RESEARCH ARTICLE OPEN ACCESS

Automatic Generation Control Using PI Controller with Bacterial Foraging for both Thermal and Hydro Plants

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Abstract
The load-frequency control (LFC) is used to restore the balance between load and generation in each control area by means of speed control. In power system, the main goal of load frequency control (LFC) or automatic generation control (AGC) is to maintain the frequency of each area and tie- line power flow within specified tolerance by adjusting the MW outputs of LFC generators so as to accommodate fluctuating load demands. In this paper, attempt is made to make a scheme for automatic generation control within a restructured environment considering effects of contracts between DISCOs and GENCOs to make power system network in normal state where, GENCO used are hydro plants as well as thermal plants. The bacterial foraging optimization technique is being developed, which is applied to AGC in an interconnected four area system.The performance of the system is obtained by MATLAB Simulink tool. The results are shown in frequency and power response for four area AGC system.
In this paper we have shown practical work by using thermal and hydro both system at Genco's side.As reheated system transfer function is being used.
Index Terms—Automatic generation control, load frequency control, four area control in power system.

I. INTRODUCTION

The power system consists of several interconnected control areas, any sudden changes in the load causes frequency fluctuations. So, Automatic Generation Control (AGC) plays a very important role in an interconnected power system for supplying electric power with good quality.One of the main objective of AGC is to control power system frequencyat nominal valueand power flows over tie line at desired level. It also improves the reliability of the power system and makes it more adequate. With any fluctuation in the load demand causes abnormal conditions, such as outages of generation, lead to mismatches in frequency and scheduled power interchanges between areas. So, there is a need for a supplementary control for these mismatches. Load frequency control(LFC) for restructured power system is done for four area system in this paper, which maintains the tie line power and scheduled system frequency constant.[11]-[13] By varying the generation according to the area control
error (ACE). AGC varies the set position of generators of that area, which minimize the average time of ACE.

Deregulation is the collection of unbundled rules and economic incentives that governments set up to control and drive the electric power industry. In a deregulated system DISCOs buy power from GENCOs at competitive price. Hence, DISCOs have various options for the transaction of power from any of the GENCOsof its own area or different area.In each area, an automatic generation controller (AGC) Supervises the tie line power and system frequency, alsocomputes the net change in the generation required which is related to the area control error-ACE and change the setposition of the generators with in that area due to which netaverage time of ACE is at minimum. Optimization of auxiliarycontroller gains has been the main area of attraction. In this paper the gain of proportional controller is controlled by the use of Bacterial Foraging Technique. The frequency and tie line power is compared for the LFC in deregulated environment by the use of this technique [8]. The most frequently used controller in LFC is Proportional Integral Controller (PI). It is simple and has better dynamic response in comparison to other controller but it fails to operate when the complexity of system increases because of the sudden load change occurs or dynamics of boiler changes. Bacterial Foraging Technique improves [10] the performance of PI Controller by varying its gain as per the requirement of load. The main contribution of this paper is comparison of frequency and tie line power for the LFC in deregulated environment. Bacterial Foraging (BF) technique is used to control the gain of proportional controller.

II. RESTRUCTURED SYSTEM FOR AGC WITH FOUR AREA

Each control area consists of n number of thermal and hydro plants and also two DISCOS as shown in the fig 1 where n is number of thermal and hydro plants used. The detailed schematic diagram of

four area thermal and hydro system is also given in fig. Power system is restructured to improve the system reliability and to maintain a proper balance in between the demand and supply. Restructured power system is basically divided into three parts GENCOs (generating companies), TRANSCOs (transmission companies), and DISCOs (distribution companies).
As there are several GENCOs and DISCOs in the deregulatedstructure, a DISCO has the freedom to have a contract with any GENCO for transaction of power. A DISCO may have a contract with a GENCO in another control area. Such transactions are called "bilateral transactions." All the transactions have to be cleared through an impartial entity called an independent system operator (ISO). The ISO has to control a number of so-called "ancillary services," one of which is AGC.[2][3][11][13]. To stabilize the contracts between GENCOs and TRANSCOs, the concept of DISCO participation matrix (DPM) is being used. DISCO participation is in the matrix form where row represents number of GENCOs and columns represents number of DISCOs. Some of the areas may have the uncontracted loads which cause sudden load change in the system and hence the frequency of the system deteriorate. The total load on the GENCOs of an area is the sum of cpf s (elements of DPM) and the pu MW load of all the DISCOs of that area. Entry in DPM is a fraction of total load power contracted by bilateral contract.

III. Four Area power system

Power systems have variable and complicated characteristics and comprise different control parts and alsomany of the parts are nonlinear [14]. These parts are connected to each other by tie lines and need controllability of frequency and power flow [13]. Interconnected multiple-area power systems can be depicted by using circles.
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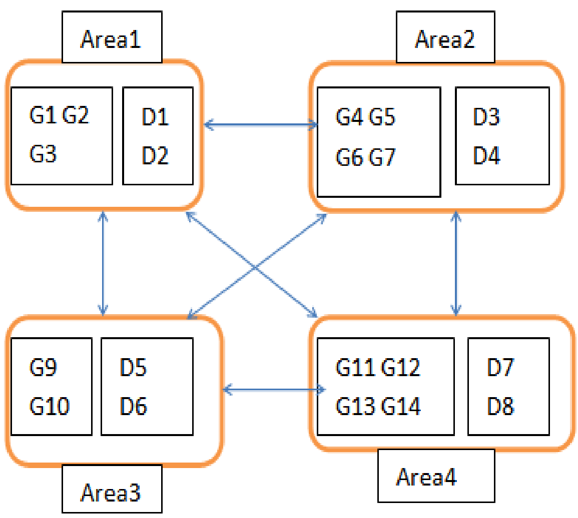


Fig-1 Simplified interconnected power system diagram

IV. Configuration of power system under deregulated environment. The Disco Participation Matrix will be:-

$$DPM = \begin{bmatrix} cpf1,1 & cpf1,2 & cpf1,3 & & cpf1,8 \\ cpf2,1 & cpf2,2 & cpf2,3 & & cpf2,8 \\ cpf3,1 & cpf3,2 & cpf3,3 & & cpf3,8 \\ cpf4,1 & cpf4,2 & cpf4,3 & & cpf4,8 \\ : & : & : & \dots\dots\dots\dots & : \\ : & : & : & & : \\ : & : & : & & : \\ : & : & : & & : \\ cp15,1 & cpf15,2 & cpf15,3 & & cpf15,8 \end{bmatrix}$$

$$DPM = \begin{bmatrix} 0.2 & 0 & 0 & 0.1 & 0 & 0 & 0 & 0 \\ 0 & 0.2 & 0 & 0 & 0 & 0 & 0 & 0.4 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.1 & 0 & 0 & 0.2 & 0 & 0 \\ 0 & 0.1 & 0 & 0.2 & 0 & 0 & 0.3 & 0 \\ 0.2 & 0 & 0.4 & 0.3 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.1 & 0 & 0 & 0.3 & 0.4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.2 & 0 & 0 \\ 0.2 & 0.3 & 0.2 & 0 & 0.5 & 0 & 0.5 & 0 \\ 0.2 & 0 & 0.1 & 0.2 & 0 & 0.2 & 0 & 0.5 \\ 0.2 & 0.3 & 0.2 & 0.2 & 0.2 & 0 & 0.2 & 0.1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

The cpf is the contract participation factor. In DPM diagonal element shows the local demand. The demand of one region's discos value to the another region's GENCO value is shown by the off diagonal element. The steady system consists of four-area. Area-1 consists of three GENCOs and two DISCOs. Their contracts at some instant of time is taken as per DPM matrix shown above. The actual and scheduled steady state power flows on the tie line is given as:-
ΔPtiei-j, schedule= [Demand from genco of area i by disco of areaj –Demand from genco of area j by disco of area i]
At any given time, the tie line power error is given by:-
ΔPtiei-j, error = ΔPtiei-j, actual - ΔPtiei-j, schedule.

The tie-line power error vanishes in the steady-state as the actual tie-line power flow reaches the scheduled power flow. This error signal is used to generate the respective ACE signals which is given to the ISO is:-
ACEi = Bi Δfi + ΔPtiei-j, error
Δfi is change of frequency of area i andBi is frequency Bias factor of area i

For four area system contracted power supplied by i-the GENCO is given as:

$\Delta P_{Mi} = cpf_{ij}\,\Delta P_{Lj}$ where N is the number of discos.

$\Delta P_{M1} = cpf_{11}\,\Delta P_{L1} + cpf_{12}\,\Delta P_{L2} + cpf_{13}\,\Delta P_{L3} + cpf_{14}\,\Delta P_{L4} + cpf_{15}\,\Delta P_{L5} + cpf_{16}\,\Delta P_{L6} + cpf_{17}\,\Delta P_{L7} + cpf_{18}\,\Delta P_{L8}$

Where, 3

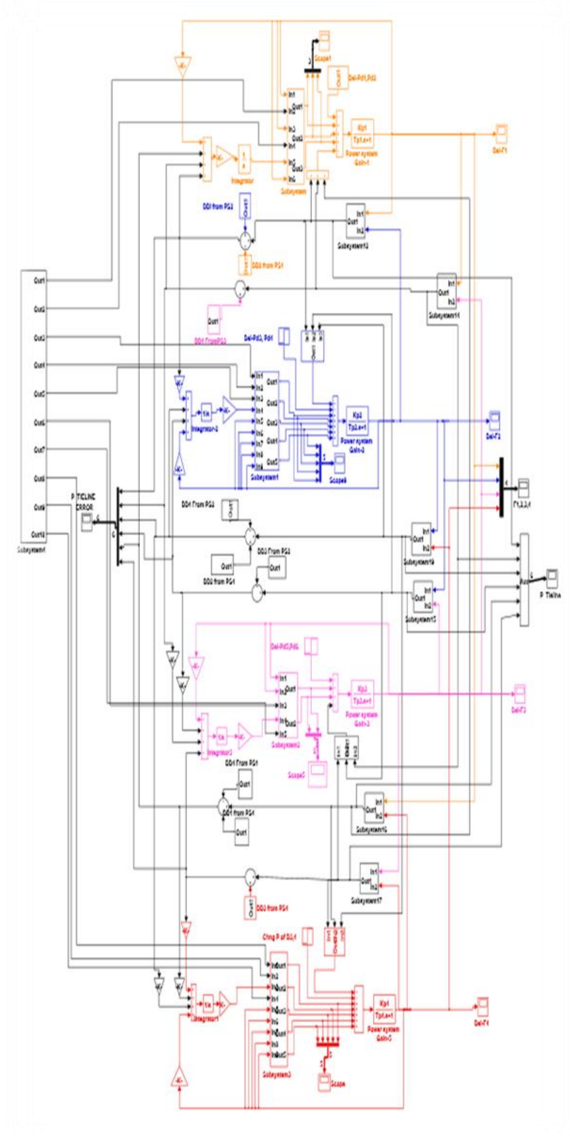
Actual Power output by each GENCOs

- $\Delta P_{M1} = 0.2\ \Delta P_{L1} + 0.1\Delta P_{L4}$
- ΔP_{M1} = 0.2 x0.1 + 0.1x0.1= 0.03 pu
- ΔP_{M2} =(0.2 x0.1 + 0.4x0.1) = 0.06,
- ΔP_{M3} = 0,
- ΔP_{M4} =(0.1 x0.1 + 0.2x0.1) = 0.03,
- ΔP_{M5} =(0.1 x0.1 + 0.2x0.1 +0.3x0.1) = 0.06,
- ΔP_{M6} =(0.2 x0.1 + 0.4x0.1 +0.3x0.1) = 0.09,
- ΔP_{M7} = 0,
- ΔP_{M8} = 0,
- ΔP_{M9} =(0.1 x0.1 + 0.3x0.1 + 0.4x0.1) = 0.08,
- ΔP_{M10} =(0.2 x0.1) = 0.02,
- ΔP_{M11} =(0.2 x0.1 + 0.3x0.1 + 0.2x0.1 +0.5x0.1 + 0.5x 0.1) = 0.17,
- ΔP_{M12} =(0.2 x0.1 + 0.1x0.1 +0.2x0.1 +0.2x0.1 +0.5x0.1) = 0.12,
- ΔP_{M13} =(0.2 x0.1+0.3x0.1+0.2x0.1+0.2x0.1+0.2x0.1+ 0.2x0.1+0.1x0.1) = 0.14,
- ΔP_{M14} = 0,
- ΔP_{M15} = 0.

The schedule tie line powers are:-

- $\Delta P_{tie1\text{-}2,\ schedule}$ =- (0.2x0.1 + 0.1x0.1) +(0.1x0.1) = -0.02pu
- $\Delta P_{tie1\text{-}3,\ schedule}$ = -(0.1x0.1) = -0.01pu
- $\Delta P_{tie1\text{-}4,schedule}$=- [(0.2x0.1+0.2x0.1+0.2x0.1)+(0.3x0.1+0.3 x0.1)]+(0.4x0.1)=- 0.08pu
- $\Delta P_{tie2\text{-}3,\ schedule}$ = 0.2x0.1 = 0.02pu
- $\Delta P_{tie2\text{-}4,\ schedule}$=0.3x0.1 + [(0.2x0.1+0.1x0.1+0.2x0.1) - (0.2x0.1+0.2x0.1)] = 0.06pu
- $\Delta P_{tie3\text{-}4,\ schedule}$ = -(0.5x0.1 + 0.2x0.1 + 0.2x0.1) = 0.09pu

For optimal design, we must formulate the state model. This is achieved by writing the differential equations describing each individual block of figure in terms of state variable. In this paper the dynamic performance is using obtained by MATLAB software for Δ, $\Delta Pgikand\ \Delta Ptiei{-}j$ for different load disruption.



.Fig-2 Block diagram of four area interconnected power system under the deregulated environment

A. Bacterial foraging optimization technique

It is recently epoch computation technique, named as Bacterial foraging(BF) which has been projected by Passino.

The bacterial foraging optimized the controller gains and other parameters. The BF technique dependent on the deportment of E.coli bacteria which is found in the human intestine.[7] This isthe bacteria generally found in groups and they will try to find food in minimum time with maximum energy and avoid the bruising phenomena. The detail algorithm is presented in Ref. [12]. In this simulation work the parameter for coding is to be S=10, Nc=10, Ns=3, Nre = 15, Ned=2, Ped=0.25. D(attr.)=0.061,W(attr.)=0.04, H(repellent)=0.061,W(repellent)= 10 and P=18 considered.

$J = (\Delta fi)2 + (\Delta Ptie\ )2\}dtB.$

B. Result And Analysis

The simulation is carried out on Four-Area interconnected deregulated system. The PI controller is implemented with and without bacterial foraging technique. The integral constant Ki is optimized and used in simulation in two different model of the system. In this system frequency of the system is compared. The tie line power is also considered before and after the deregulation. The simulation result are shown in fig(3) to fig(14). Using Simulink/MATLAB formulation the optimum AGC controller gain value, representing the scheduling of generators, tie line power exchange are done. With the help of BF algorithm frequency of the system are shown in fig(7) for four-Area conventionalcontroller, with BF controller are considered.

C. Frequency comparison of different areas

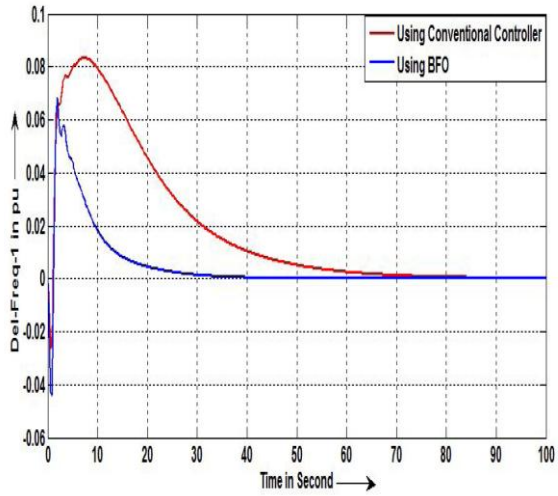


Figure 3 Frequency control in area 1

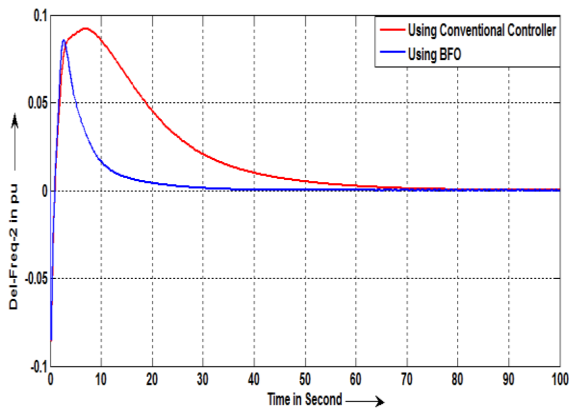


Figure 4 Frequency control in area2

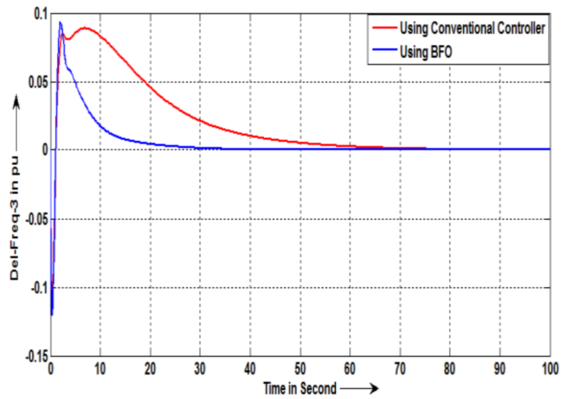


Figure 5 Frequency control in area3

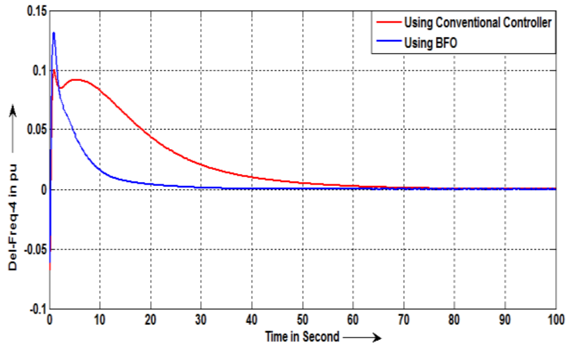


Figure6 Frequency control in area4

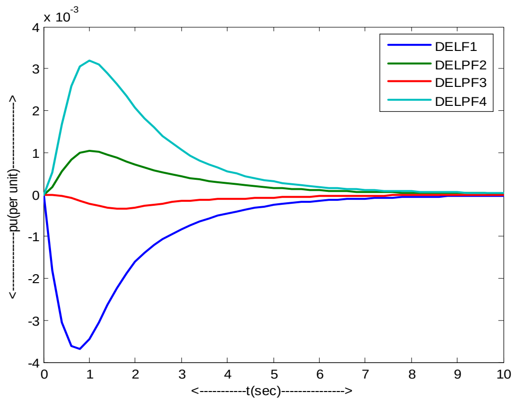


Figure7Actual value of frequency deviations

D.Tie line power comparision

Figure8 Del Tie line1-2 with and without BFO

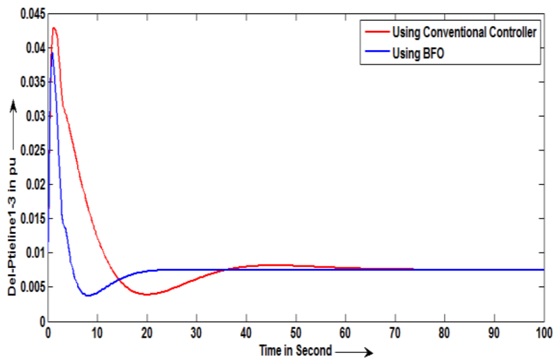


Figure9 Del Tie line 1-3 with and without BFO

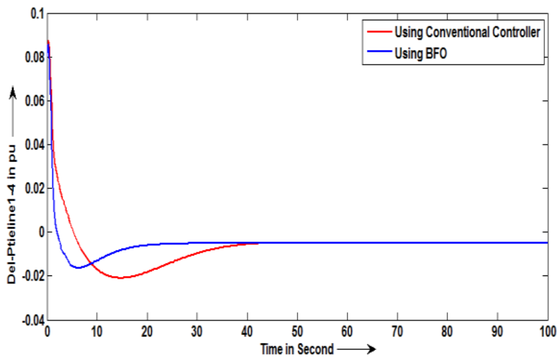


Figure 10 Del Tie line 1-4 with and without BFO

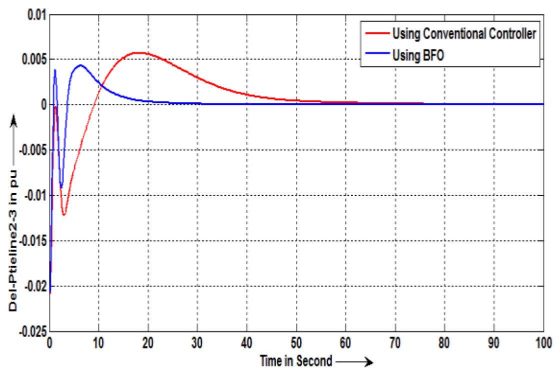


Figure 11 DelTie line2-3 with and without BFO

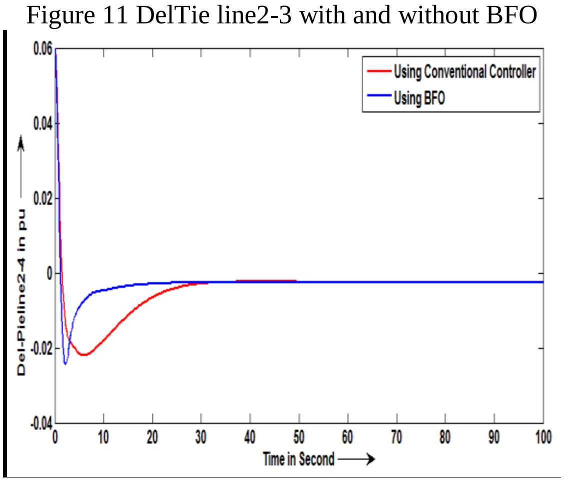


Figure 12Del Tie 2-4 with and without BFO

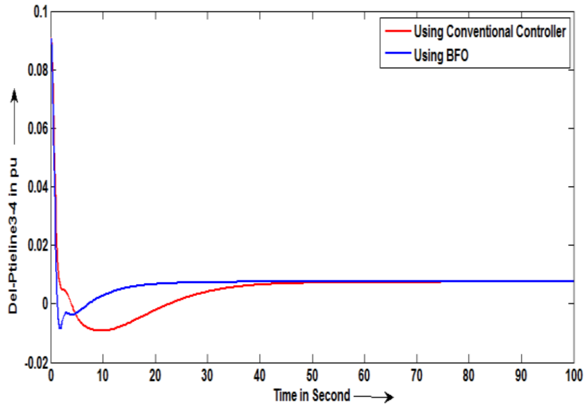
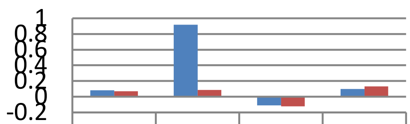


Figure 13 Del Tie line 3-4 with and without BFO

Peak Overshoot



	Del-F2 (Area -1)	Del-F2 (Area -2)	Del-F3 (Area -3)	Del-F4 (Area -4)
With conventional controller	0.083	0.92	-0.11	0.1
With BFO controller	0.0683	0.086	-0.121	0.132

Settling Time(second)

	Del-F2 (Area-1)	Del-F2 (Area-2)	Del-F3 (Area-3)	Del-F4 (Area-4)
With conventional controller	68.4	70.2	69.6	71.3
With BFO controller	32.4	33.3	29.9	31.8

E Nomenclature

Δ Deviation
s Derivative in terms of Laplace
f frequency
ω Angular speed
Tg Governor time Constant
Tij Coefficient of i-j tie Line

aij Operator
Bi Bias Factor
Pref The Output of ACE
Pl Electric Load Variations
R Regulation Parameter
Apfi ACE Participation Factors
DPM DISCO Participation Matrix
Cpfi Contract Participation Factors
ACE Area Control Error
Pi-jactual Real Tie Line Power
Pi-jscheduled Scheduled Tie Line Power Flow
Pi-jerror Tie Line Power Error
BF Bacterial foraging
Kp1,2,3 Generator Gain Constant
Tp1,2,3 Generator Time Constant
Pt Turbine output power
Tt Turbine time Constant
Pg Governor Output power
Tg Governor Time Constant

V. Conclusion

This Paper shows automatic generation control of the power system after deregulation which includes bilateral contracts.DPM provides bilateral contracts simulation.Above gains are optimized by both Bacterial Foraging and Proportional integral controller. This study shows simulation on a Four area power system considering different contracted scenarios.In this paper we consider both hydro and thermal plants which is the practical work we have shown. The dynamic and steady state responses for generated power change, for the frequency change and tie line powers change are shown in the above figures. The proposed Bacterial Foraging basedintegral controller gives better performance than conventional Proportional integral controller.This method reduces the peak deviation in frequencies andimproves the tie line power.

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