OPTIMIZATION OF AGC PARAMETERS IN THE RESTRUCTURED POWER SYSTEM ENVIRONMENT USING GA

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ABSTRACT

In this paper Automatic Generation Control (AGC) of two-area interconnected power system has been studied in the restructured environment. Genetic algorithm (GA) is used for optimization of integral control gains and bias factors. The concept of distribution company (DISCO) participation matrix(DPM)is presented to simulate the possible bilateral contracts between generating companies (GENCOs) and DISCOs. To show the effectiveness of GA two power system models are taken for the study. Dynamic responses obtained satisfy the AGC requirements.

KEYWORDS: *Automatic generation control, Area control error, Genetic Algorithm, bilateral contracts*

I. INTRODUCTION

Automatic generation control (AGC) is an important control process that operates constantly to balance the generation and load in power systems at a minimum cost [1]-[3]. The AGC system is responsible for frequency control and power interchange. In the power system, any sudden load perturbation causes the deviations in tie-line power exchanges and the frequency [4]-[6].The main task of the AGC is to provide control signals to regulate the real power output of various electric generators within a prescribed area in response to changes in area frequency and tie-line loading so as to maintain at the prescribed values [6]-[8]. Many researchers [9]-[11] studied the AGC in deregulated environment. Deregulated system is the combination of generation companies (GENCOs), Distribution companies (DISCOs), Transmission companies (TRANSCOs) and Independent system operators (ISO). In the restructured power system AGC has to be reformulated. In deregulated environment, a DISCO can contract individually with any GENCO for power demand and this transaction is completed under the supervision of ISO [9]-[11].

Recently Praghnesh Bhatt et. al [12]-[14] studied the AGC with SMES, TCPS in restructured power system. Many researchers [15]-[19] studied the AGC using GA and less attention has been given to the study of AGC in deregulated environment using GA. The concept of GA is used for better solution by using “the survival-of-the fittest” [15]-[16]. GA is time intensive, can find global minimum. GA has good features such as robustness, simplicity [16]-[19].In this paper, real coded GA is used to optimize the parameters of AGC after deregulation in the power system. The study is extended for the two area power system considering reheat type turbines. An extensive analysis is done considering different possible contracts between GENCOs and DISCOs.

II. RESTRUCTURED SYSTEM

After deregulation any DISCOs can demand for the power supply from any GENCOs. There is no boundation on the DISCOs for purchasing of electricity from any GENCOs. For understanding the concept of this kind of contracts DISCO participation matrix (DPM) is presented [9].

A DISCO has freedom to make contract with a GENCO in another control area and such transaction are called bilateral transactions. All such transactions are completed under the supervision of independent system operator (ISO). The ISO controls various ancillary services, one of which is AGC. For in-depth understanding of implications of restructuring in the power industry, refer to [9]-[14].

A DPM is a matrix with the number of rows equal to the number of GENCOs and the number of columns equal to the number of DISCOs in the system [9]. Each entry in this matrix can be thought of as fraction of a total load contracted by a DISCO (column) towards a GENCO(row). The sum of all the entries in a column DPM is unity[9].

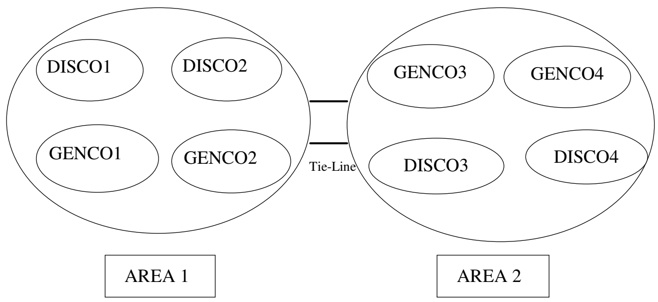


Fig.1. Schematic of a two-area system in restructured power system environment

The DPM may be defined as [9].

$$\text{DPM} = \begin{bmatrix} cpf_{11} & cpf_{12} & cpf_{13} & cpf_{14} \\ cpf_{21} & cpf_{22} & cpf_{23} & cpf_{24} \\ cpf_{31} & cpf_{32} & cpf_{33} & cpf_{34} \\ cpf_{41} & cpf_{42} & cpf_{43} & cpf_{44} \end{bmatrix} \quad (1)$$

Where, 'cpf_{ij}' are contract participation factors and may be calculated as described in[9]. It is noted that $\sum_i cpf_{ij}$ = 1.[9]

III. POWER SYSTEM MODELS

In this paper the AGC model studied by Donde et.al [9], has been taken to apply GA for optimization and study of AGC. Donde et.al considered non-reheat type turbines,further study has been extended for reheat type turbines in the two area interconnected power system. Coefficients that distribute area control error (ACE) to several GENCOs are termed as ACE participation factors (apf). Note that $\sum_{j=1}^{m} apf_j$ = 1 where m is the number of GENCOs. As a particular set of GENCOs are supposed to follow the load demanded by a DISCO, information must flow from a DISCO to a particular GENCO specifying corresponding demands. The demands are specified by cpfs (element of DPM) and the pu MW load of a DISCO. These signals carry information as to which GENCO has to follow a load demanded by which DISCO [9]. The scheduled steady state power flow on the tie line is given [9]as

$\Delta P_{tie1-2,schd}$= (demand of DISCOs in area II from GENCOs in area I)
-(demand of DISCOs in area I from GENCOs in area II) (2)

At any given time, the tie line power error $\Delta P_{tie1-2,error}$ is defined as

$$\Delta P_{tie1-2,error} = \Delta P_{tie1-2,actl} - \Delta P_{tie1-2,schd} \tag{3}$$

The area control errors in this case may be given as:

$$ACE_1 = B_1 \Delta f_1 + \Delta P_{tie1-2,error}$$

$$ACE_2 = B_2 \Delta f_2 + \Delta P_{tie2-1,error} \tag{4}$$

In this paper the AGC of two different power systems in deregulated environment is studied using GA. The MATLAB simulation model of first power system example based on the concept of Donde et. al. [9]is shown in Fig.(2) which uses non-reheat type turbines. The MATLAB simulation model of second power system example is modified by considering reheat type turbines in place of non-reheat type turbines in each area as shown in Fig.(3). The local loads in area I and II are denoted by $\Delta P_{L1,LOC}$ and $\Delta P_{L2,LOC}$ respectively.

The closed loop two area power systems shown in Fig.2 and Fig. 3 may be characterized in the steady state form as follows:

$$\dot{x} = A^{cl} x + B^{cl} u \tag{5}$$

Where x is the state vector and u is the vector of demand of the DISCOs. A^{cl} and B^{cl} are system matrices of appropriate dimensions. In this paper, as in [9], three different cases for study of AGC are considered.

IV. APPLICATION OF GA FOR OPTIMIZATION OF AGC PARAMETERS

In this paper, the performance index considered is given as:

$$\text{ISE} = \int_0^{\infty} e^2(t)\, dt \tag{6}$$

Where, e is the error.

In ISE, only error is considered and therefore no weight is given to time span of error but for the problem of AGC , it is required that settling time should be less and also oscillations should die out quick[15].

The objective (cost) function which should be minimised is given as follows:

$$J = \int_0^{T} (ACE_i)^2 \tag{7}$$

Where T is the simulation time , and

$$ACE_i = \Delta P_{tiei} + B_i \Delta f_i \tag{8}$$

$$B_i = \frac{1}{R_i} + D_i \tag{9}$$

The genetic algorithm [15]-[17] is a global search technique for obtain optimum values, which is based on the theory of natural selection, the process that drives biological evolution. There are three genetic operators [16] have been applied on parents to form children for next generation:

1. *Reproduction* – Selects the fittest individuals in the current population to be used in generating the next population. The children are called Elite children.

2. *Cross-over* – It causes pair of individuals to exchange genetic information with one another. The children are called crossover children.

3. *Mutation* – It causes individual genetic representation to be changed according to some probabilistic rule. The children in this case are called Mutation children.

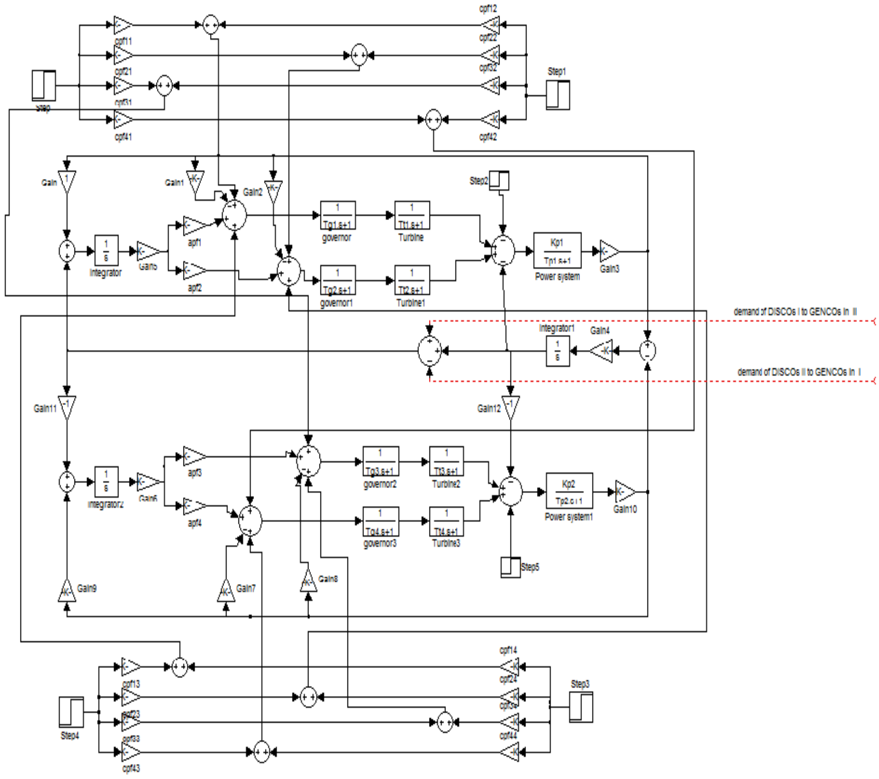


Fig. 2 MATLAB Simulation model of a two area power system with non-reheat turbine [9].

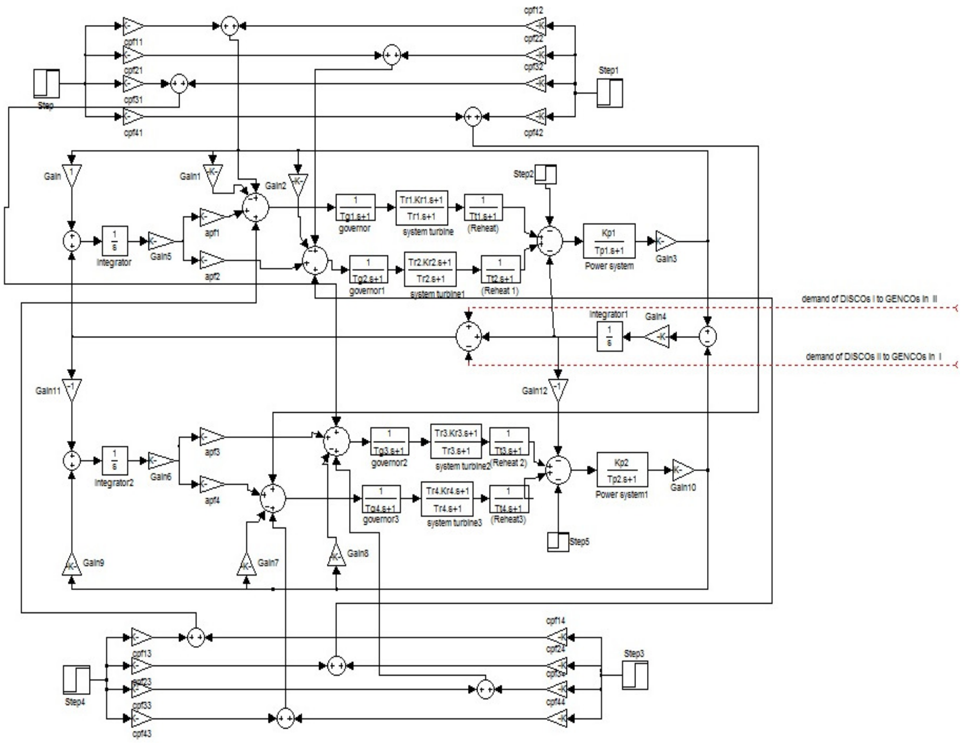


Fig. 3 MATLAB Simulation model of a Two Area power system with reheat system

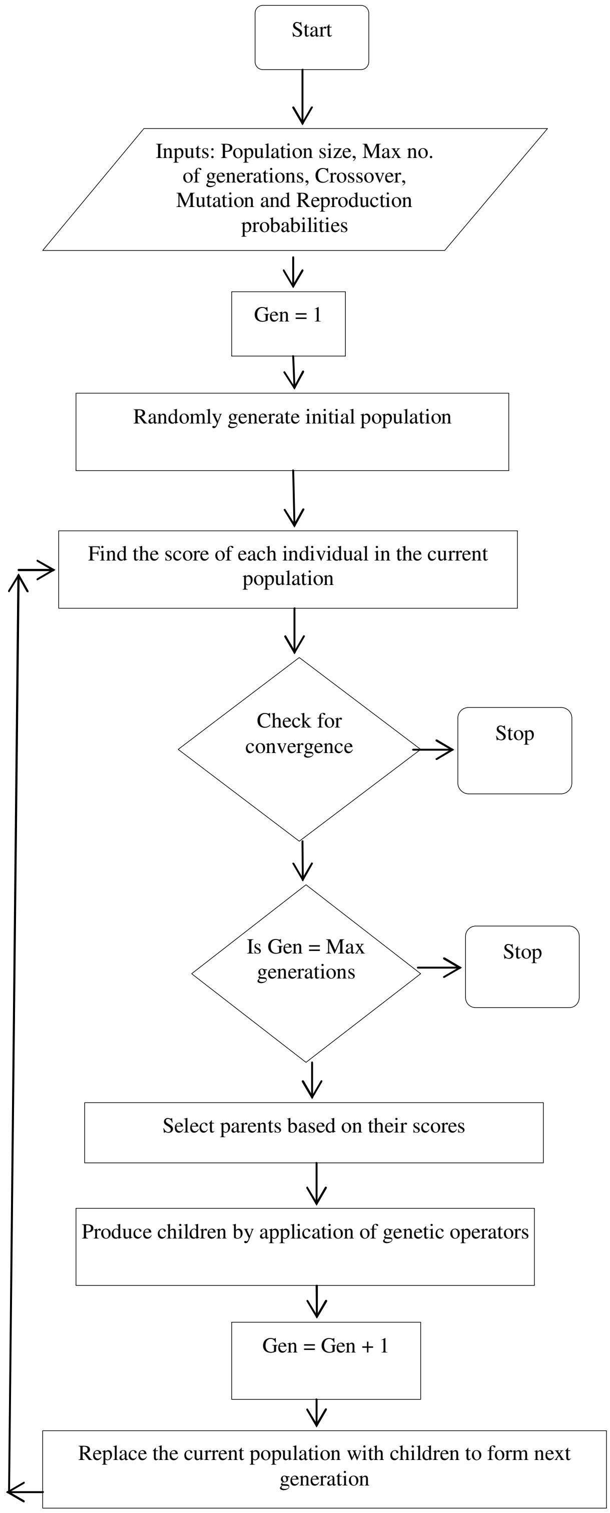


Fig.4 Flow chart for genetic algorithm.

V. Simulation Results and Discussion

The AGC of two power system models shown in Fig.(2) and Fig.(3) with corresponding parameters given in appendix is studied under different contract scenario. The AGC parameters are optimized using GA.

The different possible contracts between DISCOs and GENCOs are studied as described in case-1 and case-2. Following is the detailed analysis case wise.

A. *Case1:*

In this case we consider that all GENCOs of each area participate equally in AGC, i.e., ACE participation factors are apf_1 = 0.5, apf_2 = 1-apf_1= 0.5, apf_3 = 0.5,apf_4 = 1-apf_3 = 0.5. It is assume that the load changes occur only in area I, therefore $DISCO_1$and $DISCO_2$demands. Let the value of load demand be 0.1 pu MW for each of them. Referring to (1), DPM becomes,

$$\text{DPM} = \begin{bmatrix} 0.5 & 0.5 & 0 & 0 \\ 0.5 & 0.5 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad (10)$$

Note that $DISCO_3$ and $DISCO_4$ have no demand from any GENCOs, and therefore their corresponding participation factors are zero. In steady state, generation of a GENCO must match the demand of the DISCOs according to contract with it. The total demand of DISCOs is given[9] as

$$\Delta P_{Mi} = \sum_j cpf_{ij}\, \Delta P_{Lj} \quad (11)$$

Where ΔP_{Lj} the total demand of DISCO j and cpfs is are given by DPM. In the two-area case,

$$\Delta P_{Mi} = cpf_{i1}\Delta P_{L1} + cpf_{i2}\Delta P_{L2} + cpf_{i3}\Delta P_{L3} + cpf_{i4}\Delta P_{L4} \quad (12)$$

For the case under consideration, we have,

$$\Delta P_{M1} = 0.5 \times \Delta P_{L1} + 0.5 \times \Delta P_{L2} = 0.1 \text{ pu MW}$$

And similarly,

$$\Delta P_{M2} = 0.1\text{pu MW},$$
$$\Delta P_{M3} = 0.1 \text{ pu MW},$$
$$\Delta P_{M4} = 0.1 \text{ pu MW}$$

B. *Case 2:*

In this case we consider that all DISCOs contract with the GENCOs for power as per the following DPM:

$$\text{DPM} = \begin{bmatrix} 0.5 & 0.25 & 0 & 0.3 \\ 0.2 & 0.25 & 0 & 0 \\ 0 & 0.25 & 1 & 0.7 \\ 0.3 & 0.25 & 0 & 0 \end{bmatrix} \quad (13)$$

Each DISCO has a demand of 0.1 pu. MW power from GENCOs as per the DPM matrix and each GENCO participate in AGC as defined by following apf_s :

$apf_1 = 0.75$, $apf_2 = 1 - apf_1 = 0.25$, $apf_3 = 0.25$, $apf_4 = 1 - apf_3 = 0.5$.

The scheduled power on the tie line from area I to area II is

$$\Delta P_{tie-line1-2,schd} = \sum_{i=1}^{2}\sum_{j=3}^{4} cpf_{ij}\,\Delta P_{Lj} - \sum_{i=3}^{4}\sum_{j=1}^{2} cpf_{ij}\,\Delta P_{Lj}$$

As given by (11), in the steady state , the GENCOs must generate

$$\Delta P_{M1} = 0.5(0.1) + 0.25(0.1) + 0 + 0.3(0.1)$$
$$= 0.105 \text{ pu MW}$$

And

$$\Delta P_{M2} = 0.045 \text{ pu MW},$$
$$\Delta P_{M3} = 0.195 \text{ pu MW},$$
$$\Delta P_{M4} = 0.055 \text{ pu MW}.$$

ACE parameters, K_i and B for two- area system in deregulated environment are optimized using GA. The step of integration chosen as 0.01s . Sampling time is taken as 0.2s. The data for the system consider are given in appendix A. The real values of variables are used in GA, while AGC configuration uses different values of the same variables from their nominal values. The simulation is done using MATLAB meta-files. The optimized parameters for non-reheat and reheat turbine models are given in Table 1 and Table 2 respectively.

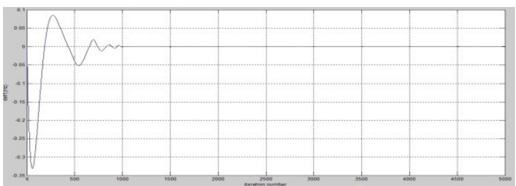
Table.1. Optimize parameters for non-reheat model

Parameters	Case 1	Case 2
K_{i1}	0.0872	0.1902
K_{i2}	0.0845	0.1564
B_1	0.6564	0.5802
B_2	0.5998	0.5568

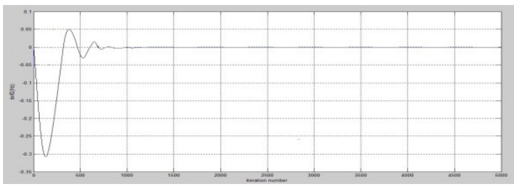
Table.2. Optimize parameters for reheat model

Parameters	Case 1	Case 2
K_{i1}	0.0764	0.1702
K_{i2}	0.0862	0.1256
B_1	0.6324	0.5732
B_2	0.5934	0.5678

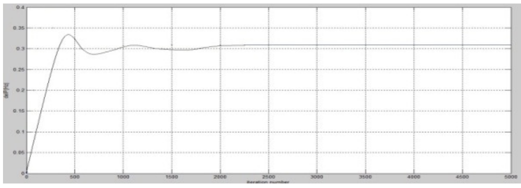
The dynamic responses of frequency and tie-line power in case 1 for non-reheat and reheat type system are shown in Fig.5 (a)-(c) and Fig.6 (a)-(c). And The dynamic responses of frequency and tie-line power in case 2 for non-reheat and reheat type system are shown in Fig.7 (a)-(c) and Fig.8 (a)-(c).



(a)

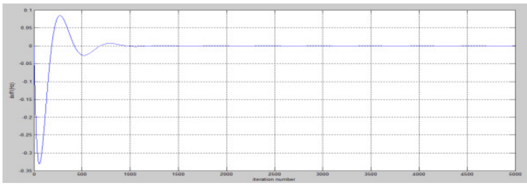


(b)

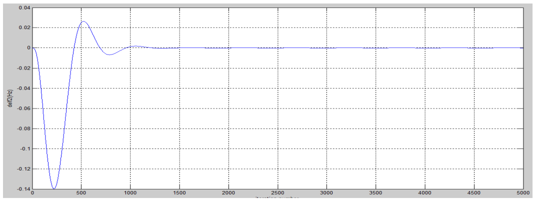


(c)

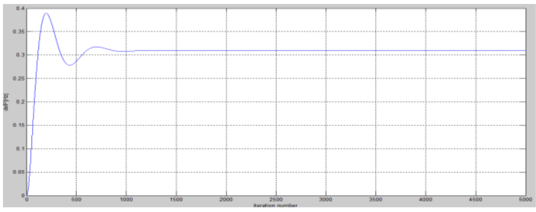
Fig.5 (a) frequency deviation in area 1,(b) frequency deviation in area 2, (c) deviation in tie-line power for, case 1 with non-reheat type system.



(a)

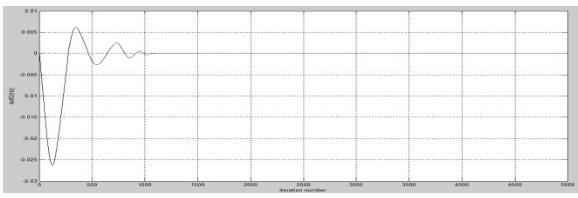


(b)

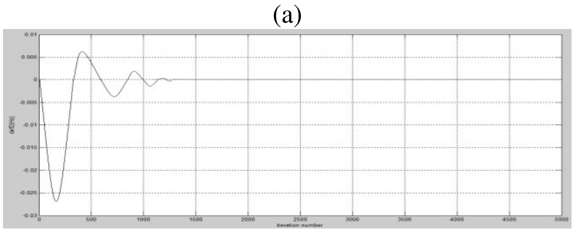


(c)

Fig. 6 (a) frequency deviation in area 1, (b) frequency deviation in area 2,(c) deviation in tie-line power, for case 1 with reheat type system.



(a)



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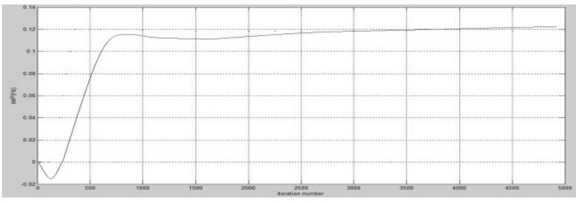
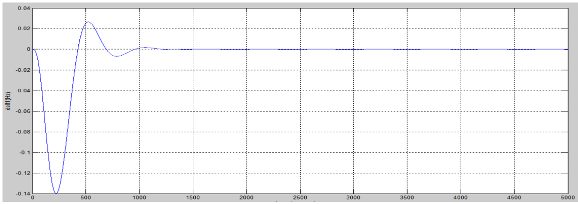
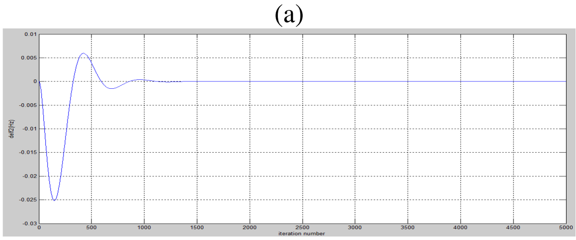


(c)

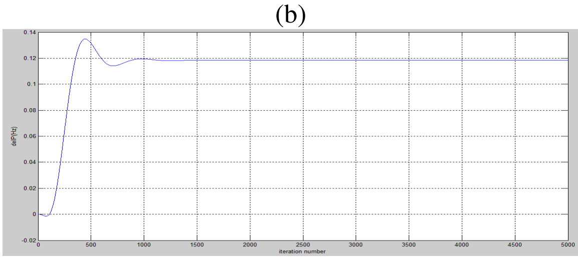
Fig. 7 (a) frequency deviation in area 1,(b) frequency deviation in area 2, (c) deviation in tie-line power, for case-2 with non-reheat type system.



(a)



(b)



(c)

Fig.8 (a) frequency deviation in area 1,(b) frequency deviation in area 2, (c) deviation in tie-line power, for case 2 with reheat type system.

VI. CONCLUSION AND FUTURE SCOPE

AGC is important in the power system. The frequency and tie-line power deviation response are obtained for 1% SLP. In this paper, we compare the dynamic responses of frequency and tie-line power for non-reheat type and reheat type systems in deregulated environment for different areas. The concept of DISCO and GENCO are very useful in deregulated environment. The simulation results are satisfactory for two different operating cases in modified AGC after deregulation. In future we apply some other artificial intelligent technique for better result with energy storage devices.

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APPENDIX

Nominal system parameters of the two-area thermal system investigated:
f = 60Hz, $T_{g1} = T_{g2} = 0.08$, $T_{r1} = T_{r2} = 10s$, $K_{r1} = K_{r2} = 0.5$, $T_{t1} = T_{t2} = 0.3s$, $K_{p1} = K_{p2} = 120$ Hz/pu MW, $T_{p1} = T_{p2} = 20s$, $T_{12} = 0.086$, $H_1 = H_2 = 5s$, $D_1 = D_2 = 8.33\times10^3$puMW/Hz, PI = 3.14, a_{12} = -1.

NOMENCLATURE

i	Subscript referred to area (1, 2).
P_{ri}	Rated power of area (MW).
H_i	Inertia constant of area (s).
ΔP_{Di}	Incremental load change in area (p.u.).
D_{ki}	$\Delta P_{Di}/\Delta f_i$ (p.u./Hz).
ΔP_{gi}	Incremental generation change in area (p.u.).
R_i	Governor speed regulation parameter of area 1.(Hz/p.u.MW).
T_{gi}	Steam governor time constant of area (s).
K_{ri}	Steam turbine reheat constant of area .
T_{ri}	Steam turbine reheat time constant of area (s).
T_{ti}	Steam turbine time constant of area (s).
B_i	Frequency bias of area.
f	Nominal system frequency (Hz).
T_{pi}	$2H_i/fD_i$ (s)
K_{pi}	$1/D_i$ (Hz/p.u.).

B_i	$(D_i + 1/R_i)$ (i.e., frequency response characteristics of area).
J	Cost function
T	Simulation time (s).
Δf_i	Incremental change in frequency of area (Hz).
ΔP_{gi}	Incremental generation of area (p.u.).
$\Delta P_{tie-lin}$	Incremental change in tie power of tie 1–2 (p.u.).
T_{12}	Synchronizing coefficients.
schd	Scheduled
actl	actual

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