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A dynamic wavelet network based adaptive load frequency control in power systems

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Abstract

This paper proposes a new adaptive load frequency controller based on a 'dynamic wavelet network (DWN)' that has lag dynamics, non-orthogonal mother wavelets as activation function and interconnection weights. A DWN is connected between the two area power systems. The input signals of the DWN are the ACEs and their changes. The outputs of the DWN are the control signals for the two-area load frequency control. Adaptation is based on adjusting parameters of DWN for load frequency control. This is done by minimizing the cost functional of load frequency errors. The cost gradients with respect to the network parameters are calculated by adjoint sensitivity analysis. It is illustrated in simulations that this control approach is more successful than conventional integral controller for load frequency control in two area systems.

Keywords: Load frequency control; Dynamic wavelet network; Power system control; Wavelet; Intelligent control

1. Introduction

Frequency is one of the stability criteria for large-scale stability of power networks. For stable operation, constant frequency and active power balance must be provided. Frequency is depending on active power. Any change in active power demand/generation at power systems is reflected throughout the system by a change in frequency. In multiarea power networks, frequency variations can lead to serious stability problems. To improve the stability of the power networks, it is necessary to design a load frequency control (LFC) systems that control the power generation and active power at tie lines. In conventional LFC applications, proportional–integral controllers are the most commonly used ones.

However, several new controllers such as intelligent controllers and adaptive controllers were applied for LFC. Neural network is an important technology, which provide good results in LFC in power system, that are excellent at developing human-made systems that can perform the same type of information processing that our brain performs. For example, in Ref. [1] successful application of layered neural networks to nonlinear power systems control is presented. To overcome the frequency change problems due to load variations, a feed forward neural network is trained to control steam admission valve of the turbine that drives the generator thereby restoring the frequency to its nominal value. The study [2] aims to develop a nonlinear neural network controller to control the deviations in load frequency of a power system and to overcome the problems of simple neural networks such as long training times and requirements large number of neurons. Ref. [3] demonstrates the effectiveness of an adaptive optimal LFC system using an artificial neural network (ANN) in a computer simulation of the two-area LFC problem. This control system is based on the pattern recognition principle and in implementation on the parallel-distributed computational architecture of ANNs.

On the other hand, wavelet and multiresolution analysis are popular concepts which take place also in power systems

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such as: in the analysis for location of faults on transmission lines [4], short-term load forecasting [5], in the protection of generators against unbalanced currents [6], in classification of power system disturbances [7], in transient and harmonic studies [8], and in fault detection and classification in transmission lines [9,10]. 'Wavelet networks' [11,12], that combines ANN and wavelet technologies are also used for detection and classification of transients in power systems [13].

There exist problems in design and implementation of ANNs or similarly wavelet networks based control designs for dynamical systems due to a large parallel input vector consisting of a number of states or past samples of process data. This 'tapped delay line' approach has been proven successful in many applications, but it has the same drawbacks: the number of layers increases exponentially and parameters in ANNs can get larger values.

This paper proposes a new controller based on neural network and wavelet technologies for LFC to overcome these drawbacks and may also allow the effectiveness of wavelets in representation of nonstationary (transient) signals and the best advantages of each. A 'dynamical wavelet network (DWN)' [14,15] that contains dynamical elements such as delayers or integrators in their processing units is used in the adaptive controller design for LFC.

The organization of this paper is as follows: in Section 2, two area LFC strategies are summarized. Section 3 presents the architecture of a dynamic wavelet network and Section 4 describes the adaptive load frequency application we have considered; given a desired trajectory, a nonlinear optimization problem with dynamic equality constraints must be solved to determine appropriate values for the dynamic wavelet network parameters. Some simulation results of adaptive LFC of a power system with two areas are presented in Section 5.

2. Two-area load frequency control

In interconnected power networks with two or more areas, the generation within each area has to be controlled so as to maintain scheduled power interchange [16]. LFC

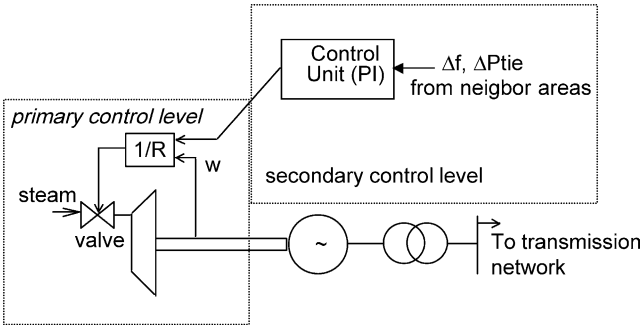

Fig. 1. Primary and secondary LFC in a power generation unit.

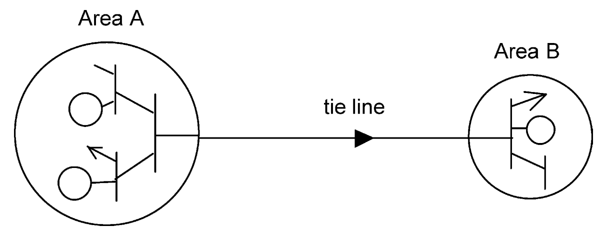

Fig. 2. Interconnection of two power areas by a tie line.

scheme have to be two main control loops. These are primary control and secondary control.

Primary control is achieved by turbine-governing system. Maintaining the frequency at scheduled value cannot be succeeded. A steady state frequency error can occur forever. So this loop does not enough for multiarea power systems. In multiarea power systems, frequency must be equal and must be hold a rated value at all areas. The second control loop is called supplementary control. This is realized in large power systems include two or more areas. Active power is controlled at the tie line between neighbor areas. Nowadays computer-aided controllers realize this action. Fig. 1 shows primary and secondary control loops.

Simulated system consists of an interconnection of two power areas. Both of them are connected each other by a tie line as shown in Fig. 2. Power flows throughout the tie line between areas. Control and balance of power flows at tie line are required for supplementary frequency control. Also damping of oscillations at tie line is another requirement for successful control of frequency and active power generation. For the simulations, linearized mathematical model given in Fig. 3 is used. This model includes classical

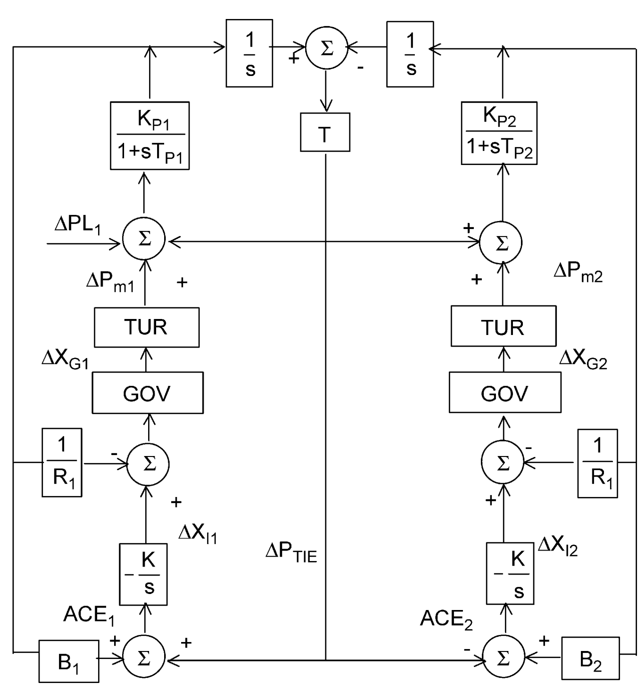

Fig. 3. Block diagram for two area power systems with supplementary control.