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A fuzzy gain scheduling PI controller application for an interconnected electrical power system

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Abstract

In this study, a fuzzy gain scheduled proportional and integral (FGPI) controller was developed to regulate and to improve the frequency deviation in a two-area electrical interconnected power system. Also, a conventional integral (I), a conventional proportional and integral (PI), and a fuzzy logic (FL), controllers were used to control the same power system for the performance comparison. Two performance criteria were utulized for the comparison. First, settling times and overshoots of the frequency deviation were compared. Later, the absolute error integral analysis method was calculated to compare all the controllers. All the models were simulated by Matlab 6.0-Simulink software. The simulation results show that the FGPI controller developed in this study performs better than the other controllers with respect to the settling time and overshoot, and absolute error integral of the frequency deviation.

Keywords: Load–frequency control; Power system; Fuzzy logic controller

1. Introduction

The behaviour of dynamic systems can be affected by disturbances and changes at the operating point. This is also a characteristic of a power system [1]. The operation of the interconnected electric power system has progressed over the years [2]. Load–frequency control is an important problem for the power systems because of supplying reliable electric power with good quality. Additionally, this is a technical requirement for the proper operation of an interconnected power system. The goal of the LFC is to maintain zero steady state errors in a multi-area interconnected power system [3]. Also, the power system should fulfill the requested dispatch conditions.

Several studies have been done in the past about the load–frequency control in interconnected power systems. In the literature, a number of control strategies have been suggested based on the conventional linear control theory. To some investigators, variable structure system control [4,5] maintains stability of system frequency. However, this method needs some information for system states, which are very difficult to obtain completely. Also, some described a minimum variance strategy for load frequency control of interconnected power systems [6]. According to [7], conventional PID control schemes will not reach a high performance. Since the dynamics of a power system even for a reduced mathematical model is usually non-linear, time-variant and governed by strong cross-couplings of the input variables the controllers have to be designed with special care [8]. Thus, a gain scheduling controller can be used for non-linear systems [3]. In this method, control parameters can be changed very quickly because parameter estimation is not required. It is easier to realize as compared with automatic tuning or adaptation of controller parameters. However, the transient response can be unstable because of abruptness in system parameters. Besides, it is impossible to obtain accurate linear time invariant models at variable operating points [3]. Some fuzzy gain scheduling of PI controllers have been

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proposed to solve such problems in power systems [3] and [9] who developed different fuzzy rules for the proportional and integral gains separately. Fuzzy logic control presents a good tool to deal with complicated, non-linear and indefinite and time-variant systems [10]. In this paper, the rules for the gains are chosen to be identical in order to improve the system performance. The comparison of the proposed FGPI, the conventional PI and I controllers, and the fuzzy logic controller suggests that the overshoots and settling time with the proposed FGPI controller are better than the rest.

2. Interconnected two-area electrical power system

Interconnected power systems naturally consist of complex and multi-variable structures with many different control blocks. They are usually non-linear, time-variant and/or non-minimum phase systems [11]. Power systems are divided into control areas connected by tie lines. In each control area, the generators are supposed to constitute a coherent group. It means that the movements of their rotors are closely related [12]. Experiments on the power systems show that tie-line power flow and frequency of the area are affected by the load changes at operating point. Therefore, it can be considered that each area needs its system frequency and tie-line power flow to be controlled [3]. Additionally, it is desired that transient frequency oscillations without a large increase in the magnitude and speed control must be reduced. Also, the number of LFC signals sent to power systems without compromising other objectives must be reduced [13].

Since the small load changes are affected by the active power, and the frequency, while reactive power is only affected by the magnitude of the bus voltage, a separate control loop can be used for frequency control. Generally, the load–frequency control is accomplished by two different control actions in interconnected two-area power systems: (a) the primary speed control and (b) supplementary or secondary speed control actions. The primary speed control performs the initial vulgar readjustment of the frequency. By its actions, the various generators in the control area track a load variation and share it in proportion to their capacities. The speed of the response is only limited by the natural time lags of the turbine and the system itself. Depending upon the turbine type the primary loop typically responds within 2–20 s. The supplementary speed control takes over the fine adjustment of the frequency by resetting the frequency error to zero through an integral action. The relationship between the speed and load can be adjusted by changing a load reference setpoint input. In practice, the adjustment of the load reference setpoint is accomplished by operating the speed changer motor. The output of each unit at a given system frequency can be varied only by changing its load reference, which in effect moves the speed-droop characteristic up and down. This control is considerably slower and goes into action only when the primary speed control has done its job. Response time may be of the order of one minute. The speed-governing system is used to adjust the frequency. Governors adjust the turbine valve/gate to bring the frequency back to the nominal or scheduled value. Governor work satisfactorily when a generator is supplying an isolated load or when only one generator in a multigenerator system is required to respond to the load changes. For power and load sharing among generators connected to the system, speed regulation or droop characteristics must be provided. The speed-droop or regulation characteristic may be obtained by adding a steady-state feedback loop around the integrator.

An uncontrolled two-area interconnected power system is shown in Fig. 1, where f is the system frequency (Hz), R_i reg-

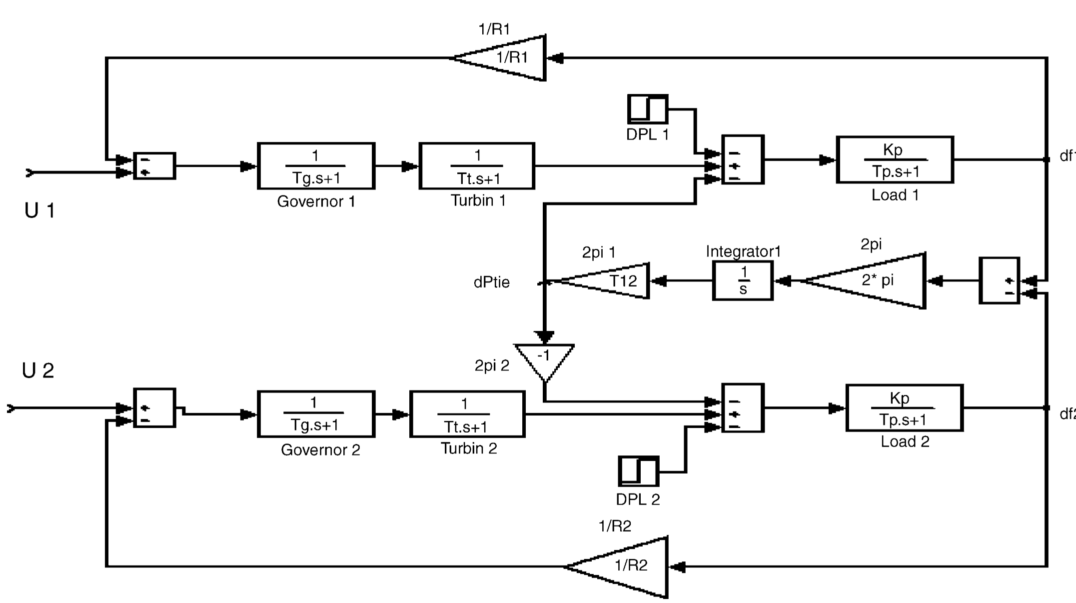

Fig. 1. A two-area interconnected power system ($DP_{1,1,2}$: load demand increments).