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Bilateral based robust load frequency control

Hassan Bevrani [a,*], Yasunori Mitani [b], Kiichiro Tsuji [a], Hossein Bevrani [c]

[a] *Department of Electrical Engineering, Osaka University, 2-1 Yamada-Oka, Suita, Osaka 565-0871, Japan*
[b] *Department of Electrical Engineering, Kyushu Institute of Technology, Kyushu, Japan*
[c] *Department of Mathematical Statistics, Moscow State University, Moscow, Russia*

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Abstract

Load frequency control (LFC) has been one of the major subjects in electric power system design/operation and is becoming much more significant today in accordance with increasing size and the changing structure and complexity of interconnected power systems. In practice, power systems use simple proportional-integral (PI) controllers for frequency regulation and load tracking. However, since the PI controller parameters are usually tuned based on classical or trial and error approaches, they are incapable of obtaining good dynamical performance for a wide range of operating conditions and various load changes scenarios in a restructured power system.

This paper addresses a new decentralized robust LFC design in a deregulated power system under a bilateral based policy scheme. In each control area, the effect of bilateral contracts is taken into account as a set of new input signals in a modified traditional dynamical model. The LFC problem is formulated as a multi-objective control problem via a mixed H_2/H_∞ control technique. In order to design a robust PI controller, the control problem is reduced to a static output feedback control synthesis, and then, it is solved using a developed iterative linear matrix inequalities algorithm to get a robust performance index close to a specified optimal one. The proposed method is applied to a 3 control area power system with possible contract scenarios and a wide range of load changes. The results of the proposed multi-objective PI controllers are compared with H_2/H_∞ dynamic controllers.

* Corresponding author. Tel.: +81 6 6879 7712; fax: +81 6 6879 7713.
E-mail address: bevrani@polux.pwr.eng.osaka-u.ac.jp (H. Bevrani).

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1. Introduction

In a deregulated environment, load frequency control (LFC) as an ancillary service acquires a fundamental role to maintain the electrical system reliability at an adequate level. That is why there has been increasing interest for designing load frequency controllers with better performance during recent years, and several optimal and robust control strategies have been developed for LFC synthesis according to the changing environment of power system operation under deregulation. Some of them suggest complex state feedback or high order dynamic controllers, which are not practical for industry practices. Usually, the existing LFC in practical power systems uses proportional-integral (PI) type controllers that are tuned online based on classical and trial and error approaches. Furthermore, in most published reports, only one single norm is used to capture design specifications, while meeting all LFC design objectives by a single norm-based control approach with regard to the increasing complexity and changing power system structure is difficult.

Naturally, LFC is a multi-objective control problem. LFC goals, i.e. frequency regulation and tracking load changes and maintaining tie line power interchanges to specified values in the presence of generation constraints and dynamical model uncertainties, determines the LFC synthesis as a multi-objective control problem. Therefore, it is expected that an appropriate multi-objective control strategy could be able to give a better solution for this problem [1]. It is well known that each robust method is mainly useful to capture a set of special specifications. For instance, the H_2 tracking design is more adapted to deal with transient performance by minimizing the linear quadratic cost of tracking error and control input, but the H_∞ approach (and μ as a generalized H_∞ approach) is more useful in holding closed loop stability in the presence of control constraints and uncertainties. While the H_∞ norm is natural for norm bounded perturbations, in many applications the natural norm for the input–output performance is the H_2 norm.

In this paper, the LFC synthesis problem is formulated as a mixed H_2/H_∞ static output feedback (SOF) control problem to obtain a desired PI controller. An iterative linear matrix inequalities (ILMI) algorithm is developed to compute the PI parameters. The model uncertainty in each control area is covered by an unstructured multiplicative uncertainty block. The proposed strategy is applied to a three control area example. The designed robust PI controllers, which are ideally practical for industry, are compared with the mixed H_2/H_∞ dynamic output feedback controllers (using the general LMI technique [2]). The results show the PI controllers guarantee the robust performance for a wide range of operating conditions as well as H_2/H_∞ dynamic controllers. The preliminary steps of this work are given in Refs. [1,3].

This paper is organized as follows: the generalized LFC model in a bilateral based power system market is given in Section 2. Section 3 presents the problem formulation via a mixed H_2/H_∞ technique for a given control area. The PI based multi-objective LFC design using a developed iterative LMI (ILMI) is given in Section 4. The proposed methodology is applied to a 3 control area power system as a case study in Section 5. Finally, to demonstrate the effectiveness of the proposed method and to compare with mixed H_2/H_∞ dynamic output feedback control design, some simulation results are given in Section 6.