Load Frequency Control of Hydro Thermal System with Grey Wolf Controller Considering Boiler Dynamics

A.Arunkumar and S.P.Umayal

Abstract - This paper describes the load frequency control(LFC) of two area interconnected hydro-thermal system usingconventional fuzzylogic controller (FLC) and proposed grey wolf optimization (GWO). The thermal system is incorporated withgovernor dead band, generation rate constraint and boiler dynamics. The hydro system is incorporated with generationrate constraint. The conventional PI controller does not yield adequate control performance with the consideration of nonlinearitiesand boiler dynamics. To overcome this drawback GWO has been employed in the system. The aim of GWO is torestore the frequency and tie line power in very smooth way toits nominal value in the shortest possible time. Time domain simulations are used to study the performance of the powersystem. System performance is examined considering 1% stepload perturbation in either area of the system.

Terms: LFC , GWO , FUZZY

I. INTRODUCTION

Load Frequency Control is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. With an increasing demand, the electric power system becomes more and more complicated. For a successful operation of power system under abnormal conditions, mismatches have to be corrected via supplementary control. For satisfactory operation of a power system the frequency should remain nearly constant. The various areas or power pools are interconnected through tie lines. These tie lines are utilized for contractual energy exchange between power pools and also inter-area support in case of abnormal conditions. The power system is subjected to local variations of random magnitude and duration. As the load varies at any area in the system considered, the frequency related with this area affected and then the other areas are also affected through tie lines. Frequency transients must be eliminated as soon as possible. Mostly the boiler system effects and its control, governor dead band effects and generation rate constraint are neglected in the Load frequency control studies for simplicity [1]. But for the realistic analysis of system performance, these should be incorporated as they have considerable effects on the amplitude and settling time of oscillations.

The conventional proportional plus integral control strategy, which is mostly used in power industry, take the error signal as ACE. The conventional PI controller does not provide adequate control performance with the consideration of boiler dynamics and non-linearities such as governor dead band and generation rate constraint. The difficulty in obtaining the optimum settling time of previously said controller is mitigated by using FLC. Simulation results confirm that the fuzzy logic controller greatly reduces the overshoots. The settling time is also reduced considerably.

1.1. SYSTEM INVESTIGATION

The detailed block diagram of two area hydro-thermalpower system investigated in this study is shown in Fig.1 [1], [17]. Area 1 comprising a reheat thermal system withgovernor dead band, generation rate constraint non-linearitiesand boiler dynamics also area 2 comprising a hydro systemwith generation rate constraint. The nominal parameters ofsystem are given in Appendix. Matlab version 7.3 hasbeen used to obtain dynamic response such as ΔF1, ΔF2, and Δ Ptie for 1% step load perturbation in either area of thesystem.

II. PROPOSED SYSTEM

2.1. Governor Dead Band

Governor Dead Band is defined as the total magnitude of asustained speed change within which there is no resultingchange in valve position. The Backlash non-linearity tends toproduce a continuous sinusoidal oscillation with a naturalperiod of about 2s [3], [8]. The speed governor dead band hassignificant effect on the dynamic performance of loadfrequency control system. Describing function approach isused to incorporate the governor dead band non-linearity. Thehysteresis type of non-linearities are expressed as,

$$y = F\, x\, x \text{ rather than as } y = F(x) \qquad (1)$$

To solve the non-linear problem, it is necessary to make the basic assumption that the variable x, appearing in theabove equation is sufficiently close to a sinusoidal equationthat is,

$$xASin\ t\ 0 \approx \omega \qquad (2)$$

where, A is amplitude of oscillation 0 ωis frequency of oscillations

As the variable function is complex and periodic functionof time, it can be developed in a Fourier series as follows, [3]
As the backlash nonlinearity is symmetrical about theorigin, $F0$ is zero. For the analysis in this paper, backlash ofapproximately 0.05% is chosen [1]. From the above equation,for simplification neglect higher order, the Fourier coefficientsare derived as N1=0.8 & N2=-0.2. By substitutingthe values in Eq.(3) the transfer function for GDB isexpressed as following

2.1.1 Generation Rate Constraint

In practice, there exists a maximum limit on the rate ofchange in the generating power. For thermal system agenerating rate limitation of 0.1 p.u per minute is considered,
[6], [18] i.e.

$$\Delta Pg \le 0.1\ p.u.MW / \min = 0.0017\ p.u.MW / s \qquad (5)$$

For hydro system the rate of generation 4.5%/s is considered [4].

2.1.2 Boiler Dynamics

Fig.2 shows the model to represent the boiler dynamics [1], [4], [9]. Boiler is a device meant for producing steamunder pressure. The model is basically for a drum type boiler.An oil/gas fired boiler system has been employed in thisstudy, since such boilers respond to load demand changesmore quickly than coal-fired units [10], [12].

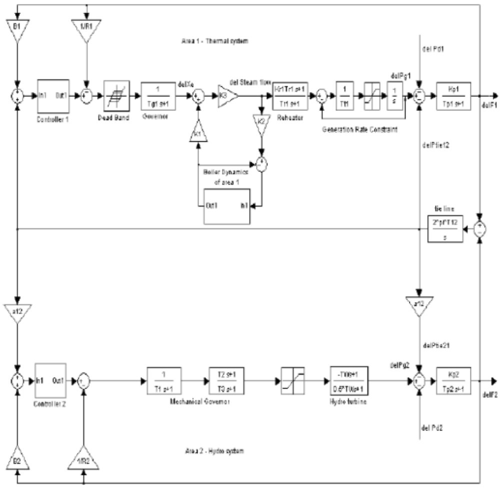

Fig 2.1. Proposed block diagram.

In Group search optimizer localization algorithm three types of members are used Producer, Scrounger and Rangers [7]. In this paper number of producer is taken one. Number of scrounger as 16 and number of rangers as 3. For each iteration there is only one producer, 16 scroungers and 3 rangers. The producer and scrounger move in the space environment and they can interchange the roles as producer, scrounger or ranger. Producer can become scrounger and vice versa depending on the localization error. The localization error calculated by the equation (2) and the member which has the minimum error leads to producer in each iteration. This producer does the visual search and scans the environment. In this algorithm the producer does the scanning randomly with three different locations or degrees. Zero degree location, right hand side location angle and left hand side location angle

III. SIMULATION RESULTS

In this paper, we use MATLAB software to simulate the load frequency controlof two area system and results are follows.

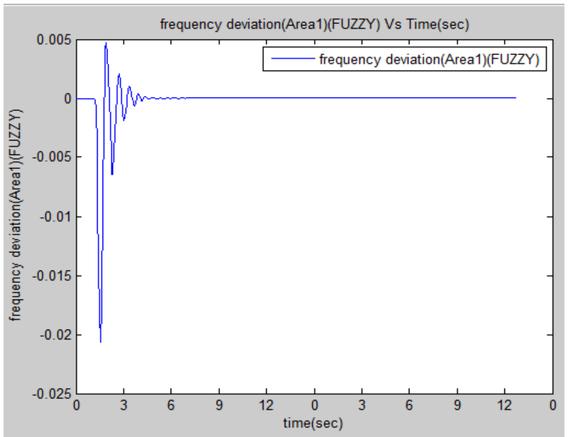

Fig 3.1 LFC using fuzzy logic (Area 1)

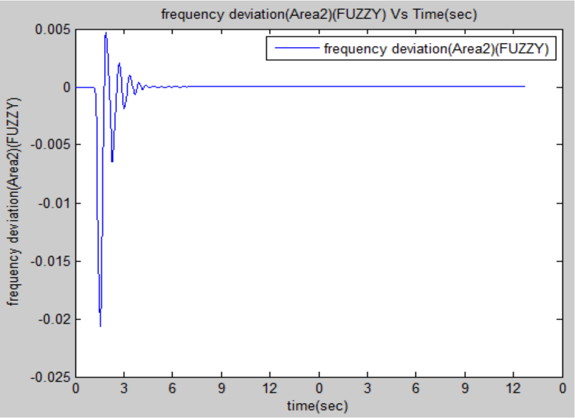

Fig 3.2 LFC using fuzzy logic (Area 2)

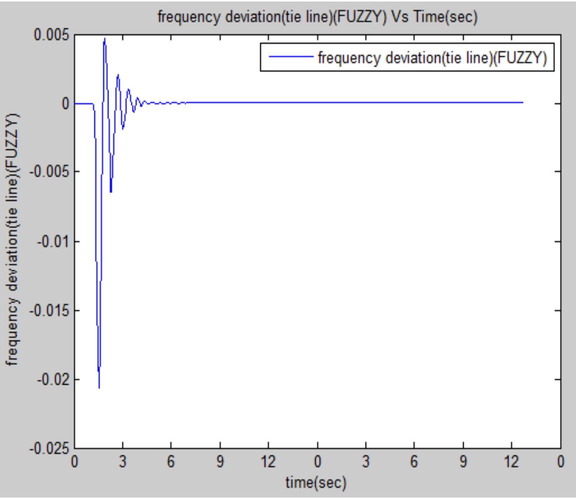

Fig 3.3 LFC using fuzzy logic (tie line)

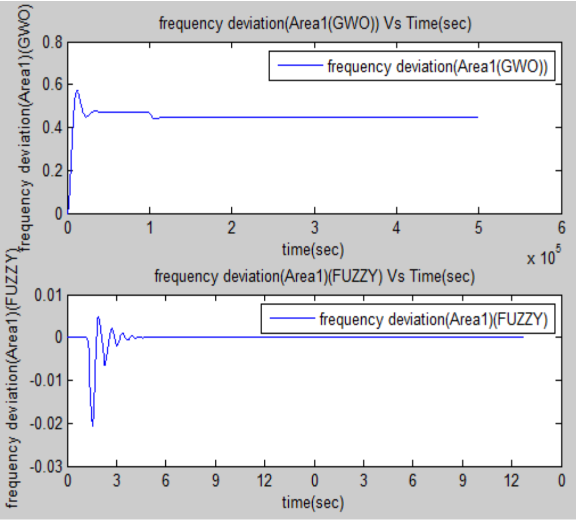

Fig 3.4 LFC using GWO vs fuzzy logic (Area 1 & Area 2)

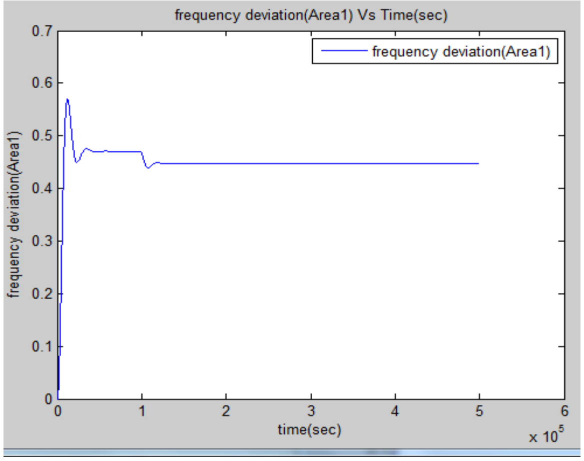

Fig 3.5 LFC using GWO (Area 1)

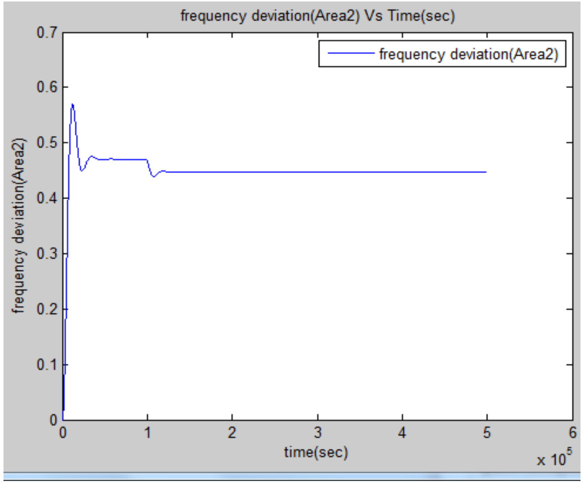

Fig 3.6 LFC using GWO (Area 2)

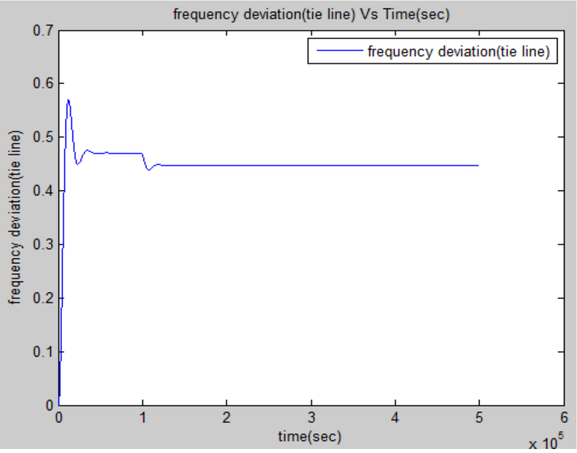

Fig 3.7 LFC using GWO (tie line)

Table 3.1. Comparison table shows the frequency deviation of LFC with fuzzy and GWO

S.No	**Parameters**	**Stability Time (Fuzzy)**	**Stability Time (Gwo)**
1	Area1 System (Frequency Deviation)	2.29	1.14
2	Area 2 System (Frequency Deviation)	2.29	1.14
3	Tie Line (Frequency Deviation)	2.29	1.14

IV. CONCLUSION

In this paper FLC is designed for load frequency control oftwo area interconnected hydro-thermal power system considering non-linearities and boiler dynamics. Theconventional PI controller does not yield adequate controlperformance with the consideration of non-linearities andboiler effects. The simulation results conclude that FLCyields fast settling time which advocates the smoothsettlement of the quality power supply.The rate at which the settling time is reduced to 1.14 sec is achieved using proposed GWO controller.

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V. REFERENCES

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