International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 3, March - 2014

Four-Area in AGC Interconnected System under the Deregulated Environment using BF Controller

Sunil Kumar Birthlia
Assistant professor ,EE Dept.
IITM, MURTHAL

Dr. Jaydeep Chakravorty
Associate Professor, EE Dept.
BUEST, Baddi

Abhishek Bhardwaj
Assistant Professor, EE Dept
BUEST, Baddi

***Abstract*— In this paper the bacterial foraging(BF) optimization control technique is developed for the design of integral controller gain, which is applied to AGC in interconnected four area system with GRC based controller under the deregulated environment to control the tie line power and frequency of the interconnected system. All four areas have different number of GENCOS, DISCOS and TRANSCOS. A DISCO can individually and multilaterally contracts with a GENCO for power requirements and these transactions are done under the ISO supervision. After deregulation, the bilateral contract on the dynamics of automatic generation control (AGC), DPM has been used. The performance of system is obtained by MATLAB-SIMULINK.**

***Index Terms*—GENCO, DISCO, TRANSCO, DPM, CPF ,AGC**

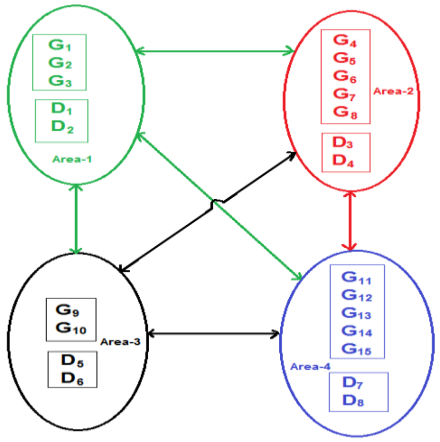
I. INTRODUCTION

Automatic Generation Control plays a very important role in an interconnected power system operation and control. It improves the reliability of system and makes the system more adequate. AGC also maintains the system frequency constant and makes the system more stable. As the load demand increases or decreases, the speed of generator prime mover set also changes which cause deviation in frequency of the system and hence affect the steady state stability of the system. Automatic generation control regulates the power output of generator in accordance with the change in system frequency, tie line power, so as to maintain the system frequency with in the permissible limit (constant). To attain zero steady state error and to maintain the system frequency constant, a control scheme is needed. Here study of the four area restructured power system is done in which each area has its own automatic generation controller (AGC) which maintains the tie line power and 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. 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 GENCOs of its own area or different area.

In each area, an automatic generation controller (AGC) Supervises the tie line power and system frequency, also computes the net change in the generation required which is related to the area control error-ACE and change the set position of the generators with in that area due to which net average time of ACE is at minimum. Optimization of auxiliary controller 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 POWER SYSTEM

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). The GENCOs generates power and DISCOs have freedom to have contract with any GENCO for the sake of power trading [2]-[3]-[11]-[13]. To visualize the contracts between GENCOs and TRANSCOs, the concept of DISCO participation matrix (DPM) is used. DISCO participation matrix is in the form of rows and columns where row represents number of GENCOs and columns represents number of DISCOs. Some of the areas may have the un-contracted 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. Due to this, DPM column entries belong to that disco is unity. Load frequency control is provided by the ISO which is an ancillary service in the deregulated power system that are required to maintain the real time balance between generation and load demand for minimizing frequency deflections and governing tie-line, allow enough Security level for predicted energy transactions and network configuration. The research work in deregulated AGC is contained in [2],[4],[5],[11].The load demand is fluctuating time to time that’s why introducing new potential generating plants such as gas fired, diesel etc are connected to the system to avoid the disturbance in the system.



.

Fig-1 Configuration of power system under deregulated environment The DMP will be:-

$$DPM = \begin{bmatrix} cpf_{1,1} & cpf_{1,2} & cpf_{1,3} & & cpf_{1,8} \\ cpf_{2,1} & cpf_{2,2} & cpf_{2,3} & & cpf_{2,8} \\ cpf_{3,1} & cpf_{3,2} & cpf_{3,3} & & cpf_{3,8} \\ cpf_{4,1} & cpf_{4,2} & cpf_{4,3} & \cdots\cdots\cdots & cpf_{4,8} \\ \vdots & \vdots & \vdots & & \vdots \\ \vdots & \vdots & \vdots & & \vdots \\ cpf_{15,1} & cpf_{15,2} & cpf_{15,3} & & cpf_{15,8} \end{bmatrix}$$

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

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 given tie line is:-

$\Delta \mathbf{P}_{\mathbf{tiei\text{-}j,\ schedule}}$ = [Demand from genco of area i by disco of area j –Demand from genco of area j by disco of area i]

The tie line error is given by:-

$\Delta P_{tiei\text{-}j,\ error} = \Delta P_{tiei\text{-}j,\ actual} - \Delta P_{tiei\text{-}j,\ schedule}$.

The tie line error disappear the steady state error. The ACE signal given to the ISO is:-

$ACE_i = B_i\ \Delta f_i + \Delta P_{tiei\text{-}j,\ error}$

Δf_i is change of frequency of area 'i' and

B_i is frequency Biase factor of area 'i'

$Genco_{1(scheduled)}$ = (0.2+0.1)*0.01 = 0.03 pu
$Genco_{2(scheduled)}$ = (0.2+0.4)*0.01 = 0.06 pu
$Genco_{3(scheduled)}$ = 0 pu
$Genco_{4(scheduled)}$ = (0.1+0.2)*0.01 = 0.03 pu
$Genco_{5(scheduled)}$ = (0.1+ 0.2 + 0.3)*0.01 = 0.06 pu
$Genco_{6(scheduled)}$ = (0.2 + 0.4 + 0.3)*0.01 = 0.09 pu
$Genco_{7(scheduled)}$ = 0 pu
$Genco_{8(scheduled)}$ = 0 pu
$Genco_{9(scheduled)}$ = (0.1 + 0.3 + 0.4)*0.01 = 0.08 pu
$Genco_{10(scheduled)}$=(0.2)*0.01=0.02pu
$Genco_{11(scheduled)}$ = (0.2 + 0.3 + 0.2+0.5+0.5)*0.01 = 0.17 pu
$Genco_{12(scheduled)}$ = (0.2 + 0.1 + 0.2+0.2+0.5)*0.01 = 0.12 pu
$Genco_{13(scheduled)}$=(0.2+0.3+0.2+0.2+0.2+0.2+0.1)*0.01= 0.14pu
$Genco_{14(scheduled)}$ = 0 pu
$Genco_{15(scheduled)}$ = 0 pu

The schedule tie line powers are:-

$\Delta P_{tie1\text{-}2,\ schedule}$ = (0.2 + 0.1)*0.1 – (0.1x0.1) = 0.02pu
$\Delta P_{tie1\text{-}3,\ schedule}$ = (0.1x0.1) = 0.01pu
$\Delta P_{tie1\text{-}4,\ schedule}$ = [(0.2 + 0.2 + 0.2)*0.1 + (0.3 + 0.3)*0.1] – (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 + [(0.2 + 0.1 + 0.2)*0.1 + (0.2 + 0.2)*0.1] = 0.06pu
$\Delta P_{tie3\text{-}4,\ schedule}$ = (0.5 + 0.2+ 0.2)*0.1 = 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 obtained using MATLAB software for $\Delta f_i, \Delta P_{gik}\ and\ \Delta P_{tie\ i-j}$ for different load disruption.

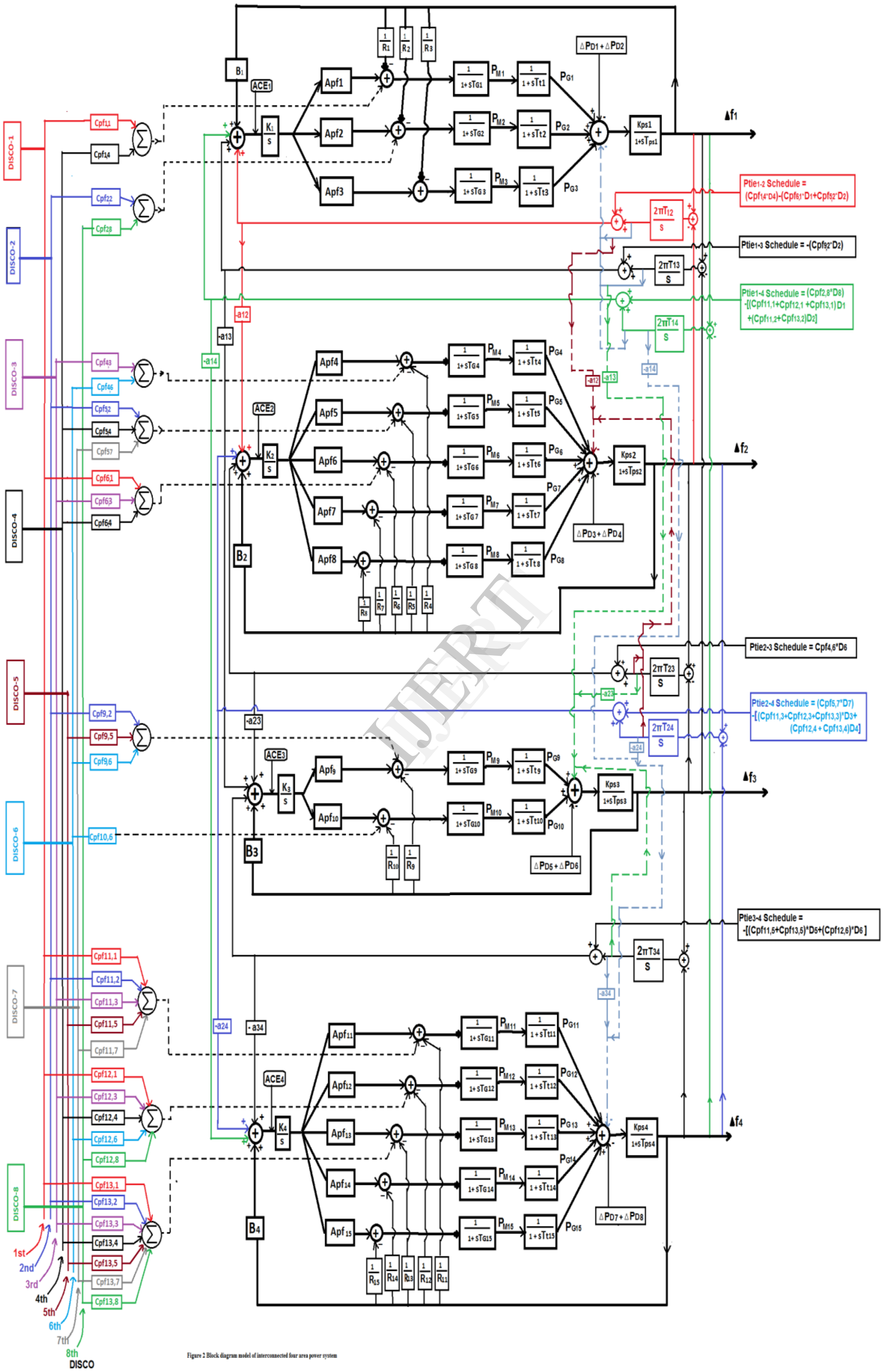


Fig-2 Block diagram of four area interconnected power system under the deregulated environment

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

The 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.

$$J = \int_0^T \{(\Delta f_i)^2 + (\Delta P_{tie})^2\}dt$$

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 K_i 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 conventional controller, with BF controller are considered.

C. Frequency comparison of different areas

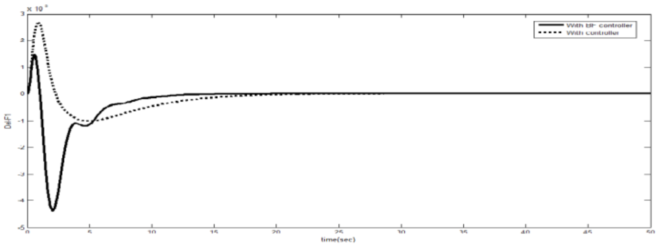


Fig (3) Frequency comparison of Area-1

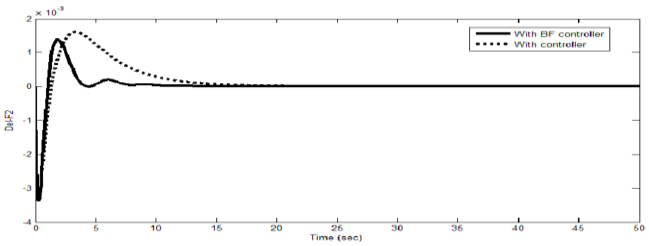
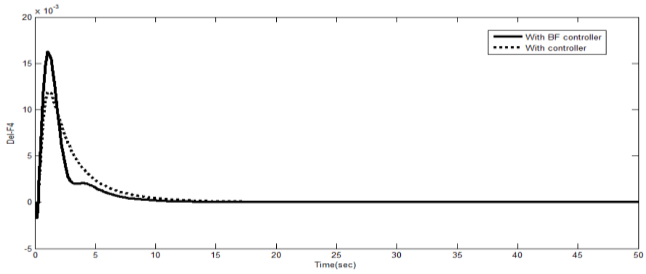


Fig (4) Frequency comparison of Area-2



Fig(5) Frequency comparison of Area-3

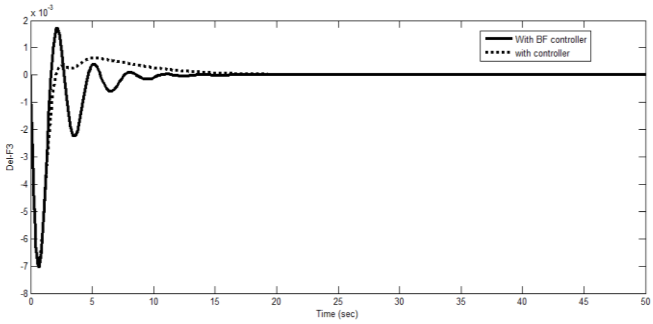


FIG (6) Frequency comparison of Area-4

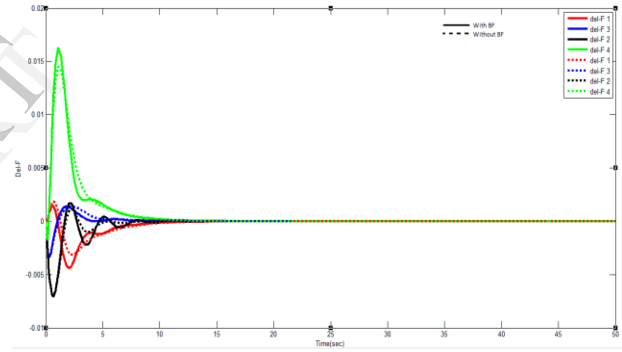


Fig (7) Frequency comparison with and without BF controller

D. Tie-line power comparison

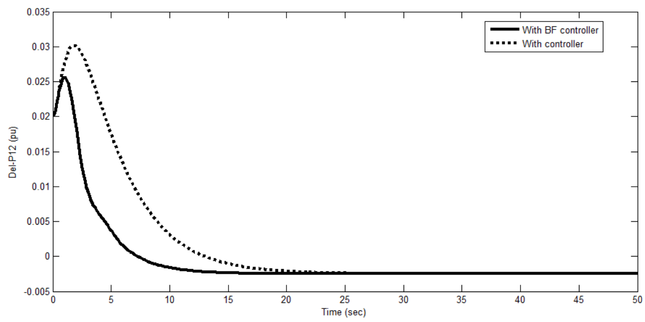


Fig8. DelPtie1-2 with and without BF controller

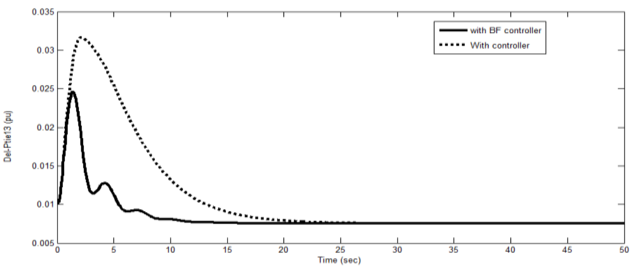


Fig9. DelPtie1-3 with and without BF controller

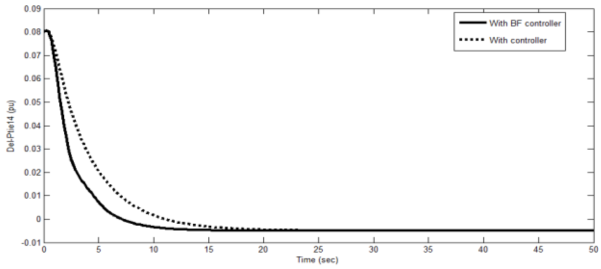


Fig10. DelPtie1-4 with and without BF controller

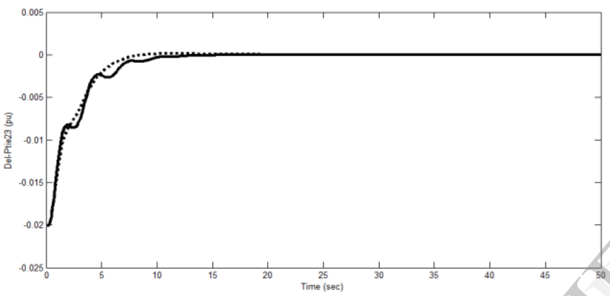


Fig11. DelPtie2-3 with and without BF controller

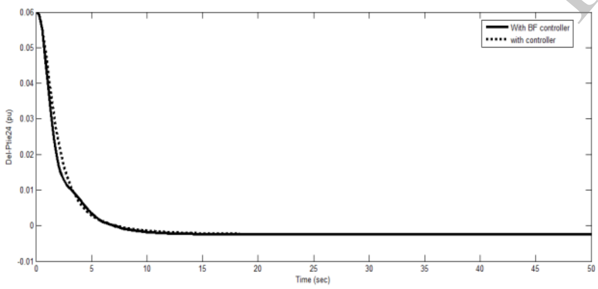


Fig12. DelPtie2-4 with and without BF controller

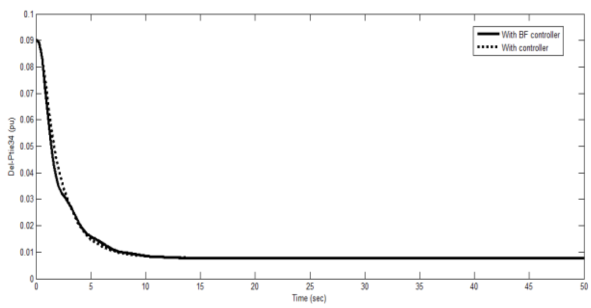


Fig13. DelPtie3-4 with and without BF controller

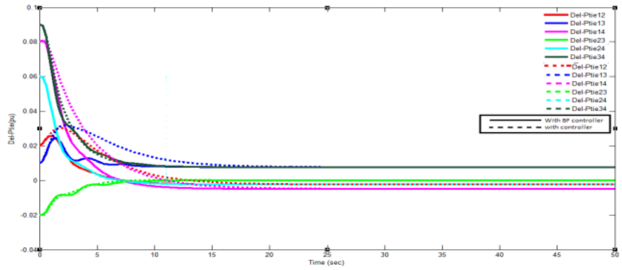
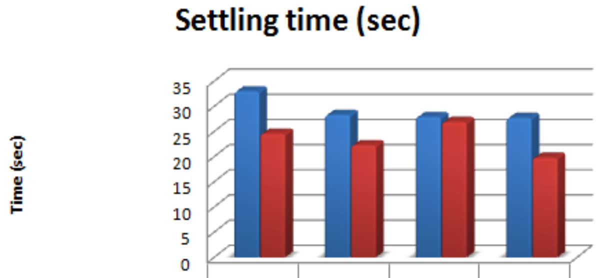
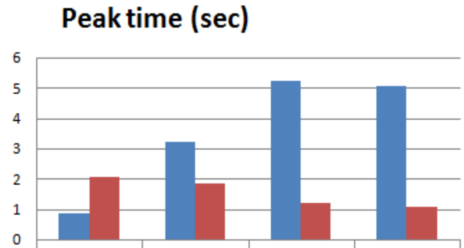


Fig14. Del-P tie line power of all four area with and without BF controller.



	1	2	3	4
with Conventional PI controller	33	28.3	27.9	27.7
BFO with PI controller	24.6	22.3	26.9	19.8



	1	2	3	4
with Conventional PI controller	0.86	3.23	5.23	5.07
BFO with PI controller	2.05	1.83	1.19	1.08

E. Nomenclature

Δ	*Deviation*
s	*Derivative in terms of Laplace*
f	*frequency*
ω	*Angular speed*
T_g	*Governor time Constant*
T_{ij}	*Coefficient of i-j tie Line*
a_{ij}	*Operator*
B_i	*Bias Factor*
P_{ref}	*The Output of ACE*
P_l	*Electric Load Variations*
R	*Regulation Parameter*
apf_i	*ACE Participation Factors*
DPM	*DISCO Participation Matrix*
cpf_i	*Contract Participation Factors*
ACE	*Area Control Error*
$P_{i\text{-}jactual}$	*Real Tie Line Power*
$P_{i\text{-}jscheduled}$	*Scheduled Tie Line Power Flow*

Pi-jerror	*Tie Line Power Error*
BF	*Bacterial foraging*
$K_{p1,2,3}$	*Generator Gain Constant*
$T_{p1,2,3}$	*Generator Time Constant*
P_t	*Turbine output power*
Tt	*Turbine time Constant*
Pg	*Governor Output power*
T_g	*Governor Time Constant*

III. CONCLUSION

This Paper encapsulates automatic generation control of the power system after deregulation includes bilateral contracts.DPM facilitates bilateral contracts simulation. Controller gains are optimized by both Bacterial Foraging and Proportional integral controller. This is study using simulation on a Four area power system considering different contracted scenarios. The dynamic and steady state responses for generated power change, for the frequency change and tie line powers change are shown in figure(7,) The simulation reveals that the proposed Bacterial Foraging based integral controller gives better performance than Proportional integral controller. This method reduces the peak deviation in frequencies and improves the tie line power.

APPENDIX-1

Base=1000MVA

Time constant T_{ps}=2H/D

T_{ps1}=16.669, T_{ps2}=8.89, T_{ps3}=16.669, T_{ps4}=8.89

Power system Gain K_{ps}=1/D

K_{ps1}=1.66, K_{ps2}=1.11, K_{ps3}=1.66, K_{ps4}=1.11,

Governor time constant (T_g)

$T_{g1}= T_{g2}= T_{g3}=0.067$

$T_{g4}= T_{g5}= T_{g6}\ T_{g7}= T_{g8}=0.167$

$T_{g9}= T_{g10}=0.06$

$T_{g11}= T_{g12}= T_{g13}\ T_{g14}= T_{g15}=0.06$

Turbine time constant (T_t)

$T_{t1}= T_{t2}= T_{t3}=0.167$

$T_{t4}= T_{t5}= T_{t6}\ T_{t7}= T_{t8}=0.06$

$T_{t9}= T_{t10}=0.25$

$T_{t11}= T_{t12}= T_{t13}\ T_{t14}= T_{t15}=0.1$

Speed Regulation(R)

$\frac{1}{R_1}=\frac{1}{R_2}=\frac{1}{R_3}=6.67$

$\frac{1}{R_4}=\frac{1}{R_5}=\frac{1}{R_6}=\frac{1}{R_7}=\frac{1}{R_8}=3.2$

$\frac{1}{R_1}=\frac{1}{R_2}=10$

$\frac{1}{R_{11}}=\frac{1}{R_{12}}=\frac{1}{R_{13}}=\frac{1}{R_{14}}=\frac{1}{R_{15}}=3.2$

Frequency Bias Factor (B)

B_1=20.9, B_2=16.9, B_3=20.9, B_4=20.9,

$a_{12}= a_{13}= a_{14}= a_{23}= a_{24}= a_{34}=1$

REFERENCES:

[1] Vaibhav Donde, M.A. Pai and Iran A. Hiskens, "Simulation and Optimization in a AGC System after Deregulation," IEEE Trans. Power Systems, VOL. 16, no. 3, AUGUST 2001.

[2] Ranjit Roy, S.P.Ghoshal and Praghnesh Bhatt, "Evolutionary Computaion based Four-Area Automatic Generation Control in Restructured Environment" in third International Conference on Power Systems, Kharagpur,India, 27-29th Dec, 2009.

[3] Surya Prakash and S.K. Sinha, "Intelligent PI Control Technique in Four Area Load Frequency Control of Interconnected Hydro-themal Power System," in International Conf. on Computing, Electronics and Electrical Technologies[ICCEET],2012.

[4] Kanika Wadhwa, J. Raja and S.K. Gupta, "BF Based Integral Controller for AGC of Multiarea Thermal System under Deregulated Environment",IEEE 5th Power India Conference,19-22th Dec,2012.

[5] E.Rakhahani and J.Sadeh, "LOAD Frequency Control Of Multi-Area Restructured Power System,"IEEE Trans. Power Systems,2008.

[6] F.Liu, Y.H.Song, J.Ma, S.Mei and Q.Lu, "Optimal Load Frequecy Control in Restructured Power Systems," IEE Proc.-Gener. Transm. Distrib., Vol. 150, No.1, Jan,2003.

[7] Kevin M. Passino, "Biomimicry of Bacterial Foraging for Distributed Optimization and Control," IEEE Control Syst. Mag., vol. 22, no. 3,pp. 52-67,Jun. 2002.

[8] B. Parashuramulu and Ashwani Kumar. "Load Frequency Control of Hybrid Systems in Open Access Environment" IEEE Annual India Conference(INDICON),2010.

[9] Sanjoy Debbarma, Lalit Chanda Saikia and Nidul Sinha, "AGC of Multi-area thermal system under deregulated environment using a non-integer controller," Electirc Power System Research,pp. 175-183,2013.

[10] Richard D.Christie and Anjan Bose , "Load Frequency Control Issues In Power system Operations After Deregulation,"IEEE Transaction Power Systems,1995.

[11] Elyas Rakhshani and Javed Sadeh, "Simulation Of Two-Area AGC System in a Competitive Environment Using Reduced-Order Observer Method," IEEE Transaction Power Systems,2008.

[12] J.Nanda, S.Mishra,L.C. Saikia, Maiden application of Bacterial Foraging based optimization technique in multi area automatic generation control, IEEE Transaction on Power system 24(May(2)) (2009) 602-609.