

AGC in Deregulated Environment Using Bacterial Foraging Optimisation

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Abstract: Automatic Generation Control (AGC) is an integral part of Energy Management System. This paper deals with the automatic generation control of interconnected Thermal-Hydro and Thermal-Thermal system in deregulated power system with Bacterial foraging technique.

Keywords: Automatic Generation Control, Bacterial Foraging Technique, Deregulation.

I. INTRODUCTION

An interconnected power system consists of control areas which are connected to each other by tie lines. In a control area, all the generators speed up or slow down together to maintain the frequency and relative power angles to scheduled values in static as well as dynamic conditions. In an interconnected power system, any sudden small load perturbation in any of the interconnected areas causes the deviation of frequencies of all the areas and also of the tie line powers.

The main objectives of Automatic Generation Control (AGC) are:

1. To maintain the desired megawatt output and the nominal frequency in an interconnected power system.
2. To maintain the net interchange of power between control areas at predetermined values.

AGC with Optimization Techniques:

The AGC problem has been augmented with the valuable research contributions from time to time, like AGC regulator designs incorporating parameter variations/uncertainties, load characteristics, excitation control and parallel AC/DC transmission links. The microprocessor-based regulator, self-tuning regulator, and adaptive regulator designs have been presented. The most recent advancement in this area is the application of artificial intelligence techniques such as neural networks, fuzzy logic, genetic algorithms etc. to tackle the difficulties associated with the design of regulators with nonlinear models and/or insufficient knowledge about the system.

However, the implementation of AGC strategy based on a linearized model on an essentially nonlinear system did not necessarily ensure the stability of the system. Hence attention was paid to consider the system nonlinearities. The destabilizing effect of governor dead-band non-linearity on conventional AGC system was studied and it was shown that governor dead-band non-linearity tends to produce continuous oscillations in the area frequency and tie

line power transient response. The successful operation of interconnected power systems requires the matching of total generation with total load demand and associated system losses. With time, the operating point of a power system changes and hence, these systems may experience deviations in nominal system frequency and scheduled power exchanges to other areas, which may yield undesirable effects. There are two variables of interest, namely, frequency and tie-line power exchanges. Their variations are weighted together by a linear combination to a single variable called the area control error (ACE).

II. MATHEMATICAL MODELING OF AGC WITH RESTRUCTURING

Deregulation is the collection of restructured rules and economic incentives that governments set up to control and drive the electric power industry. Deregulated system will consist of generation companies (GENCOs), distribution companies (DISCOs), transmission companies (TRANSCO) and independent system operator (ISO). GENCO, TRANSCO, DISCO, ISO and many ancillary services (AGC) of a vertically integrated utility will have a different role to play and therefore have to be modeled differently.

For AGC studies it is necessary to obtain appropriate models of the power systems in deregulated environment. In this chapter, models of the following types of power systems have been considered for AGC studies

- (i) Two area Thermal-Thermal
- (ii) Two area Thermal-Hydro

The models of above mentioned interconnected power systems with integral control scheme, state space modeling of these power systems to design optimal controllers and stability studies of these power system models have been dealt with in this chapter. The discrete versions of these power system models have also been obtained.

2.1 Two Area Thermal-Thermal System:

Perturbed model of a two area Thermal-Thermal power system with conventional integral controller scheme is shown in Fig. 2.1.

Different variables have been defined as:

State Variable:

$$X_1 = \Delta F_1 \quad X_2 = \Delta P_{t1} \quad X_3 = \Delta P_{g1} \quad X_4 = \Delta F_2 \quad X_5 = \Delta P_{t2}$$

$$X_6 = \Delta P_{g2} \quad X_7 = \Delta P_{tie1-2} \quad X_8 = \int ACE_1 dt \quad X_9 = \int ACE_2 dt$$

Control Inputs: u_1 & u_2

Disturbance Inputs: $d_1 = \Delta P_{D1}$ $d_2 = \Delta P_{D2}$

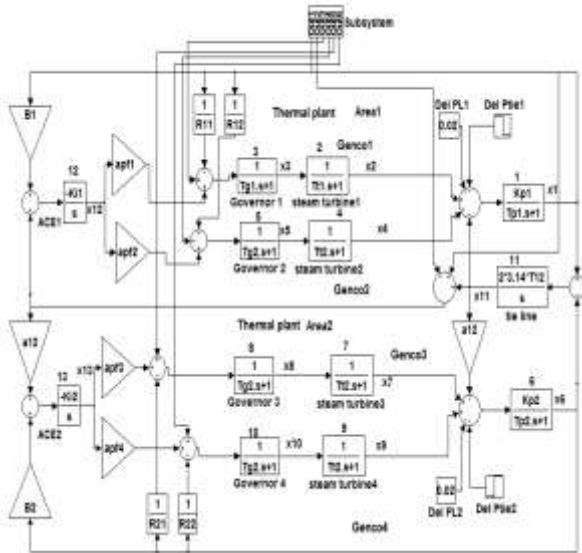


Fig. 2.1. Transfer Function Model of Two Area Thermal-Thermal System in Deregulated Environment.

2.2. Two Area Thermal-Hydro Power System:

Two-area Thermal-Hydro power system with conventional integral controller scheme is shown in Fig. 2.2.

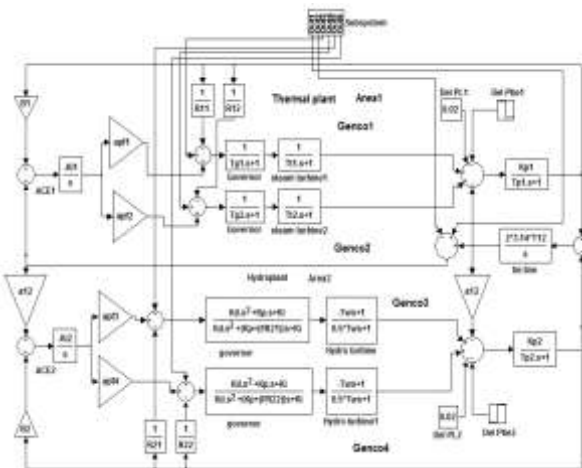


Fig. 2.2. Transfer Function Model of Two Area Thermal-Hydro System Deregulated Environment

III. RESULT ANALYSIS

Result of Two Area Thermal-Thermal Power System:

Simulations Model performed with no controller, with integral controller. BF based integral controller is

applied to two-area electrical power system by applying 0.01 p.u. step load disturbance to area 1.

Fig. 3.1 to Fig. 3.3 show the dynamic responses of frequency deviations in two areas (i.e., Δf_1 and Δf_2) and the tie line power deviation (ΔP_{tie}) for the two area thermal-thermal power system for sample values of area load disturbances ($d_1 = 0.01$ p.u.).

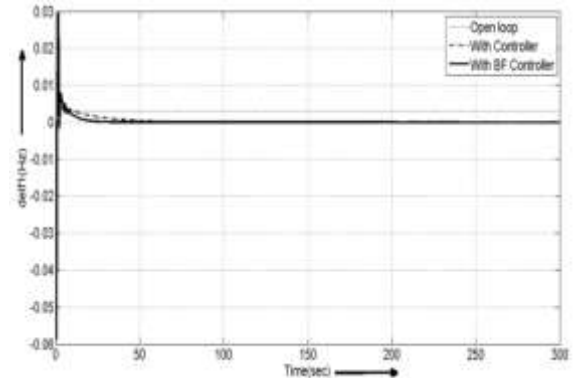


Fig. 3.1. Shows Δf_1 of Two-Area Thermal-Thermal Power System with Open loop, with Conventional Controller and With BF based Integral Controller

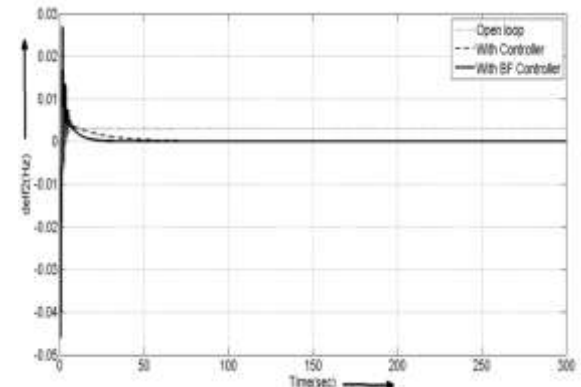


Fig. 3.2. Shows Δf_2 of Two-Area Thermal-Thermal Power System with Open Loop, with Conventional Controller and with BF Based Integral Controller

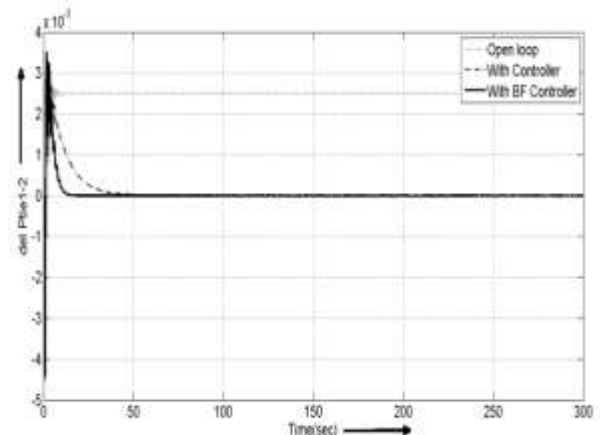


Fig. 3.3. Shows ΔP_{tie1-2} of Two-Area Thermal-Thermal Power System with Open Loop, with Conventional Controller and With BF based Integral Controller

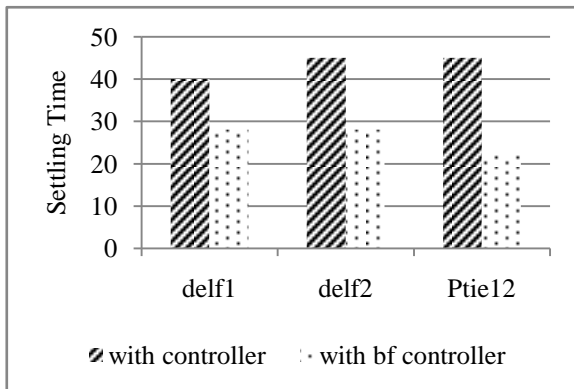
These figures show the performance of BF based integral controller trained with full state feedback in comparison with open loop and integral controllers on same scale.

In Fig. 3.1 to Fig.3.3 shows three graphs in one graph. In this dotted line shows the dynamic performance in case of without controller, dash dot line shows the performance of with controller and solid line shows with BF based integral controller. BF based integral controller has given the performance quite superior in terms of settling time and peak overshoot to that of integral controller.

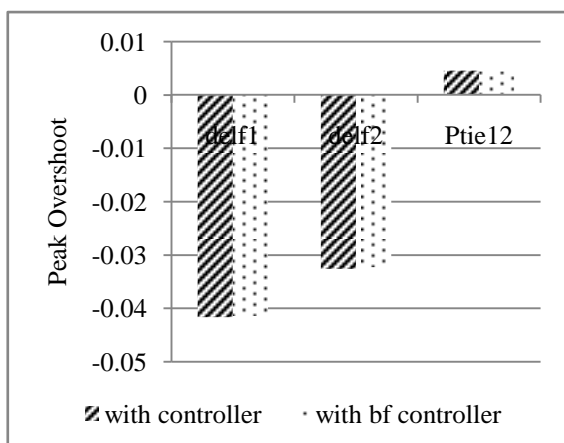
In this system both area are thermal area. Table 3.1 shows the settling time comparison of two-area with conventional controller and with Bacterial Foraging controller. Graph 3.1(a) and Graph 3.1(b) shows the clear comparison of two-area Thermal-Thermal system.

Table 3.1. Settling Time of Two-Area Thermal-Thermal System in Deregulated Environment

	delf1	delf2	Ptie12
With Controller	40 sec	45 sec	45 sec
With BF Controller	28 sec	28 sec	22 sec



Graph 3.1(A). Bar Graph for Settling Time



Graph 3.1(b). Bar graph for Maximum Peak Overshoot

Result of Two Area Thermal-Hydro Power System:

Fig. 3.4 to Fig. 3.6 show the dynamic responses of frequency deviations in two areas (i.e., ΔF_1 and ΔF_2) and the tie line power deviation (ΔP_{tie}) for the two area Thermal-Hydro power system.

Fig. 3.4 to Fig. 3.6 shows the dynamic responses. This shows two area Thermal-Hydro power systems with Open loop, Conventional controller and with BF based integral controller

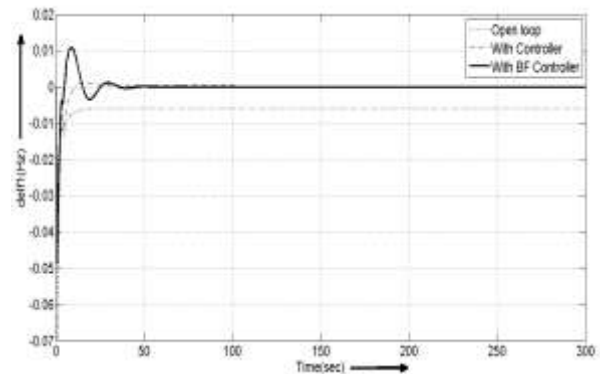


Fig. 3.4. Shows ΔF_1 of Two-Area Thermal-Hydro Power System with Open Loop, with Conventional Controller and with BF Based Integral Controller

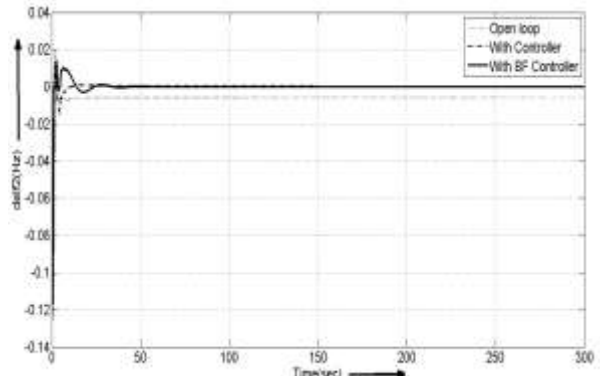


Fig. 3.5. Shows ΔF_2 of Two-Area Thermal-Hydro Power System with Open Loop, with Conventional Controller and with BF Based Integral Controller

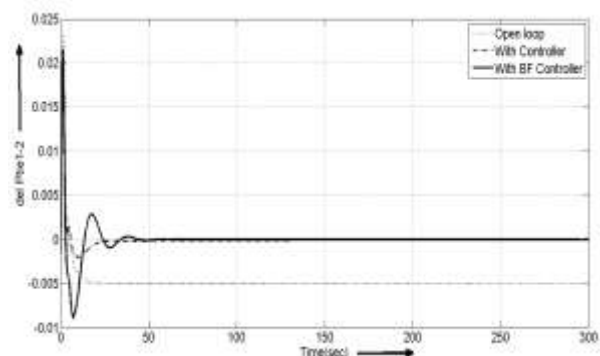


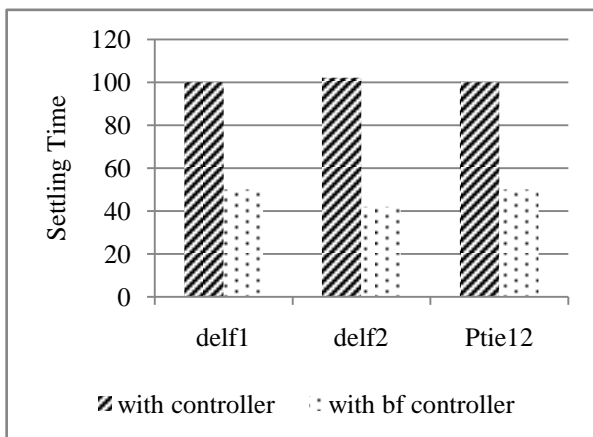
Fig. 3.6. Shows ΔP_{tie1-2} of Two-Area Thermal-Hydro Power System with Open Loop, with Conventional Controller and with BF Based Integral Controller

Fig. 3.4 to Fig. 3.6 shows the performance of BF based integral controller trained with full state feedback in comparison with open loop and integral controllers on same scale. It is evident that, the BF based integral controller has given the performance quite superior in terms of settling time and peak overshoot to that of integral controller.

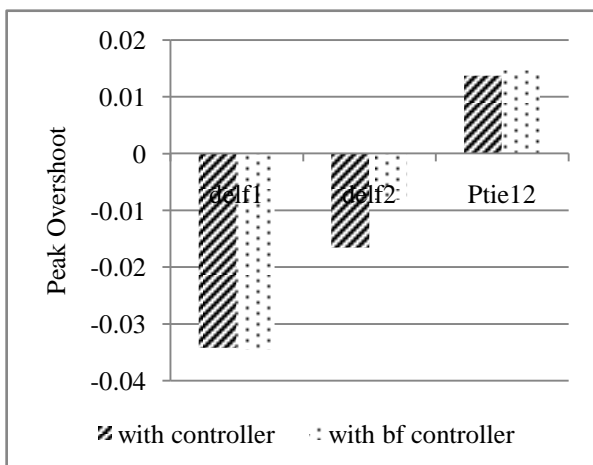
Table 3.2 shows the settling time comparison of two-area with conventional controller and with Bacterial Foraging controller. Graph 3.2(a) and Graph 3.2(b) is made to show the comparison of two-area Thermal-Hydro System in case of settling time (T_s) and maximum peak overshoot (M_p)

Table 3.2: Settling Time of Two-Area Thermal-Hydro System in Deregulated Environment

	delf1	delf2	Ptie12
With Controller	100 sec	102 sec	100 sec
With BF Controller	50 sec	42 sec	50 sec



Graph 3.2(a). Bar Graph for Settling Time



Graph 3.2(b). Bar Graph for Maximum Peak Overshoot

In this dotted line shows the dynamic performance in case of without controller, dash dot line shows the performance of with controller and solid line shows

with BF based integral controller. BF based integral controller has given the performance quite superior in terms of settling time and peak overshoot to that of integral controller.

IV. CONCLUSION

Simulation model of two-area Thermal-Thermal and two area Thermal-Hydro interconnected power systems has been developed. See the dynamic response of these models by without applying the controller. Then conventional controller is applied to see the dynamic response. Without controller steady state error is present in the power system. To remove this steady state error, controller is applied to the simulation model. Integral controller is optimized by the BF technology. Apply the BF based integral controller to the simulation model. It has been demonstrated that, the BF controllers can be successfully developed, which can give performance much superior than the integral controllers under simultaneous load disturbances of any random magnitudes within any chosen range in various interconnected areas.

It has been demonstrated that, the BF controllers can be successfully developed, which can give performance much superior than the integral controllers under simultaneous load disturbances of any random magnitudes within any chosen range in various interconnected areas and deregulated areas. The BF controllers developed in present work offer the benefits over conventional integral controllers like;

1. Fast transient recovery
2. Less time to settle the excursions of system state variables within acceptable limits
3. Ability to give satisfactory performance even with incomplete state feedback
4. Ability to give satisfactory performance under simultaneous load perturbations in all the interconnected areas and deregulated area

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