Multiple models and neural networks based decoupling control of ball mill coal-pulverizing systems

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**ABSTRACT**

Using a ball mill coal-pulverizing system as a motivating/application example, a class of complex industrial processes is investigated in this paper, which has strong couplings among loops, high nonlinearities and time-varying dynamics under different operation conditions. Focusing on such processes, an intelligent decoupling control method is developed, where the effects of nonlinearities are dealt with by neural network compensations and coupling effects are handled by specifically designed decoupling compensators, while the effect of time-varying dynamics is treated by a switching mechanism among multiple models. The stability and convergence of the closed-loop system are analyzed. The proposed method has been applied to the ball mill coal-pulverizing systems of 200 MW units in a heat power plant in China. Application results show that the system outputs are maintained in desired scopes, the electric energy consumption per unit coal has been reduced by 10.3%, and the production rate has been increased by 8%.

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1. Introduction

For many multivariable industrial processes, satisfactory control performance can generally be achieved by using decentralized control [1]. However, there is a class of complex industrial processes which has strong couplings between loops, high nonlinearities and time-varying dynamics with different operation conditions. Even if the choice of pairings is proper, the couplings between loops is still strong, satisfactory control performance can hardly be achieved by solely using decentralized control, and decoupling design is strongly required. A typical example is a ball mill coal-pulverizing system, which is important heat-power equipment in power plants, and widely used in China to pulverize raw coal into fine powder. The mill's outlet temperature, inlet pressure and differential pressure are strongly coupled with each other, while the process dynamics varies greatly with the variation of coal moisture. Therefore, ball mill coal-pulverizing system can hardly be controlled using three single-loop conventional controllers. In practice, the system is manually controlled by operators and accidents such as powder mis-emission and mill blockage often occur. Therefore, decoupling control of such complex industrial processes becomes the key issue for this class of systems.

Motivated by the practical needs, many decoupling control approaches have been proposed in the literature. Early results include linear decoupling control such as inverse Nyquist array approach [2] and Bristol–Shinskey method [3]. There are also a number of contributions in relative gain array [4]. To deal with unknown or time-variant parameters in the systems, adaptive decoupling controllers were proposed, for example, in [5–7], and [8], which combined the decoupling designs with self-tuning controls. Furthermore, global convergence of the closed-loop systems was provided in [7] and [8]. However, these early decoupling control methods are mainly confined to linear systems. For nonlinear systems, some results have been developed for affine nonlinear systems, for instance, fuzzy decoupling control [9] and hierarchical fuzzy sliding mode decoupling control [10]. It should be noted that results developed in [9] was applied to a prototype passive line-of-sight stabilization system, and [10] to a double inverted pendulum system.

Since many practical industrial processes are nonaffine nonlinear systems. The above developed approaches may not be applicable and it is a challenging task to develop an approach which can handle nonaffine nonlinear systems. So far, only few results have been reported in the literature. In [11] a neural decoupling control scheme was developed, which is based on multivariable generalized predictive control strategy. However, the result in [11] is only preliminary and general decoupling approach for the nonaffine nonlinear systems is still an open research problem. Due to the complexity of the general nonaffine nonlinear systems, it is reasonable to confine our attention to a class