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Algorithm for Optimization of Automatic Generation Control Techniques in Inter Connected Power System

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ABSTRACT: This paper presents the particle swarm optimization (PSO) technique for optimization of the integral controller gains (Ki) in the automatic generation control (AGC) of two area thermal-thermal interconnected power system in deregulation environment. Both control area contain the dynamics of thermal systems. Further each area has two GENCO's and two DISCO's which have bilateral contract with each other. The dynamic response of the system has been studied for 1% step load perturbations in area1. The automatic generation control in deregulated environment is studied for three different contract scenarios. To visualize bilateral contracts in deregulated environment, the concept of DISCO participation matrix (DPM) is used. The optimized gain is used in the system to improve its performance. Simulations had been performed using MATLAB / Simulink.

Keywords: AGC (Automatic Generation Control), Deregulated Environment, Particle Swarm Optimization (PSO), Integral Controller, Area Control Error (ACE), DISCO participation matrix (DPM)

I. INTRODUCTION

Automatic generation control (AGC) mainly involves the problems of transient load perturbations that make the frequency and tie-line power to deviate from their predetermine values [1]. These perturbations also lead to the mismatch in generation of power system and overall load demand. But these are the most important parameters of power system that are needed to be controlled to their nominal values even after the disturbances [2]-[3].

At Present, the electric power industry is in transition from vertically integrated utilities to an industry that will incorporate competitive companies, which is known as deregulation. Also, major changes have been introduced into the structure of electric power utilities all around the world. The reason for this was to improve the efficiency in the operation of power system by means of deregulating the industry and opening it up to private competition. In this new framework, consumers will have an opportunity to make a choice among competing providers of electric energy. The net effect of such changes will mean that the transmission generation and distribution systems must now adapt to a new set of rules dictated by open markets. The deregulated power system consists of GENCOs, TRANSCOs and DISCOs with an open access policy. In the new structure, GENCOs may or may not particulate in their own or other areas.

Thus, various combinations of possible contracted scenarios between DISCOS and GENCOS are possible. All the transactions have to be cleared by the independent system operator or other risible organizations. Due to these, a study on simulation and optimization in an AGC system after deregulation [6]-[9]. This increases the complexity of the load frequency issue and calls for more insight and research. So here, the effect of bilateral contracts on the dynamics of the system is taken into account and the concept of DISCO participation matrix for these bilateral contracts is simulated. Automatic generation control (AGC) in a multi area interconnected power system has four principal objectives when operating in either the so-called normal or preventive operating states:

(i) Ensuring zero steady state error for frequency deviations.
(ii) Minimizing unscheduled tie line power flows between neighboring control areas.
(iii) Getting good tracking for load demands and disturbances.
(iv) Maintaining acceptable overshoot and settling time on the frequency and tie line power deviations.

Particle Swarm Optimization (PSO) algorithms are adopted in order to obtain the optimal parameters of the load-frequency controllers.

Here, we adopt the PSO method because, PSO is easier to implement and there are fewer parameters to adjust than conventional method.

II. SYSTEM UNDER INVESTIGATION

Deregulated power system contains various GENCOs and DISCOs, a DISCO has a freedom to make contract with GENCOs in another control area independently [10]. Hence it is known "bilateral transaction". All these transactions can be supervised through a ISO. ISO has an impartial entity and controls a lot of ancillary services and AGC is one of them. In restructured environment, DISCOs have a liberty to demand the power from various GENCOs. To understand the visualization of contract easier, the concept of DPM is used.

In DPM, the number of the columns equals to the number of DISCOs and the number of the rows equals to the number of GENCOs in the system. The sum of cpf s (elements of DPM) determines the total load on GENCO and the p.u. load of all the DISCOs. Each element of this matrix is a fraction of total load contracted by a DISCO toward a GENCO. The total sum of all the elements of a column in the DPM is equal to unity [10],[11].

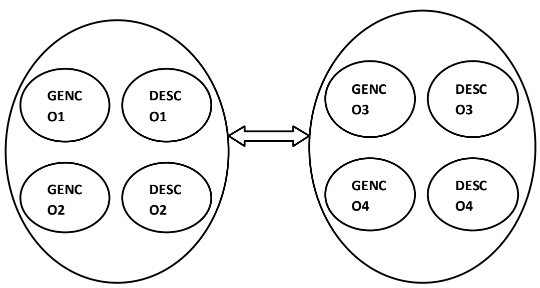


Fig. 1. The configuration of two-area interconnected power system in deregulated environment.

DPM=

$$\begin{vmatrix} cpf_{11} & cpf_{21} & cpf_{31} & cpf_{41} \\ cpf_{12} & cpf_{22} & cpf_{32} & cpf_{42} \\ cpf_{13} & cpf_{23} & cpf_{33} & cpf_{43} \\ cpf_{14} & cpf_{24} & cpf_{34} & cpf_{44} \end{vmatrix}$$

Where cpfs represents "contract participation factor". It is noted that

$$\sum_{i=1} cpf_{ij} = 1 \qquad \ldots(1)$$

In restructured environment, change in the load demand of a DISCO results in change of a local load in the same DISCO area. This corresponds to the local load power system block. The coefficient, which give this sharing, are represented as "area control error (ACE) participation factors" (apf) and

$$\sum_{j=1}^{n} apf_j = 1 \qquad \ldots(2)$$

Where *n* is the number of GENCOs in the each control area. Unlike traditional AGC system, any DISCO can demand for the power supply from any GENCO.

The model presented [10] is considered in this case for further study and analysis of AGC using MATLAB simulation and design of controllers based on PSO optimization. There are two DISCOs and two GENCOs in each control area as shown in Fig. 1. GENCOs are thermal units. The MATLAB simulation model of two-area thermal system in deregulated environment is shown in Fig. 3.

The scheduled tie-line power flow at steady state in case of two-area power system flow is represented as follow [10].

ΔPtie-line1-2, scheduled = [power supplied from GENCOs of area 1 to DISCOs of area 2] - [power supplied from GENCOs of area 2 to DISCOs of area 1] …(3)

The tie-line power error may be represented as follows [10].

ΔPtie-line1-2, error = ΔPtie-line1-2, actual – Δptie - line1-2, scheduled …(4)

For each case, the particle optimization technique is applied to derive the gain of optimum controller. The gain is applied to the system and various parameters like frequency deviation, tie line power etc. are calculated. Firstly discrete equations are developed from state space equations and those equations are utilized in particle foraging optimization algorithm [12].

III. CASE STUDY

A two area thermal-thermal system is considered and three different cases of disturbance are analyzed. DPM for three different cases are shown.

Case 1:

In base case, all of them apfs are same as 0.5 for all the GENCOs. DPM is formed by only taking cpf_{11}, cpf_{12}, cpf_{21}, cpf_{22} are equal to 0.5 [10].

DPM =

$$\begin{vmatrix} 0.5 & 0.5 & 0 & 0 \\ 0.5 & 0.5 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{vmatrix}$$

In the steady state, the GENCO's generation can equal to the contract demand of the DISCOs with it, given as follow:

$$\Delta P_{Gi} = \sum_i cpf_{ij}\ \Delta P_{Lj} \qquad \ldots(5)$$

Where ΔP_{Lj} is the total demand of DISCOj.

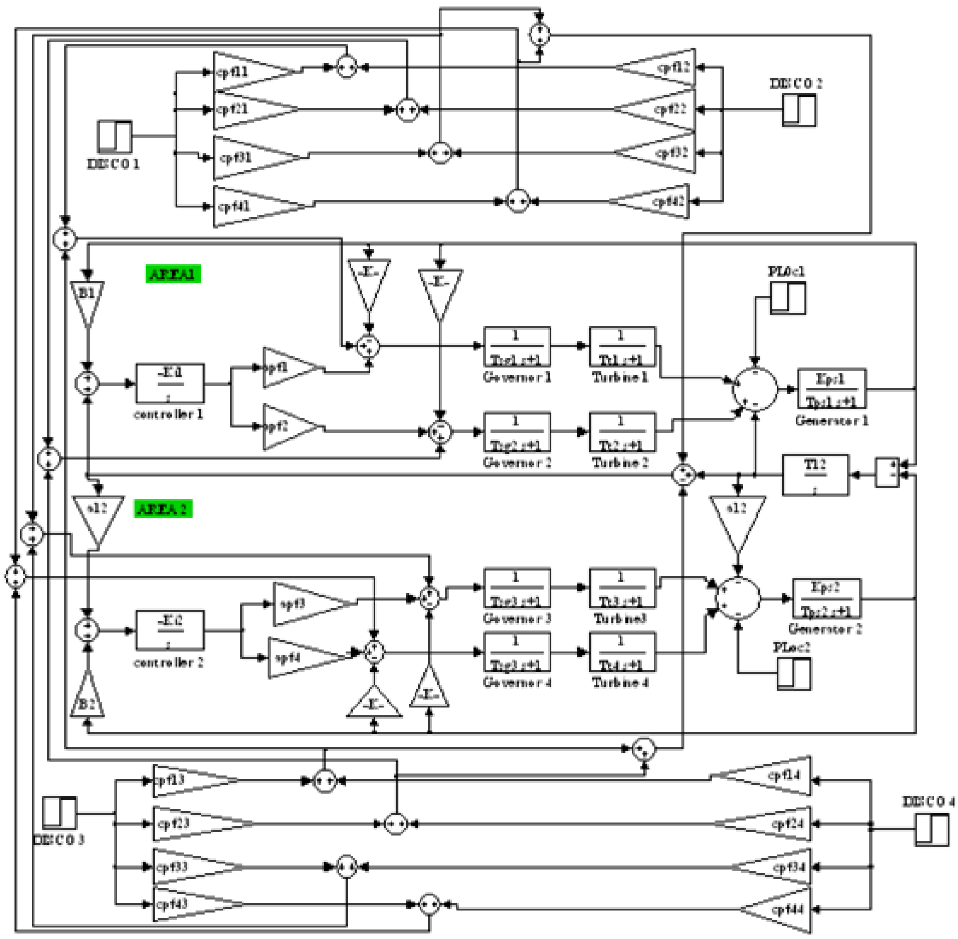


Fig. 2. MATLAB simulation model of two-area thermal system in deregulated environment.

DPM =

0.5	0.25	0	0.3
0.2	0.25	0	0
0	0.25	1	0.7
0.3	0.25	0	0

This is consider that DISCOs demands 0.1 pu MW total power from GENCOs as denoted by elements in DPM and all GENCOs participated in AGC as represented by the following = apfs; apf_1=0.75, apf_2 = 0.25, apf_3 = 0.25, apf_4 = 0.5.

The scheduled power on the tie-line is given as follow [10]:

$$\Delta P_{tie-line1-2,scheduled} = \sum_{i=1}^{2}\sum_{j=3}^{4} cpf_{ij} * \Delta P_{Lj} - \sum_{i=3}^{4}\sum_{j=1}^{2} cpf_{ij} * \Delta P_{Lj} \quad (6)$$

- Genco1(scheduled)=(0.5+0.25+0+0.3)*0.01=0.0105p.u.
- Genco2(scheduled)=(0.2+0.25+0+0)*0.01=0.0045 p.u.
- Genco3(scheduled)=(0+0.25+ 1 +0.7)*0.01= 0.0195p.u.
- Genco4(scheduled) =(0.3+0.25+0+0)*0.01=0.0055 p.u.

$\Delta P_{tie-line1-2,scheduled}$=(0+0+0+0.3)*0.01-(0+0.25+0.25+0.3)*0.01=0.011p.u. …(7)

Case 3:

It may happen that when a DISCO demands more power than the contracted power, the contract violates. It is to be noted that this un-contracted power demands have to be met by the GENCOs of the same area as the DISCO [10].
The more power can be considered as a local load. Case 2 considers again with addition that DISCO1 demands 0.1 pu MW more [10].

In area 1 total local load = $DISCO_1$ load + $DISCO_2$ load = (0.1 + 0.1) + 0.1 = 0.3 pu MW …(8)

Similarly,

In area 1 total local load = $DISCO_3$ load + $DISCO_4$ load

$$= 0.1 + 0.1 = 0.2 \text{ pu MW} \quad (9)$$

The un-contracted load of $DISCO_1$ is reflected by GENCOs in its area.

IV. OPTIMIZATION OF INTERGAL CONTROLLER GAIN USING PSO

PSO is a robust stochastic optimization technique based on the movement and intelligence of swarms. PSO applies the concept of social interaction to problem solving. It was developed in 1995 by James Kennedy (social-psychologist) and Russell Eberhart (electrical engineer). It uses a number of agents (particles) that constitute a swarm moving around in the search space looking for the best solution. Each particle is treated as a point in a N-dimensional space which adjusts its “flying” according to its own flying experience as well as the flying experience of other particles. Each particle keeps track of its coordinates in the solution space which are associated with the best solution (fitness) that has achieved so far by that particle. This value is called personal best , ***pbestd***.

Another best value that is tracked by the PSO is the best value obtained so far by any particle in the neighborhood of that particle. This value is called ***gbestd***. Unlike in genetic algorithms, evolutionary programming and evolutionary strategies, in PSO, there is no selection operation.

All particles in PSO are kept as members of the population through the course of the run PSO are the only algorithm that does not implement the survival of the fittest. No crossover operation in PSO. In EP balance between the global and local search can be adjusted through the strategy parameter while in PSO the balance is achieved through the inertial weight. The modified velocity and position of each particle can be calculated using the current velocity and the distance from p_{besti} to g_{bestd} as shown in the following formulas,

$$v_{id}^{(t+1)} = v_{id}^{t} * w + c_1 * \text{rand}(\,) * (p_{bestid}^{t} - p_{id}^{t}) + c_2 * \text{Rand}(\,) * (g_{bestd}^{t} - p_{id}^{t}) \quad \ldots(10)$$

$$p_{id}^{(t+1)} = p_{id}^{t} + v_{id}^{(t+1)} \quad \ldots(11)$$

In general, the inertia weight *w* is set according to the following equation,

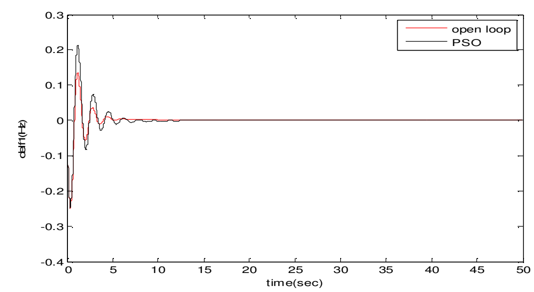
$$w = w_{max} - [(w_{max} - w_{min}) * It]/(It_{max}) \quad \ldots(12)$$

V. SIMULATION, RESULTS AND DISCUSSION

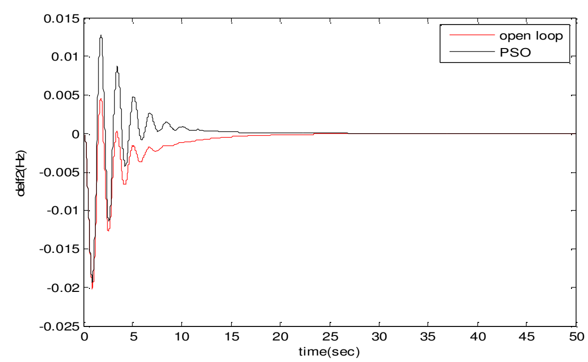
In this section, integral controller gains of each control area in the two-area power system in deregulated environment are optimized using PSO technique. The power system simulation is done using MATLAB. The cost function J obtained using equation (1) is optimized by the PSO technique.

In case 1, the optimum values of integral gains are KI1=1 and KI2 = 0.1556.

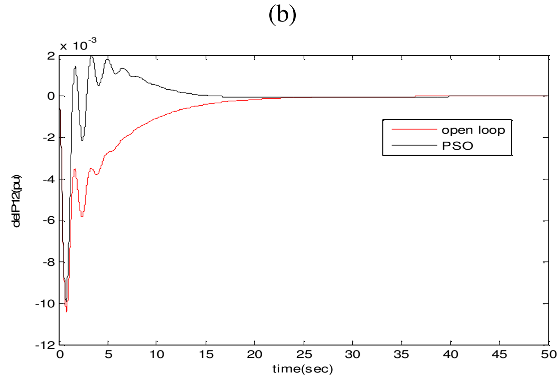
The dynamic responses of frequency and tie-line power for open loop and PSO are shown in Fig. 3 (a)-(c). In case 2, the two optimum values of integral gains are KI1 = 0.0377 and KI2 = 0.6032. The dynamic responses of frequency and tie-line power for open loop and PSO are shown in Fig. 4 (a)-(c). In case 3, the two optimum values of integral gains are KI1 = 1.5 and KI2 = 0.9069. The dynamic responses of frequency and tie-line power for open loop and PSO are shown in Fig. 5 (a)-(c).



(a)

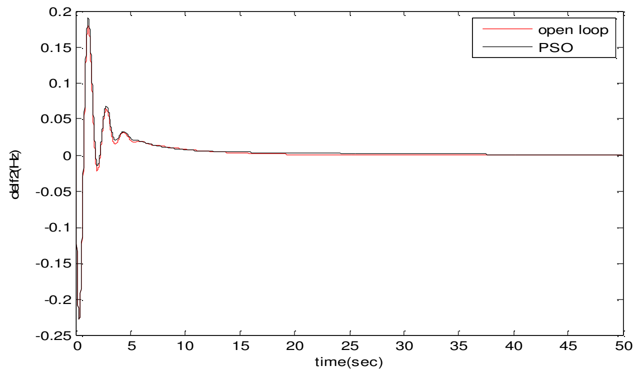


(b)

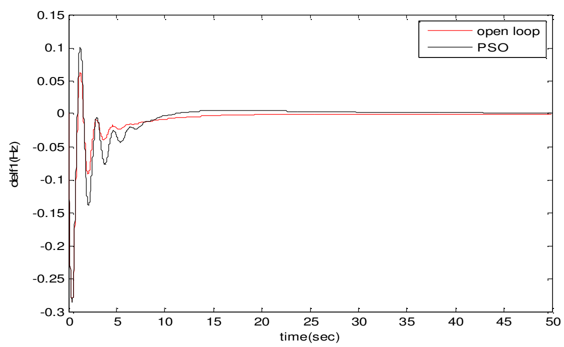


(c)

Fig. 3. (a) Frequency response of area 1. (b) Frequency response of area 2. (c) Deviation of tie-line power.



(a)



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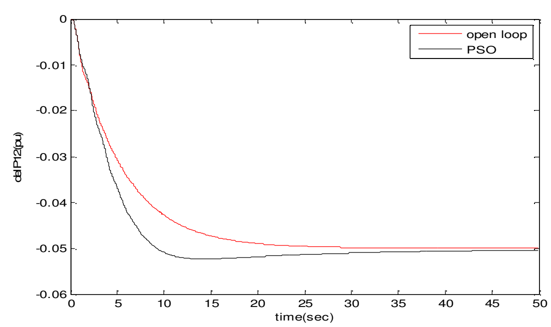
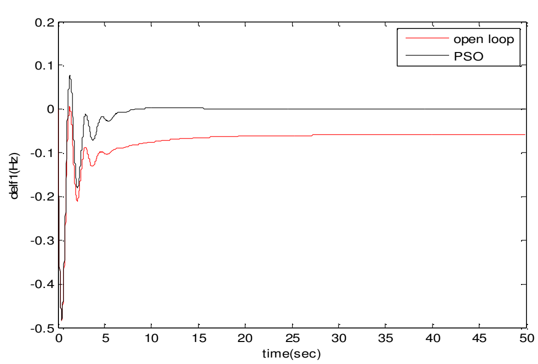
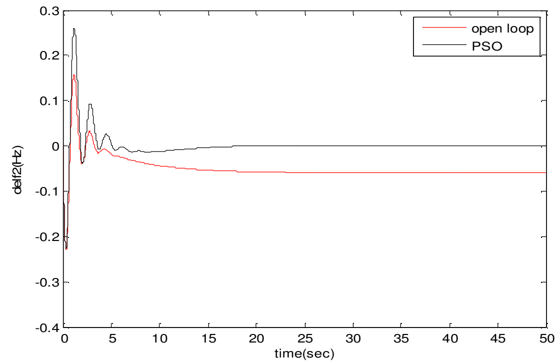


(c)

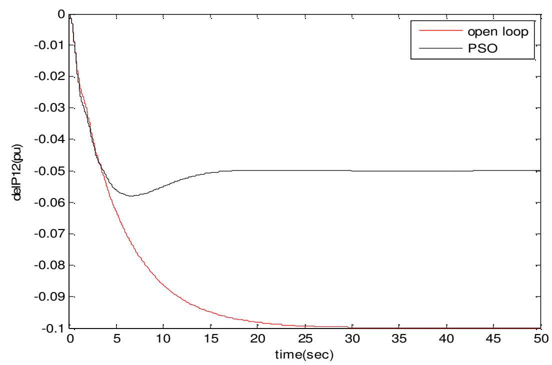
Fig. 4. (a) Frequency response of area 1. (b) Frequency response of area 2. (c) Deviation of tie-line power.



(a)



(b)



(c)

Fig. 5 (a) Frequency response of area 1. (b) Frequency response of area 2. (c) Deviation of tie-line power.

V. CONCLUSION

In deregulated environment, bilateral contracts between DISCOs in one control area and GENCOs in another control area are considered. Bilateral contracts make the base for choosing the elements of DPM. The AGC is studied for different possible contracts in deregulated environment. The tie-line scheduled power flow between two controls areas matches with the contract. The dynamic responses obtained for different possible contracts satisfy the AGC requirements.

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