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Electric Power Systems Research 69 (2004) 169–177
ELECTRIC POWER SYSTEMS RESEARCH
www.elsevier.com/locate/epsr

Fuzzy based coordinated controller for power system stability and voltage regulation

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Received 13 February 2003; received in revised form 3 August 2003; accepted 21 August 2003

Abstract

This paper deals with the design of a fuzzy based coordinated controller to prevent an electric power system losing synchronism after a large sudden fault and to achieve good post-fault voltage level. The developed controller has a fuzzy logic unit (FLU) which, accepts change in terminal voltage and speed deviation as its inputs and generates the required weightage for the transient controller and voltage controller. The performance of the proposed controller is compared with those existing control switching coordinate controller. The simulation study is carried out for the configuration of a single machine infinite bus power system.

Keywords: Power system; Fuzzy logic; Coordinate control; Transient stability; Voltage regulation; State feedback control

1. Introduction

In this paper, we consider the problem of transient stability and voltage regulation of power system. Today's power systems are large in structure and complex to operate and control. The problems are due to a large disturbance on power system, change in load and due to inter-connections. A large disturbance on power system, occurring near the generator, causes vast changes in the load angle, power transfer and the generator voltage, which may cause machine to fall out of step. This category of stability is known as transient stability, which is a fast phenomenon occurring within a span of a few seconds. The purpose of implementing stability controllers in power system is to prevent such instances of a generator losing synchronism after a large disturbance.

The generator model in a power system essentially offers a nonlinear problem and it is difficult to a design good conventional controller. The controller design using linear control theory and linearized model around an operating point, has been studied widely [1,5,6,9,11,12]. But, in case of large disturbances, these linearized control techniques are not effective. The feedback linearization methods provide better performance than the linear control techniques for transient stability control. However, there is considerable variation in post-fault voltage from the pre-fault one, which is of concern. In view of practical point, voltage quality is an important parameter in power system operation. So the post-fault voltage should reach the pre-fault value as closely as possible. On this problem, a number of attempts have been made [3,11], in designing of voltage controllers, but they are sensitive to large disturbances. Wang and Hill [10], proposed a switching control strategy from the local control laws to enhance the transient stability and voltage regulation. The performance of this scheme essentially depends upon the selection of switching time. Guo et al. [3] proposed a global control scheme to achieve transient stability and pre-fault voltage level, although it is better than the switching control scheme, but it requires the design of some positive constants.

In this paper, we are proposing a fuzzy based coordinated control scheme, which decides the operating regions of local control laws, such as, transient controller and voltage controller. The proposed fuzzy system accepts two inputs, change in terminal voltage and speed deviation. The method overcomes the limitations of trial and error in selection of switching time with respect to following facts.

- A fuzzy system is designed, that gives the operating regions of local controllers.

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0378-7796/$ – see front matter
doi:10.1016/j.epsr.2003.08.008

- The proposed controller does not depend upon any of the constant parameters.
- The proposed method performs better than the existing method.

The proposed coordinated controller will have a fuzzy logic unit (FLU) and a control law, which generates the required weightages for the local controllers. The input signals of fuzzy system are first characterized by linguistic variables using fuzzy set notations. Then, a decision table is developed relating to the inputs and output of the controller. The performance of this controller is compared with switching control scheme.

The paper is organized as follows. Section 2 deals with the modeling of a single machine infinite bus power system. Section 3 discusses the switching coordinate controller. In Section 4, the fuzzy based coordinated controller is defined and its design procedure is discussed. The simulation results and discussion are presented in Section 5 and finally the conclusions are given in Section 6.

2. Dynamical model of power system

In the present paper, we consider a single machine infinite bus (SMIB) power system as shown in Fig. 1. A SMIB system qualitatively exhibits important characteristics of the behavior of multi-machine system, is relatively simple to study and analyse, and helps to bring out the performance advantage of intelligent coordinated controller.

The actual dynamic response of synchronous generator in a practical power system when a fault occurs is very complicated. However, the classical third-order dynamical model of power system has been used for designing the excitation controller and can be written as follows [3,11,13].

Mechanical equations:

$$\dot{\delta} = \omega \tag{1}$$

$$\dot{\omega} = \frac{-D}{2H}\omega + \frac{\omega_0}{2H}(P_m - P_e) \tag{2}$$

Generator electrical equations:

$$\dot{E}'_q = \frac{1}{T'_{do}}(E_f - E_q) \tag{3}$$

Electrical equations:

$$E_q = \frac{x_{ds}}{x'_{ds}}E'_q - \frac{x_d - x'_d}{x'_{ds}}V_s\cos\delta \tag{4}$$

$$P_e = \frac{V_s E_q}{x_{ds}}\sin\delta \tag{5}$$

$$I_q = \frac{V_s}{x_{ds}}\sin\delta = \frac{P_e}{x_{ad}I_f} \tag{6}$$

$$Q_e = \frac{V_s}{x_{ds}}E_q\cos\delta - \frac{V_s^2}{x_{ds}} \tag{7}$$

$$E_q = x_{ad}I_f \tag{8}$$

$$E_f = k_c u_f \tag{9}$$

$$V_t = \frac{1}{x_{ds}}[x_s^2E_q^2 + V_s^2x_d^2 + 2x_sx_dx_{ds}P_e\cot\delta]^{1/2} \tag{10}$$

$$x_{ds} = x_d + x_T + \tfrac{1}{2}x_l \tag{11}$$

$$x'_{ds} = x'_d + x_T + \tfrac{1}{2}x_l \tag{12}$$

$$x_s = x_T + \tfrac{1}{2}x_l \tag{13}$$

The above notation for the variables and parameters described are standard, and their description is given in Appendix A. For more details, the readers are suggested also to refer [14]. Now, the problem is to design a control signal u_f, which is used to generate E_f so as to maintain the transient stability and voltage regulation.

3. Switching coordinate controller

As discussed in [10], a nonlinear coordinate control scheme was proposed where a switching strategy is used between the different local control actions to enhance the transient stability and achieve voltage regulation. We now summarize the local control laws such as direct feedback linearization (DFL) nonlinear controller and voltage controller.

3.1. Direct feedback linearization (DFL) nonlinear controller

Wang et al. have proposed in [8,9] a method of DFL to design a nonlinear controller for transient stability. The key feature of the direct feedback linearization is that the

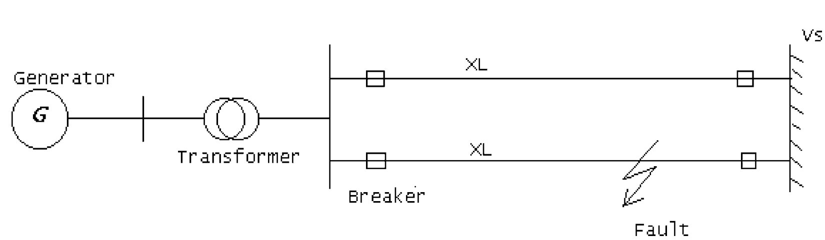

Fig. 1. A single machine infinite bus power system.