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Load Frequency Control of an Interconnected Reheat Thermal system using Type-2 fuzzy system including SMES units

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ABSTRACT

The transient behavior of many large scale systems is heavily influenced by perturbations and in particular, usually, due to changes in operating points. Load Frequency Control (LFC) in power systems is very important in order to supply reliable electric power with good quality. The goal of LFC is to maintain zero steady state errors for frequency deviations in each control area. Several control strategies, such as classical control, optimal control, suboptimal control, adaptive control, variable structure control etc. have been employed in the past to explore an optimum controller for LFC. In practice LFC systems use simple Proportional Integral (PI) controllers, Proportional Integral Derivative (PID) controllers etc. This paper presents a method based on Type-2 Fuzzy System (T2FS) for Load frequency control (LFC) of power systems including Superconducting magnetic energy storage (SMES) units of a two-area interconnected reheat thermal system. This paper proposes a Type-2 (T2) fuzzy approach for load frequency control of two-area interconnected reheat thermal power system with the consideration of Generation Rate Constraint (GRC), Boiler Dynamics (BD) and SMES. The salient advantage of this controller is its high insensitivity to large load changes and plant parameter variations even in the presence of non-linearities. The proposed method is tested on a two-area power system to illustrate its robust performance with various area load changes. The performance of the Type-2 (T2) fuzzy controller is compared with optimal PID (Khamsum's optimal PID) controller and Fuzzy PI Controller (Type-1 Fuzzy) controller in the presence of GRC, BD and SMES. Simulation results confirm the high robustness of the proposed SMES controller with small power capacity against various disturbances and system uncertainties in comparison with SMES in the previous research.

1. Introduction

Large scale power systems are normally divided into control areas based on the principle of coherency. The coherent areas are interconnected through tie lines which are used for contractual energy exchange between areas and provide inter-area support during abnormal operations [15] Automatic Generation Control (AGC) or Load Frequency Control [3,9] is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. Load fluctuations such as the generation outages, cause the system frequency to decay from the desired value. To ensure the quality of the power supply, it is necessary to regulate the generator loads depending on the optimal frequency value with a proper LFC design. Therefore, in designing the controller, the non-linear effects due to the physical components of the system, the load change inherent Characteristics and the parametric uncertainty and disturbances should be taken into account [21,31]. 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 through out the system [19].

In the past decades, fuzzy logic controllers (FLCs) have been successfully developed for analysis and control of non-linear systems [5,30,10]. The fuzzy reasoning approach is motivated by its ability to handle imperfect information, especially uncertainties in available knowledge. Stimulated by the success of FLCs, Talaq and Al-Basri [16], Yesil et al. [7] and Chang and Fu [4] proposed different adaptive fuzzy scheduling schemes for conventional PI andor PID controllers. These methods provide good performances but the system transient responses are relatively oscillatory.

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

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authors have proposed fuzzy logic based controllers to power systems [1,11,13,18–20,26]. 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 sets, 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. 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 [17,22,23]. The proposed controller is simulated for a two-area power system in the presence of Generation Rate Constraint (GRC), Boiler Dynamics (BD) including Superconducting Magnetic Energy Storage (SMES) units was compared with Optimal PID (Khamsum's PID) [2] controller and Type-1 fuzzy controller [11]. Results of simulation show that the T2 fuzzy controllers guarantee the robust performance.

2. Power system modelling and problem formulation

Usually, a large scale power system consists of a number of interconnected control areas, which are connected by tie-lines power. There are different complicated non-linear models for large scale power systems [29]. However, for the design of LFC a simplified and linearized model is usually used [12]. The detailed power system modeling of two area reheat thermal power system including, Generation Rate Constraint (GRC), Boiler Dynamics (BD) and SMES units for load frequency control is investigated in this study as shown in Fig. 1 with Area Control Error (ACE) and its derivative are given as the inputs to the controllers [14]. Both areas have installed SMES1n and SMES2 in order to stabilize frequency oscillations. The detailed block diagram of the interconnected power system model is shown in Fig. 2. The Parameters of the two areas is given in Table 1. Modelling of Speed Governors and turbines are discussed in [28]. In a power system having steam plants, power generation can change only at a specified maximum rate. As described in Fig. 3, by adding limiters to the governors can 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. 3.

Fig. 4 shows the model to represent the boiler dynamics [8]. Boiler is employed to generate steam under pressure. Here, drum

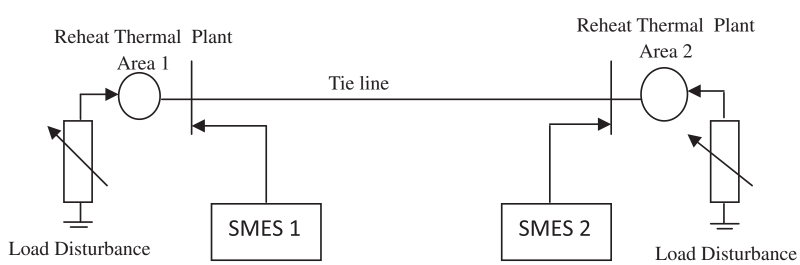

Fig. 1. Two-area interconnected power system including SMES units.

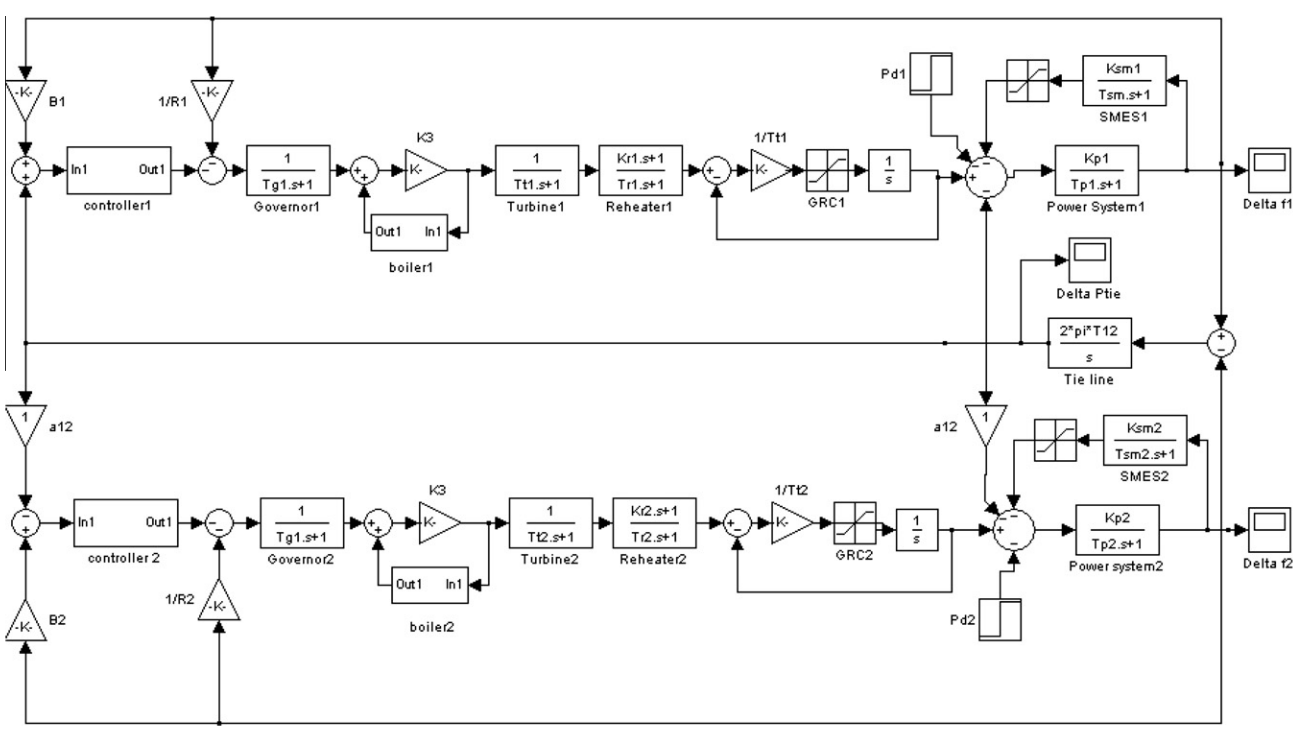

Fig. 2. Block diagram of two-area interconnected system.