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# Robust load-frequency control for uncertain nonlinear power systems: A fuzzy logic approach

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**Abstract**

A new robust load-frequency control (LFC) methodology is proposed for controlling uncertain nonlinear power systems. Critical nonlinearity in the power system—the valve position limit on the governor, and the parametric uncertainty are concerned. The Takagi–Sugeno fuzzy model of the power system under consideration is first constructed to design the robust fuzzy-model-based LFC. Sufficient conditions for the robust asymptotic convergence of the frequency deviation are then provided in terms of linear matrix inequalities. Boundedness of the other system variables is also studied to ensure justifiable grounds for use of the proposed LFC method. Simulation results convincingly validate the effectiveness of the novel LFC design scheme and the theoretical discussions, which give a positive answer to the quality control of the electric energy.


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## 1. Introduction

The more industry and commerce grow, the more reliable electric energy with good quality, which is evaluated in terms of a frequency and a rated power, etc., is required. The introduction of the deregulation policy to power system operation makes the load-frequency control (LFC) be refocused because the repeatedly deregulated power generation under the inevitable electricity market game provokes large deviation from the standard frequency of power systems. During the last three decades, various control strategies for LFC have been proposed [1–6]. In the literature, it is commonly conjectured that, since a normally operated power system is only exposed to small change in the vicinity of the load demand, a linearized model is enough to express the dynamic behavior of the system around the operating point.

However, when a sudden large change in the load demand occurs by deregulated operations, frequent on–off controls of large capacity load units may cause large amount of overshoot or long-lasting oscillation on the valve position of the governor [4]. Therefore, it is necessary to consider the limits on the valve position for avoiding large overshoot and oscillation, or due to the mechanical characteristics, which means that the system is nonlinear. Hence, contrary to the previous theoretical point of view, the linearized model is not a good representation of the power system. Furthermore, existing LFC schemes based on the linearized model may not effectively achieve the LFC objective. So far, there have been few research works tackling on the LFC issue considering the valve position limits. Recently, Moon et al. [4,5] studied an LFC scheme considering the valve position limits. However, they used it in simulation only. This nonlinearity must be taken into theoretical consideration in the LFC design procedure to promise high power quality.

On the other hand, it is occasionally very difficult to obtain the accurate values of some parameters of the power systems. This is due to the inaccurate measurement or on-line variation of parameters, and definitely influences on the stability of the power system. Therefore, robustness against the parametric uncertainties should also be secured in the LFC problem.

Nonlinearities from the valve position limits and the parametric uncertainties weigh the stability analysis and the LFC design down with additional difficulties. Until now, various control techniques have been developed for uncertain nonlinear systems. Among them, the Takagi–Sugeno (T–S) fuzzy-model-based control technique is very popular today because it is highly regarded as a powerful resolution to bridge the gap between the fuzzy logic