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Decentralized biased dual mode controllers for load frequency control of interconnected power systems considering GDB and GRC non-linearities

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Abstract

A new design of decentralized biased proportional and integral dual mode controllers for load frequency control of interconnected power systems considering governor deadband (GDB) and generation rate constraint (GRC) non-linearities is presented in this paper. Any optimum controller selected for load frequency control of interconnected power systems should not only stabilize the power system but also reduce the system frequency and tie line power oscillations and settling time of the output responses. Hence, a simple design of biased controllers with proportional and integral modes using an integral square error (ISE) criterion and maximum stability margin (MSM) criterion based on minimum settling time for interconnected power systems are discussed. These controllers are designed and implemented in a two area interconnected thermal power system with GDB and GRC non-linearities. The proposed controller is found to be simple in structure and easy for implementation. The closed loop system was simulated, and the frequency and tie line power deviations resulting from a step load disturbance are presented. Comparison of the performances of the proportional plus integral biased controller and the proposed proportional (P) and integral (I) biased dual mode controllers shows that the system performance is improved significantly with the proposed controllers. Further, it is also shown that the biased dual mode controllers are found to be less sensitive to changes in system parameters.

Keywords: Load frequency control; Governor deadband; Generation rate constraint; Dual mode controller; Interconnected power systems

1. Introduction

The load frequency control (LFC) problem is of vital importance for power engineers because of the large size and complexity of interconnected systems. Unpredictable changes in the load demand occur continuously in interconnected power systems. These changes in load always cause a mismatch between power generation and consumption, which adversely affects the quality of generated power in several ways. Among these, the frequency deviation and the deviation in scheduled tie line power are the most important. Therefore, the objective of LFC in interconnected power systems is twofold: minimizing the transient errors in the frequency and the scheduled tie line power and ensuring zero steady state errors of these two quantities.

There has been considerable effort devoted to LFC of interconnected power systems in the literature [1]. A number of control strategies have been employed in the design of load frequency controllers in order to achieve better dynamic performance. The application of a decentralized control strategy to the LFC problem has found wide acceptance because of its role in eliminating some of the

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Nomenclature

f	area frequency in Hz
P_{ei}	total power exchange of area i in p.u. MW/Hz
P_{Di}	area real power load in p.u. MW
P_{ci}	area speed changer output in p.u. MW
X_E	governor valve position in p.u. MW
P_G	mechanical (turbine) power output in p.u. MW
k_p	gain associated with transfer function of area in Hz/p.u. MW
T_P	area time constant in seconds
R	steady state regulation of governor in Hz/p.u. MW
T_g	time constant of governing mechanism in seconds
k_r	reheat coefficient of steam turbine
T_r	reheat time constant of steam turbine in seconds
T_t	time constant of steam turbine in seconds
β_i	frequency bias constant in p.u. MW/Hz
N_1, N_2	Fourier series second and third term constant coefficients respectively
N	number of interconnected areas
Δ	incremental change of variable
s	Laplace frequency variable

Superscript

T	transpose of matrix

Subscript

i, j	area indices (i, j = 1, 2,..., N)

problems associated with other centralized or multi-level control strategies. The main desirable features of decentralized LFC are the following:

(i) It should provide better transient response and improved stability margin.
(ii) The area control error (ACE) should be zero at steady state, i.e. frequency and tie line power deviation should be zero under steady state.
(iii) The control law should be independent of disturbance.
(iv) Each area controller should use its own area output information.

A number of decentralized control methods have been employed in the design of decentralized LFC in order to achieve better dynamic performance [1–8]. It is a well accepted fact that the classical conventional solution of this problem has been one of the first practical applications of decentralized control of large scale dynamic systems. This solution, heuristic in nature, was so successful that few modifications have been added since the initial approaches were performed [3]. These conventional controllers for LFC are still popular with the industries because of their simplicity, easy realization, low cost, robustness and decentralized nature of the control strategy. It has been demonstrated that there is no significant advantage in using more complex controllers over using conventional controllers [9,10]. The conventional and most widely used control by the power industry is the classical proportional plus integral (PI) control. Generally, the conventional approach using PI controllers results in relatively large overshoots in the transient frequency and tie line power deviations. Furthermore, the settling time of the system frequency and the tie line power deviations are also relatively long [11]. Therefore, a design of decentralized proportional plus integral biased controllers has been presented to obtain better transient as well as steady state responses of the output and improvement in the stability of the system [12]. These biased controllers are designed based on a compromise between the controllers designed on the basis of the integral square error (ISE) criterion and the maximum stability margin (MSM) criterion. This has been applied to an interconnected power system without considering the system non-linearities such as GDB and GRC.

However, in the simultaneous presence of important system non-linearities like governor deadband (GDB) and generation rate constraints (GRC), these controllers do not provide any significant improvement in the system performance [13] but exhibit relatively poor dynamic performance as evidenced by large overshoot and transient frequency and tie line power oscillations. Hence, it becomes important to consider these system non-linearities while designing the controllers. It is well known that if the control law employs integral control, the system has no steady state error. However, it increases the type of the system by one. Therefore, the response with integral control is slow during a transient period. In the absence of integral control, the gain of the closed loop system can be increased significantly, thereby improving the transient response. Since the proportional plus integral control does not eliminate the conflict between static and dynamic accuracy [14,15], this conflict must be resolved by employing the principle of dual mode control.

Therefore, this paper proposes a new design of decentralized biased dual mode controllers for LFC of interconnected power systems considering GDB and GRC non-linearities. This has been applied to a two area interconnected thermal power system. The computer simulation results prove that the proposed control is effective and provides significant improvement in system performance. Moreover, it has also been observed that the proposed controllers are less sensitive under system parameter variations.