International Journal of Recent Engineering Research and Development (IJRERD)
ISSN: 2455-8761
www.ijrerd.com || Volume 02 – Issue 12 || December 2017 || PP. 26-31

Load Frequency Control of Multi Area Power System Using Supplementary Adaptive Control

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Abstract: In an interconnected power system, as a power load demand varies randomly, both area frequency and tie-line power interchange also vary. The objectives of load frequency control (LFC) are to minimize the transient deviations in these variables (area frequency and tie-line power interchange) and to ensure their steady state errors to be zeros. Among all the LFC controller designs, the most widely used for industry practices are PI controllers. The adaptive dynamic programming (ADP) based designs are model free, and have attracted a lot of attention in the power system control field. In this paper, load frequency control (LFC) with supplementary adaptive dynamic programming (ADP) is proposed. The primary proportional-integral (PI) controller uses different proportional and integral thresholds for updating the actions, while the supplementary ADP controller is updated in an aperiodic manner. Finally the test system is simulated in the environment of Matlab Simulink to validate robustness of proposed method.

Key Index: Load Frequency Control, adaptive dynamic programming, proportional-integral (PI) controller.

I. Introduction

Load frequency control (LFC) criteria play an increasingly important role in the provision of LFC as an unbundled service in the new open access transmission regimes. These criteria need to be appropriately formulated to be meaningful in the new environment; in particular, they impact considerably the monitoring and metering requirements for LFC [1]. In actual power system operations, the load is changing continuously and randomly. As the ability of the generation to track the changing load is limited due to physical/technical considerations, there results an imbalance between the actual and the scheduled generation quantities. This imbalance leads to a frequency error—the difference between the actual and the synchronous frequency. The magnitude of the frequency error is an indication of how well the power system is capable to balance the actual and the scheduled generation. The presence of an actual-scheduled generation imbalance gives rise initially to system frequency excursions in accordance to the sign of the imbalance. Then, the governor responses take effect and act to reduce the magnitude of the actual-scheduled generation imbalance. Within a few seconds, this so-called *primary speed control* [2] serves to *damp out* the frequency excursions and to *stabilize* the frequency at a new value, which is different than the synchronous frequency. The LFC function [2] is then deployed as the *secondary control process* to maintain the frequency error within an acceptable bound. The LFC is performed by the automatic generation control (AGC) by adjusting load reference set points of governors of selected units in the *control area* and then adjusting their outputs [2]–[4]. Each control area measures the actual frequency and the actual net interchange, typically, every 2–4 seconds. These measurements are used to evaluate the frequency and the net interchange errors. The net interchange error is defined as the difference between the net actual and the net scheduled interchange with the connected control areas. The area control error (ACE) [5] is then computed by taking into account the effects of frequency bias; it is the basis for the control signals sent by the control area to the generators participating in AGC.

II. Power Generating System

A comprehensive introduction to the dynamic models of general power systems can be found in [1]. In this chapter, the modeling of a typical power generating system, including the modeling of three types of generating units, the tie-line modeling and the modeling of parallel operation of interconnected areas will be introduced.

The tie-line is used for the interconnection of two or more power systems. The flow of electric power between two areas is because of the tie line. An area will get energy with the use of tie-lines from another area, whenever the load is changed in that area. Therefore load frequency control also requires the control on the tie-line power swap error. Error in the power of tie line is the integral of the frequency variation among two areas. Linear combination of error in the tie line power and frequency gives the area control error. ACE is a symbol of a divergence between generation of two areas and load. The purpose of load frequency control is to reduce the error in frequency of both areas as well as to remain error in the tie line power to preferred value which is not an easy task in because of fluctuating load. The error in frequency ought to maintain at zero and the steady state errors within the frequency of the power system is that the outcome in error in tie-line power as a result of the tie line power error is that the integral of the frequency variation between each areas.

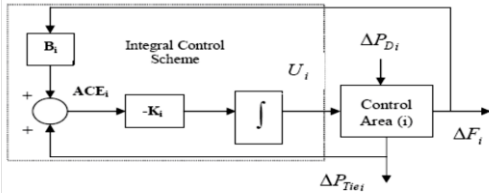

Figure 1: Conventional PI controller

The prime application PI controller is that it keeps the error at zero at the steady state. PI controller with predetermined gains is measured at insignificant working conditions, at immense range of working circumstances it is unsuccessful to provide the optimum control performance.

III. Artificial Neural Networks

The recent rise of interest in neural networks has its roots in the recognition that the brain performs computations in a different manner than do conventional digital computers. Computers are extremely fast and precise at executing sequences of instructions that have been formulated for them. A human information processing system is composed of neurons switching at speeds about a million times slower than computer gates. Yet, humans are more efficient than computers at computationally complex tasks such as speech understanding. Moreover, not only humans, but also even animals, can process visual information better than the fastest computers.

Artificial neural systems, or neural networks (NN), are physical cellular systems, which can acquire, store, and utilize experiential knowledge. The knowledge is in the form of stable states or mappings embedded in networks that can be recalled in response to the presentation cues. Neural network processing typically involves dealing with large-scale problems in terms of dimensionality, amount of data handled, and the volume of simulation or neural hardware processing. This large-scale approach is both essential and typical for real-life applications. By keeping view of all these, the research community has made an effort in designing and implementing the various neural network models for different applications.

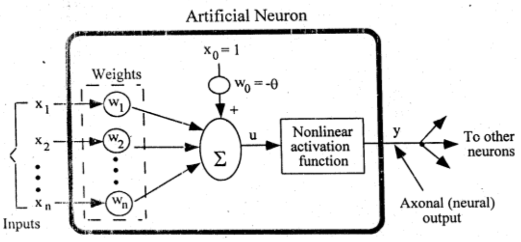

Figure 2: An artificial neuron

The artificial neuron is developed to mimic the first-order characteristics of the biological neuron. In similar to the biological neuron, the artificial neuron receives many inputs representing the output of other neurons. Each input is multiplied by a corresponding weight, analogous to the synaptic strength. All of these weighted inputs are then summed and passed through an activation function to determine the neuron input. This artificial neuron model is shown in Figure 2.The schematic diagram of artificial neuron is shown in Figure 3. The artificial neuron mainly performs two operations, one is the summing of weighted net input and the second is passing the net input through an activation function. The activation function also called nonlinear function and some time transfer function of artificial neuron.

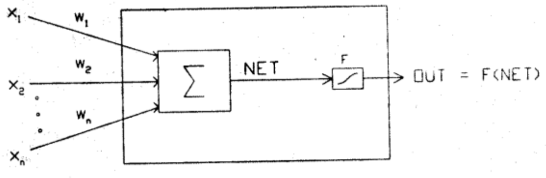

Figure 3: Artificial neuron using activation function

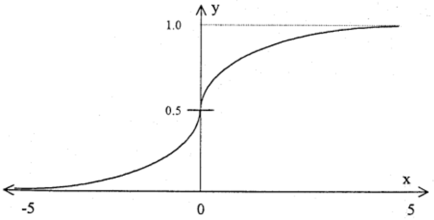

Figure 4: A sigmoid (S-shaped) function

Moreover, sigmoid functions are continuous and monatomic, and remain finite even as x approaches to±∞. Because they are monatomic, they also provide for more efficient network training. The selection of an activation function is depends upon the application to which the neural network used and also the level (in which layer) neuron. The activation functions that are mainly used are the sigmoid (unipolar sigmoidal), the hyperbolic tangent (bipolar sigmoid), radial basis function, hard limiter and linear functions. The sigmoid and hyperbolic tangent functions perform well for the prediction and the process-forecasting types of problems. However, they do not perform as well for classification networks. Instead, the radial basis function proves more effective for those networks, and highly recommended function for any problems involving fault diagnosis and feature categorization. The hard limiter suits well for classification problems. The linear function may be used at output layer in feed forward networks.

IV. Learning Mechanisms

In general the training of any artificial neural network has to use one of the following basic learning mechanisms. The basic learning mechanisms of neural networks include error-correction learning, memory-based learning, Hebbian learning, Competitive learning and Boltzmann learning.

V. Simulation Results

In this Section, one area and three area power system model of simulation results are presented. In order to verify the proposed topology, matlab simulation is carried out. The block diagram for single-area power system is shown in Fig. 5.1.

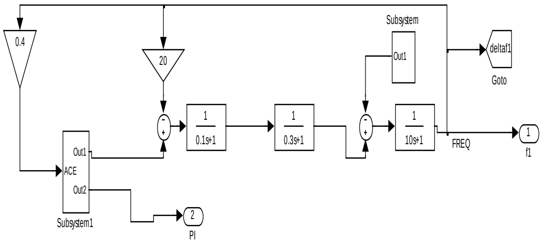

Figure 5: Simulink Block-diagram of a single-area power system model

Simulation results of a single area and multi area is considered in this section to analyze the efficacy of proposed system. The applied disturbances in the load model are shown in Figure 5.

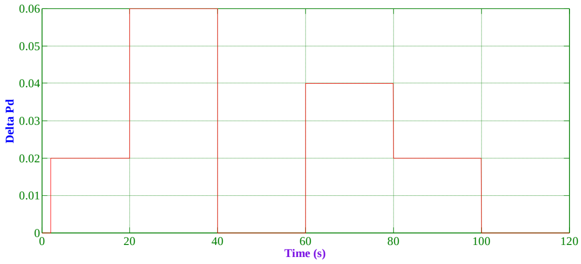

Figure 6: Load disturbances.

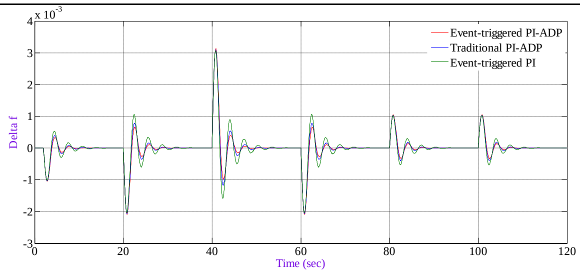

Figure 7: System frequency deviation with the Event triggered PI-ADP, traditional PI-ADP and event-triggered PI control in one-area power system

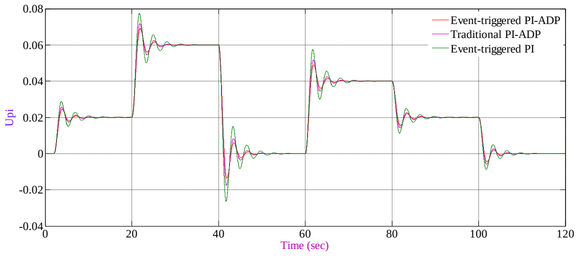

Figure 8: PI output with the Event triggered PI-ADP, traditional PI-ADP and event-triggered PI control in one-area power system

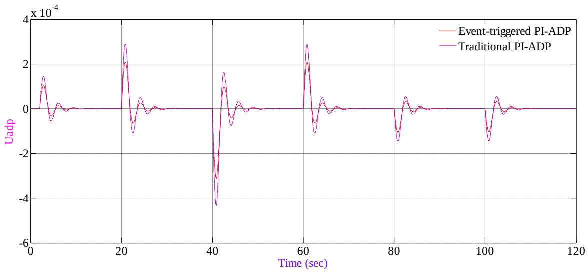

Figure 9: ADP output with Event triggered PI-ADP and traditional PI-ADP

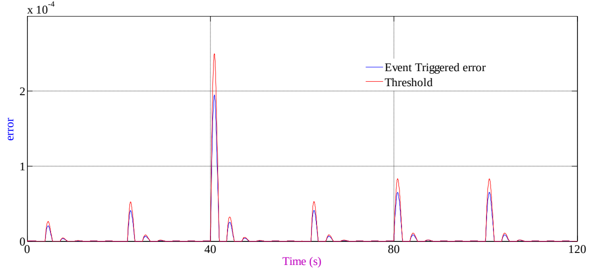

Figure 10: illustration of event triggered error and threshold of one area power system

Figure 7 shows the dynamics of the one area power system. In this it shows that the proposed method is effective when compared to event triggered and traditional PI-ADP. The output of PI controller of three different control methods is shown in Figure 8. ADP output with traditional PI-ADP and proposed event PI-ADP method is shown in Figure 9. The comparison between threshold and the event triggered error of proposed method is shown in Figure 10.

The parameters used in the test system are presented in Table 1.

Table 1: Simulation parameters

	Tg	Tt	M	D	β	1/R	T21= -T12	T31= -T13	T32= -T23
Area 1	0.1	0.3	10	1	0.4	20	-0.1986	-0.21480	-0.18300
Area2	0.17	0.4	12	1.5	0.4	20			
Area3	0.2	0.35	12	1.8	0.4	20			

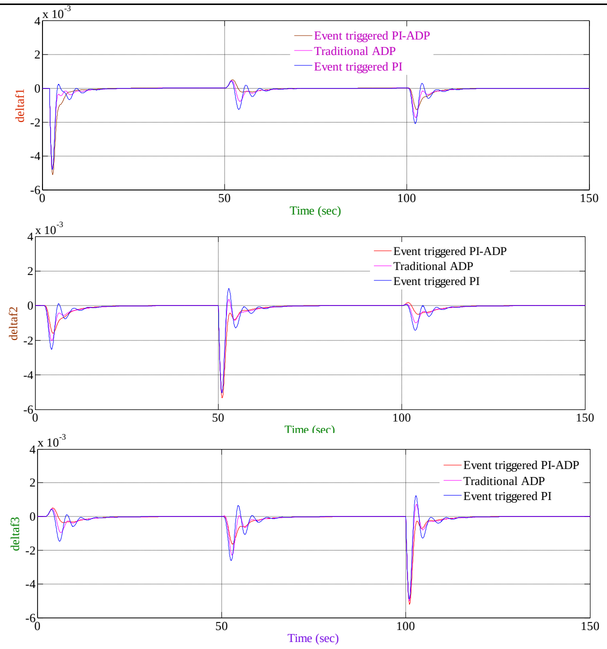

Figure 11: Illustration of load frequency deviation of 3-area power system

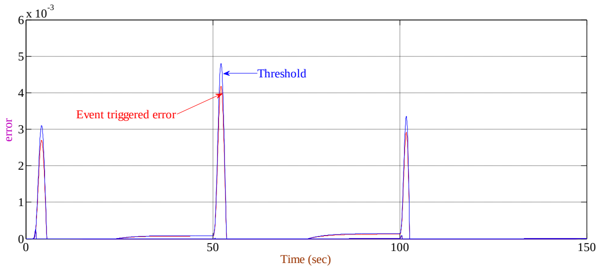

Figure 12: Illustration of event triggered error and threshold of 3-area power system

In the proposed event-triggered PI controller, weights of action network and the integral action are updated if the thresholds are exceeded. Therefore it reduces the calculation time and cost significantly.

VI. Conclusions

In this paper, an event-triggered method for LFC system with PI and supplementary ADP control is proposed. The proportional and integral actions of the PI controller used different thresholds for communication transmission, while the ADP controller with the actor-critic framework provided the supplementary signal for the PI controller in an aperiodic manner. By using the proposed design, the unnecessary events transmission was prevented. The comparative studies conducted demonstrated the proposed method could significantly save the computation cost without loss of control performance.

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