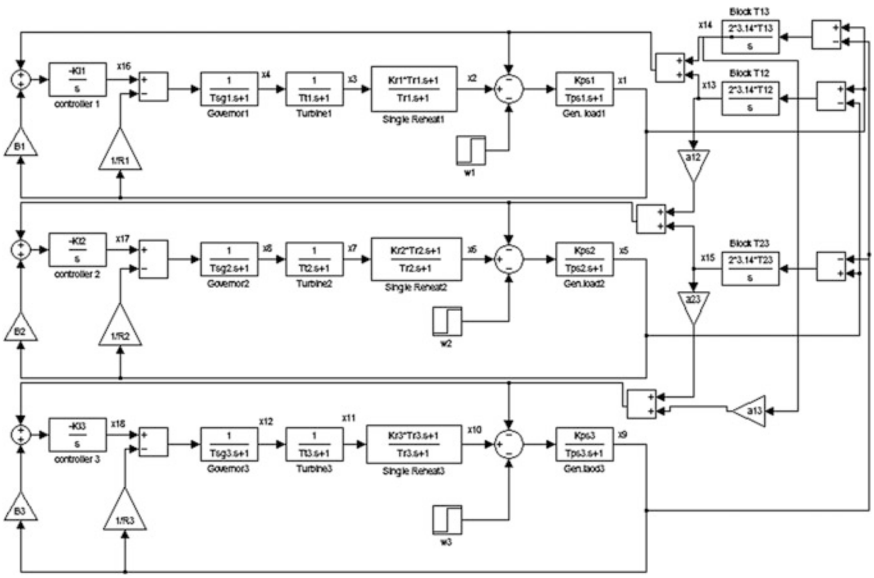

Fig. 1 MATLAB simulation model of three-area thermal power system

3 Simulation and Results

In this case, multiarea control system is unequal and consists of thermal system with reheat turbine. MATLAB version 7.10 is used to obtain dynamic response for Δf_1, Δf_2, Δf_3, $\Delta P_{tie\_line1\text{-}2}$, $\Delta P_{tie\_line1\text{-}3}$, and $\Delta P_{tie\_line2\_3}$ for 1 % step load perturbation (SLP) in either area. The MATLAB simulation model of a conventional three-area system is shown in Fig. 1 [16]. Following parameters have been used for PSO strategy [15, 17]:

$c_1 = 2$, $c_2 = 2$, $w_{max} = 0.9$, $w_{min} = 0.4$, $It_{max} = 50$, Population Size = 20

Table 1 provides optimum values of integral controller gains.

The frequency deviation response of the area1, area2, and area3 are shown in Fig. 2a–c. Tie-line power deviation response is shown in Fig. 2d–f. Further, it is examined that dynamic response satisfies the requirement of AGC problem in term of settling time and steady-state error.

For same input model parameters, the output response of BF technique is different [16]. The output parameters of BF technique are obtained from Ref. [16] and compared with those of applied PSO technique. Table 2 provides the comparison of

Table 1 Optimum values of integral controller gains

Controller gains	Values
K_{i1}	0.3848
K_{i2}	0.2410
K_{i3}	0.2080

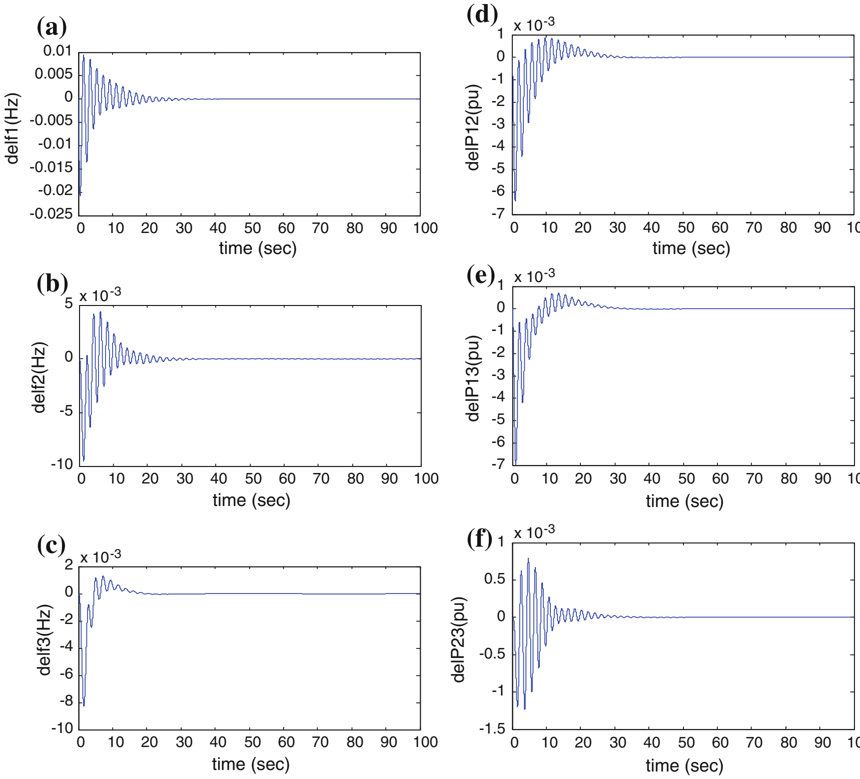

Fig. 2 **a** Frequency deviation in the area 1. **b** Frequency deviation in the area 2. **c** Frequency deviation in the area 3. **d** Power deviation in tie-line between area 1 and area 2. **e** Power deviation in tie-line between area 2 and area 3. **f** Power deviation in tie-line between area 1 and area 3

output integral gain values from both BF and PSO techniques. Table 3 provides the comparison of output parameters of BF and PSO techniques. Figure 3 shows combined output response of area1, area2, and area3 using BF and PSO.

Table 2 Comparison of output integral gains values

Optimum gains	BF	PSO
K_{i1}	0.4465	0.3848
K_{i2}	0.2191	0.2410
K_{i3}	0.2799	0.2080

Table 3 Comparison of output parameters

Output parameters	BF			PSO		
	Delf1	Delf2	Delf3	Delf1	Delf2	Delf3
Rise time	0.0030	2.6188	3.2231	0.000017	0.0232	0.000041
Settling time	26.4	37.6	40.8	23.9	24.9	16.5
Settling min	−0.0145	−0.0030	−0.0017	−0.0135	−0.0095	−0.00041
Settling max	0.0071	0.0015	0.00033	0.0094	0.0044	0.0013

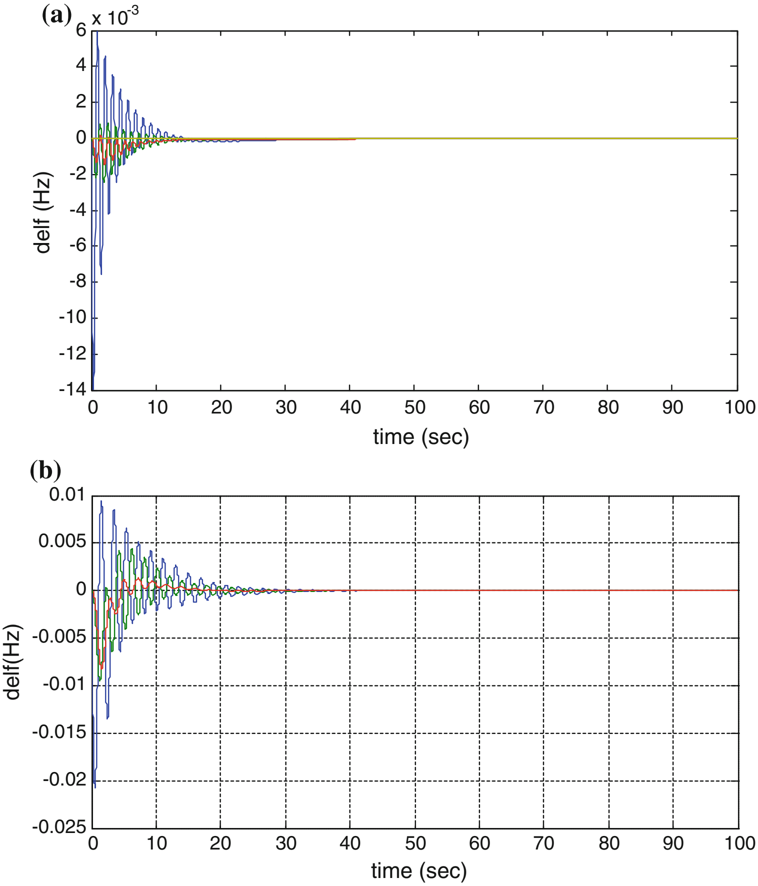

Fig. 3 Combined output response of area1, area2, area3 by using **a** BF and **b** PSO

4 Conclusion

In this paper, AGC of multiarea unequal thermal-thermal power system is presented. PSO technique is used to optimize the controller gains. In the multiarea power system, frequency response and power deviation response of tie-line are obtained for 1 % SLP. It is observed that frequency response and power deviation response settle with zero steady state error and satisfy the requirements. Also after comparison of results with Bacterial-foraging technique, it is found that PSO performs better than BF because of its fast convergence speed.

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