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Robust decentralized load frequency control of interconnected power system with Generation Rate Constraint using Type-2 fuzzy approach

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ABSTRACT

The Load Frequency Control (LFC) problem has been a major subject in electrical power system design/operation. LFC is becoming more significant recently with increasing size, changing structure and complexity in interconnected power systems. In practice LFC systems use simple Proportional Integral (PI) controllers. As the PI control parameters are usually tuned, based on classical approaches. Moreover, they have fixed gains; hence are incapable of obtaining good dynamic performance for a wide range of operating conditions and various load changes, in multi-area power system. Literature shows that fuzzy logic controller, one of the most useful approaches, for utilizing expert knowledge, is adaptive in nature and is applied successfully for power system stabilization control. This paper proposes a Type-2 (*T*2) fuzzy approach for load frequency control of two-area interconnected reheat thermal power system with the consideration of Generation Rate Constraint (GRC). The performance of the Type-2 (*T*2) controller is compared with conventional controller and Type-1 (*T*1) fuzzy controller with regard to Generation Rate Constraint (GRC). The system parametric uncertainties are verified by changing parameters by 40% simultaneously from their typical values.

1. Introduction

With an increasing demand for electric power, the electric power system becomes more and more complicated. Therefore the supply of electric power with stability and high reliability is required. The power system operates in normal state which is characterized by constant frequency and voltage profile with certain system reliability. For a successful operation of power system under abnormal conditions, mismatches have to be corrected via supplementary control [1]. Automatic Generation Control (AGC) or load frequency control [2,15] is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. An interconnected power system can be considered as being divided into control areas. These control areas are connected by the tie lines. In each control area, all generators are assumed to form a coherent group. The power system is subjected to local variations of random magnitude and duration. For satisfactory operation of a power system the frequency should remain nearly constant. The frequency of a system depends on active power balance. As frequency is a common factor throughout the system, a change in active power demand at one point is reflected throughout the system [12].

A number of control strategies have been employed in the design of load frequency controllers [2,14,16,20,21], in order to achieve better dynamic performance. Among the various types of load frequency controllers, the most widely employed is the conventional proportional integral (PI) controller [11,13]. Conventional controller can be simple for implementation but takes more time for control and gives large frequency deviation. A number of state feedback controllers based on linear optimal control technique have been proposed to achieve better performance [10]. Fixed gain controllers are designed at nominal operating conditions and they fail to provide best control performance over a wide range of operating conditions. Therefore, to keep the system performance near its optimum, it is desirable to track the operating conditions and use updated parameters to compute the control. Adaptive controllers with self-adjusting gain settings have been proposed for LFC [13]. Literature survey shows that only a few investigations have been carried out using LFC. The objective of this research is to investigate the load frequency control and inter-area tie-power control problem for a multi-area power system taking into consideration the uncertainties in the parameters of the system. Power system is a highly non-linear and uncertain system, to take care of these uncertainties many authors have proposed fuzzy logic based controllers to power systems [1,4,9,12,13,19]. This fuzzy logic, also called as Type-1 fuzzy, can further be modified to Type-2 fuzzy by giving grading to the membership functions which are themselves fuzzy. Or in other words, in Type-2 fuzzy set,

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at each value of the variable the membership is a function but not just a point value. Therefore, a Type-2 fuzzy set can be visualized as a three dimensional set. The advantage of the third dimension gives an extra degree of freedom for handling uncertainties. Taking this feature into consideration, a robust decentralized control scheme is designed using Type-2 fuzzy logic [17,18]. The proposed controller is simulated for a two-area power system in the presence of Generation Rate Constraint (GRC) for different operating conditions and was compared with conventional controller and Type-1 fuzzy controller [4]. Results of simulation show that the *T*2 fuzzy controllers guarantee the robust performance for a wide range of operating conditions.

2. System model

The detailed block diagram modeling of two area reheat thermal power system with the consideration of Generation Rate Constraint (GRC), for load frequency control, is investigated in this study as shown in Fig. 1 with Area Control Error (ACE) and its derivative as the inputs to the controllers [10]. The parameters of the two areas is given in Table 1. In a power system having steam plants, power generation can change only at a specified maximum rate. As described in Fig. 2, by adding limiters to the governors, it is possible to restrict the generation rate for the steam plants. A typical value of the Generation Rate Constraint (GRC) for thermal units is considered as 3%/min. Two limiters, bounded by ±0.0005 are used within the automatic generation controller to prevent the excessive control action. The generation rate constraints for all the areas are taken into account by adding limiters to the turbines as shown in Fig. 2.

Table 1
Parameters of the two areas for the Operating Point-2.

Area-1		Area-2	
T_{G1}	0.042	T_{G2}	0.042
T_{T1}	0.112	T_{T2}	0.112
T_{12}	0.763	T_{12}	0.763
T_{P1}	20	T_{P2}	20
K_{P1}	120	K_{P2}	120
R_1	3.36	R_2	3.36
B_1	0.61	B_2	0.61
*K*p	0.6	*K*p	0.6
*K*i	0.8	*K*i	0.8

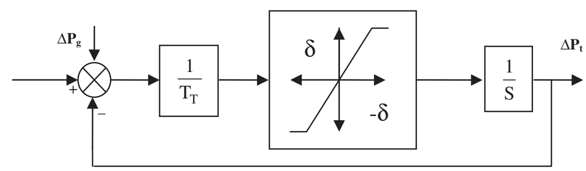

Fig. 2. Nonlinear turbine model with GRC.

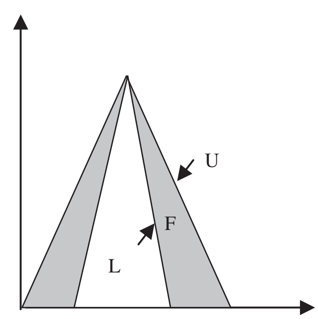

Fig. 3. Membership function interval Type-2 Fuzzy Logic Set.

3. Type-2 (*T*2) fuzzy logic controllers

A fuzzy system that uses Type-2 fuzzy sets and/or fuzzy logic and inference is called a Type-2 (*T*2) fuzzy system. In contrast, a fuzzy system that employs ordinary fuzzy sets, logic, and inference is called Type-1 (*T*1) fuzzy system [8,9]. *T*1 fuzzy systems, especially fuzzy controllers and fuzzy models, have been developed and applied to practical problems. A Type-1 fuzzy set (*T*1 FS) has a grade of membership that is crisp, whereas a Type-2 fuzzy set (*T*2 FS) has a grade of membership that is fuzzy, so *T*2 FS are 'fuzzy–fuzzy' sets. One way of representing the fuzzy membership of fuzzy sets is to use the Footprint Of Uncertainty (FOU), which is a 2-D representation, with uncertainties about the left and pairs of the left side of the membership function and also about the right and pair of the right side of the membership function. Operation of Type-2 fuzzy set is identical with the operation of Type-1 fuzzy

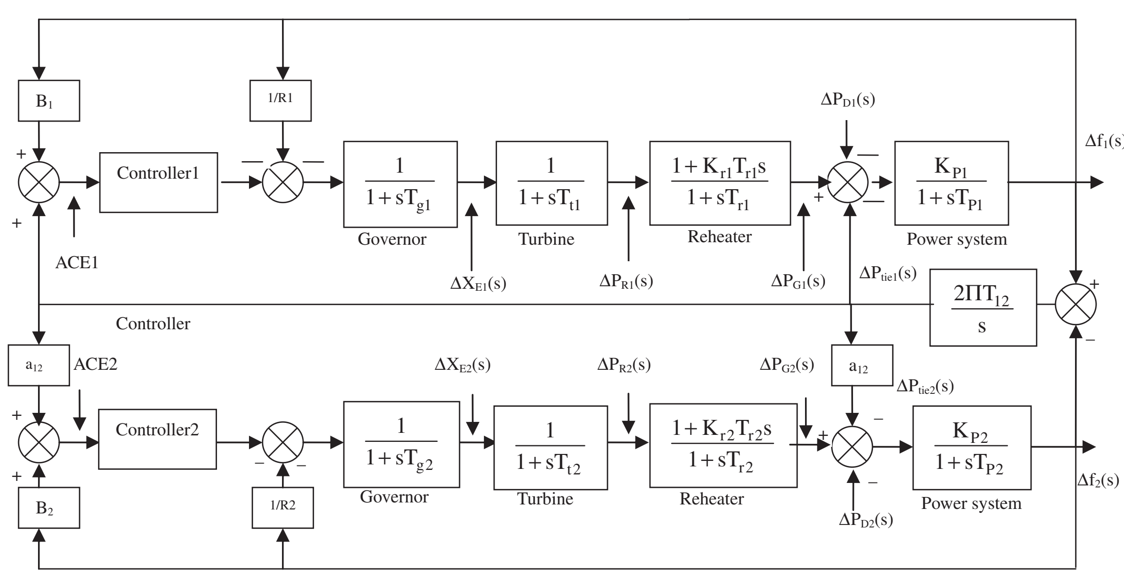

Fig. 1. Block diagram of Two-Area Power System.