LFC OF TWO INTERCONNECTED POWER SYSTEM USING INTELLIGENT CONTROLLER METHOD

S.M. KAMALI NALLADURAI[1], R.S.D WAHIDA BANU[2]

In this paper the brain emotional learning based intelligent controller (BELBIC) has been proposed for solving the frequency variation problems due to the uncertainty in loads in the two interconnected power systems. It is a recent advanced controller based on emotional processing method in the brain. The deviations in the frequency can be minimized by tuning the proposed controller. The steady state error in the interconnected system can be eliminated by the PI controller, but it develops overshoot problems in the system. The illustrated results show that BELBIC method is more robustness with acceptable response in the system parameters.

Keywords: Load frequency control, Brain Emotional Learning Based Intelligent Controller, Anti Windup Control

1. Introduction

The primary concern in the designing of interconnection of two power systems is the control of load frequency, which becomes more significant when increasing the size and the structure. It is necessary to maintain the frequency and the power flow in the tie line, where two power systems interconnected together, without deviation even under load disturbances [1]. The Load Frequency Control (LFC) attains the primary function are providing better electricity and safe system operation. Hence, it necessitates designing a load frequency control for maintaining the better reliability in the electric power system at a required level. The commonly used technique is the PI controller for controlling such load frequency. But the selection of its gain becomes a major drawback because of the non-linearity of the power system. The conventional PI controller can able to maintain the constant load frequency under inconsistent load conditions in the two interconnected power system. But it generates sudden overshoot problems, in order to provide an efficient solution to the LFC problem. Many controllers such as Optimal Control (OC) [17]-[18] and Sliding Mode Controller (SMC) [19] are used. But in the SMC and OC involves more complex, and stability of the power

[1] Department of EEE, Mahendra Institute of Technology, Namakkal-636307, India, E-mail: kamalinalladurai@gmail.com
[2] Principal, Government College Of Engineering Salem - 636011, India

system is not assured. Hence, the designing of a controller with less processing time is necessary. As a result, the efficient, intelligent controller is proposed to minimize the problems such as overshoot and the high settling time.

2. Modelling Of The Proposed System

The inter-area tie line power with real oscillations and the controlling of load frequency are the main aspects of this paper. Area control error is a vital role and acts as the input signal for the BELBIC controller [6]. Also the BELBIC controller controls and maintains the load frequency of the two interconnected power areas simultaneously through a tie line as shown in the Fig. 1.

In the case of two or more interconnected power system, the load frequency will start to oscillate due to the different load frequency of different power system that leads to provide stability problems. In order to avoid these stability problems, the Automatic Generation Control (AGC) technique must be added to reduce the frequency deviations.

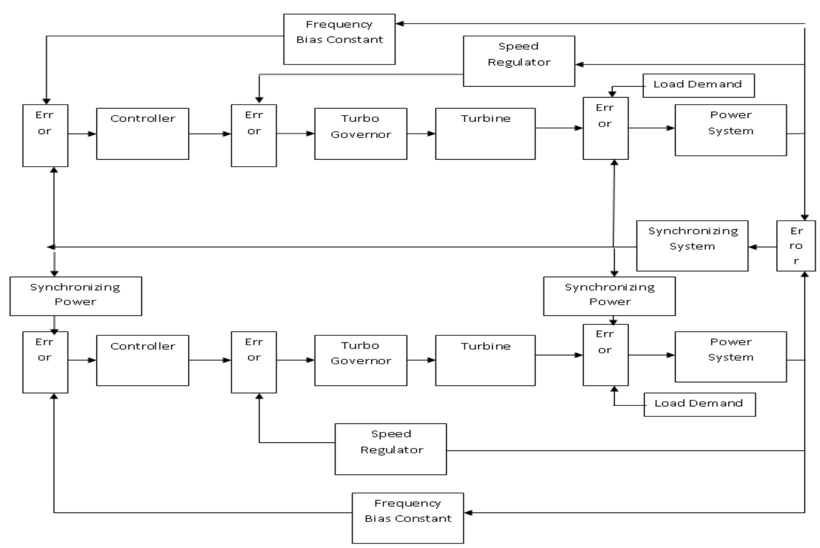

Fig1. Block diagram of proposed system

2.1 Drawbacks in the Conventional PI Controller

The PI controller is the simplest controller with real speed of response, which can be referred to the following equation (1).

$$U(s) = K_P E(s) + \frac{K_i}{s} E(s) \tag{1}$$

But it produces low steady state error and long settling time.

2.2 Anti Windup PI Controller

The Anti-windup PI controller is designed by introducing the integrator windup phenomenon in the PI controller with feedback. In this controller, to reduce the overshoot and the settling time a maximum integrated output value is kept within the limits. Hence, it can recover quickly from the nonlinearities.

2.3 Fuzzy gain scheduling PI Controller

Intelligent fuzzy logic controller (FLC) is designed to tune the gains of the PI controller in AGC. The fixed values of the gains in PI controller irrespective of error may increase the settling time. It is referred as fuzzy gain scheduling (FGSPIC). In FGSPIC based PI receives ACE continuously. It decides the proportional gain and integral gain of the PI controller based on present ACE and change in ACE. Proportional Controller has the effect of reducing rise time, but never eliminates the steady state Error. An integral control has the effect of eliminating steady state error, but the high value of an integral controller may make the transient response worse.

However, the overshoot controlled by the FGSPI controller is not up to the required level. Thus to decrease the overshoot to a very low-value BELBIC is introduced in the AGC of the interconnected power system.

3. BELBIC Controller Structure (Proposed controller)

In 2004, Lucas introduced BELBIC, is a non-linear and neuromorphic controller based on the computational learning method to produce control actions. Since BELBIC is a bio-inspired control method, the structure is based on the limbic system of mammalian's brain. It has four main sections such as the amygdala (A), orbitofrontal cortex (O), thalamus (TH) and sensory cortex (CX) as shown in Fig. 2 and Fig. 3. Amygdala plays an important role because the emotional learning process is taking place.

Amygdala receives inputs from the Thalamus and cortical areas while the Orbitofrontal receives inputs from Amygdala and cortical areas. The system also receives a Primary Reward signal (REW) in addition to Sensory Cortex inputs. There is also one *O* node for each of the stimuli in the Orbitofrontal except for the thalamic node. The output node, *E*, simply sums the outputs from the A node and then subtracts the inhibitory outputs from the *O* nodes. The result is the output from the model. The E′ node sums the outputs from *A* except A_{th} and then subtracts from inhibitory outputs from the *O* nodes.

$$E = \sum_i A_i - \sum_i O_i \quad (2)$$

$$E' = \sum_i A_i - \sum_i O_i \quad (3)$$

The thalamic connection is calculated as the maximum of stimuli inputs (*S*):

$$A_{th}=\max(S_i) \quad (4)$$

Unlike other inputs to the Amygdala, the thalamic input is not planned as the Orbitofrontal part and cannot be inhabited.

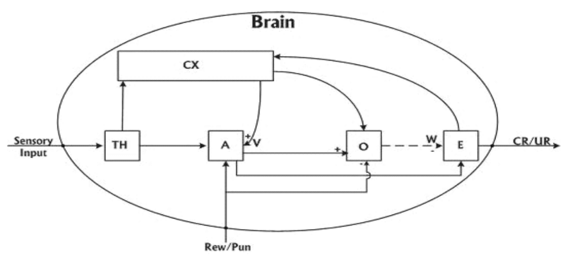

Fig 2. Simplified model of BELBIC

The output of the node is obtained by multiplying the input by a plastic connection weight *V* for each *A* node.

$$A_i=S_iV_i \quad (6)$$

The connection weights V_i are directly proportional to the difference in the activation of the *A* nodes and primary reward(PR). The learning rule of Amygdala is given as follow:

$$\Delta V_i = \alpha \left\{ S_i \max(0, PR - \sum_i A_i) \right\} \quad (7)$$

where α is a learning rate parameter which is used to adjust the learning speed. Its value is set between 0 (no learning) and 1 (instant adaptation). The Orbitofrontal learning rule and the Amygdala rule are more similar, but the weights of the Orbitofrontal connection should be increased and decreased to track the required inhibition.

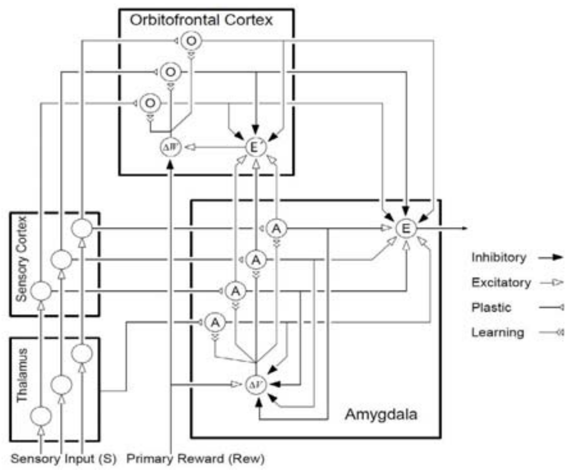

Fig 3. A graphical depiction of the computational model of emotional learning

The learning rule in Orbitofrontal cortex is calculated as follows:

$$\Delta W_i = \beta\{S_i(E' - PR)\} \quad (8)$$

where,
ΔWi = Change in the weight of Orbitofrontal connection
B = Orbitofrontal learning rate
The Orbitofrontal connection node values are calculated as follows:

$$O_i = S_i W_i \quad (9)$$

3.1 Design of Two Interconnected Power System

The two interconnection power systems consist of more complex and multi-variable structures with several interconnected control areas. In each area, there is an own generator or group of generators, which is responsible for its load and scheduled interchanging with neighboring areas connected through tie-lines. The tie-lines provide support for the contractual exchange of power between areas and the case of abnormal conditions. During the variable load conditions, the power flow and frequency of the tie line will be affected at the operating point. Hence for the stable operation of power system with variable load and abnormal system parameters, the deviations in the system frequency and tie-line power should be minimized as quickly as possible. Thus to ensure the quality of power supply, a load frequency controller [2] is needed to maintain the system frequency at the desired nominal value. The linear combinations of system frequency and the tie line power flow are known as area control error (ACE). The frequency and interchanged power are kept at their desired values by means of feedback of area control error containing deviation in frequency and error in tie line power, and controlling the prime movers of generators. The area control error (ACE) for i_{ts} area is defined as:

$$\beta_i = \frac{1}{R_i} + D_i \tag{10}$$

Where R_i is the regulation constant, and D_i is the damping ratio of i_{ts} system. Each interconnected power system area has three major components namely turbine, governor, and generator. The transfer function block diagram of uncontrolled two-area system is illustrated in Fig. 6. The frequency deviations in area1 and area2 are $\Delta f1$ and $\Delta f2$ respectively in Hz. Likewise, $\Delta PL1$ and $\Delta PL2$ represent the load demand changes in areas 1 and two respectively in per unit (p.u.) [2].

3.2 Designing BELBIC Model for Load Frequency Controller

The main aim of the load frequency controller is to get the damping frequency in the tie-line area for a better performance. For this, BELBIC controller is considered as controller in each control area. According to Fig. 2, in each control area the ACE acts as the input signal of the BELBIC controller that is used by the LFC system. Fig. 7 shows the block diagram of the new control system incorporating the emotional controller (BELBIC).

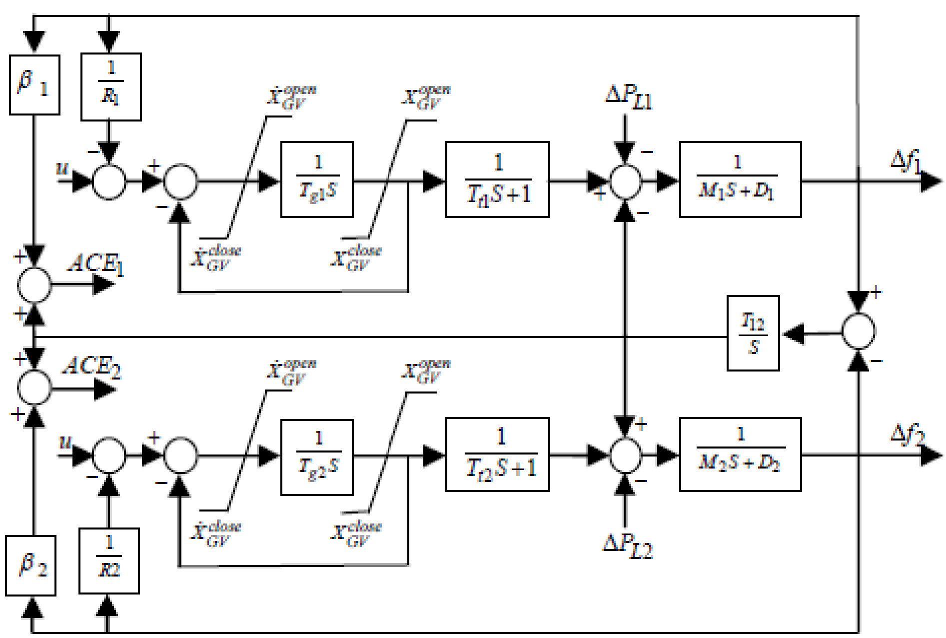

Fig. 4. Transfer function block diagram of two interconnected power systems

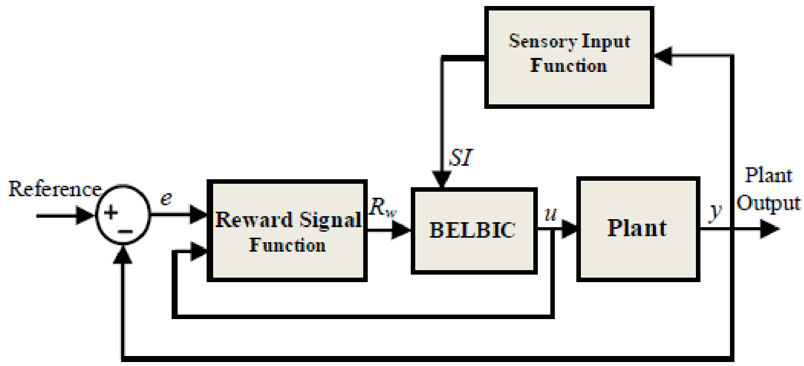

Fig 5. Designing BELBIC model for Load Frequency Controller

As it is illustrated in Fig. 2, sensory input (*SI*) and reward signal (PR) can be the arbitrary function of the reference, and the plant input and output. It is all up to the designer to find a proper function for control. In this work, the functions used in emotional cues and sensory input blocks are considered as follow:

$$R_W = k_1(ACE_i) + k_2 \frac{d(ACE_i)}{dt} + k_3 \int (ACE_i).dt \quad (11)$$

$$SI = k_4 |ACE_i| + k_5 |ACE_i.\Delta f_i| \quad (12)$$

Where ACE_i represents the area control error, Δf_i represent the frequency deviation for the wi_{th} area and k_1,k_2, k_3, k_4, k_5 are gains, which must be tuned for designing a satisfactory controller. The gain k_1 and k_2 are responsible for tuning the overshoot. The gain k_3 is responsible for tuning the settling time. The gain k_4 responsible for tuning the steady-state error and the gain k_5 is responsible for smoothing the beginning of the response.

4. Results and Discussions

The simulation results of the two interconnected power system were analyzed using MATLAB R2011b. Primarily the system on a conventional PI controller was focused. Then the same system is analyzed using an Anti Windup PI controller and BELBIC. The decisive factors considered in this paper are settling time and overshoot. To examine the performance of the plant, in this paper two interconnected power systems are disturbed by 1% step load. Table 1 shows the parameters of the system considered.

Table 1

Parameters of Power Plant

R1, R2	2Hz/p.u.M.W
T_T	0.3 Sec
T_H	0.08 Sec
K_p	100
T_p	20 Sec
A_{12}	-1
T	0.0707
B	0.425 p.u.M.W / Hz

Fig. 6. shows the frequency deviation in system1 of the two areas interconnected system with various controllers. Experiments performed by various controllers with different load perturbations also done.

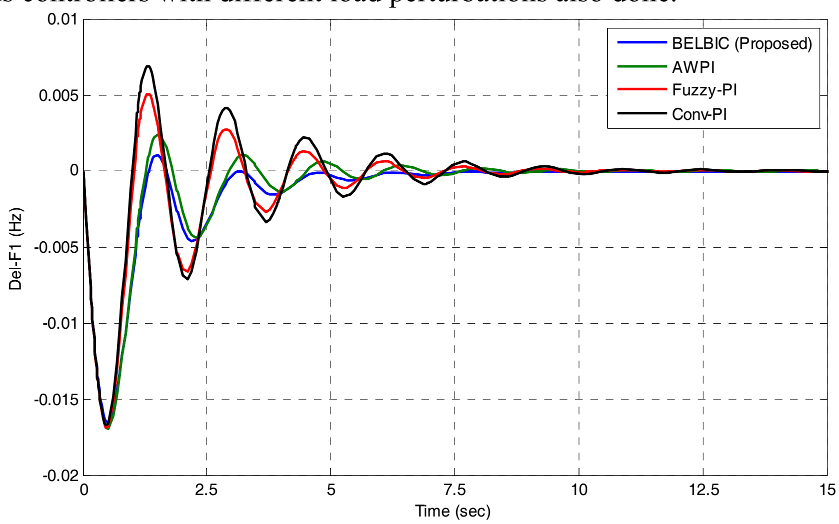

Fig. 6. Frequency deviation in system 1 with all controllers

Frequency deviation of all controllers in system 1 and system 2 are performed and compared. Table II shows performance comparisons of various controllers.

Table 2

Comparison of controller performance

Controllers	**Load (p.u)**	**t_s**	**e_{ss}**	**%M_p**
		TT	**TT**	**TT**
Conventional PI	0.01	11.25	10	69
FGSPIC	0.01	8.5	5	48
AWPIC	0.01	7.5	3	25
BELBIC	0.01	6.3	5	10

5. Conclusion

In this paper, a new control system incorporating the emotional controller (BELBIC) is used for control of frequency and damping the tie-line power variation in a multi-machine power system. The performance of designed controller is experimented on a two-area power system with considering governor limiters and the results obtained are compared with the conventional PI controller, FGSPI controller, AWPI controller. The robustness of the proposed method is tested against change of parameters. The simulation studies show that the designed controllers by BELBIC have a very desirable dynamic performance even when the system parameters change.

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