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Advanced control algorithms for steam temperature regulation of thermal power plants

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Abstract

A model-based controller (Dynamic Matrix Control) and an intelligent controller (Fuzzy Logic Control) have been designed and implemented for steam temperature regulation of a 300 MW thermal power plant. The temperature regulation is considered the most demanded control loop in the steam generation process. Both proposed controllers Dynamic Matrix Controller (DMC) and Fuzzy Logic Controller (FLC) were applied to regulate superheated and reheated steam temperature. The results show that the FLC controller has a better performance than advanced model-based controller, such as DMC or a conventional PID controller. The main benefits are the reduction of the overshoot and the tighter regulation of the steam temperatures. FLC controllers can achieve good result for complex nonlinear processes with dynamic variation or with long delay times.

Keywords: Thermal power plants; Power plant control; Steam temperature regulation; Predictive control; Fuzzy logic control

1. Introduction

Current economic and environment factors put a stringer requirement on thermal power plants to be operated at a high level of efficiency and safety at minimum cost. In addition, there are an increment of the age of thermal plants that affected the reliability and performance of the plants. These factors have increased the complexity of power control systems operations [1,2].

Currently, the computer and information technology have been extensively used in thermal plant process operation and control. Distributed control systems (DCS) and management information systems (MIS) have been playing an important role to show the plant status. The main function of DCS is to handle normal disturbances and maintain key process parameters in pre-specified local optimal levels. Despite their great success, DCS have little function for abnormal and non-routine operation because the classical proportional-integral-derivative (PID) control is widely used by the DCS. PID controllers exhibit poor performance when applied to process containing unknown non-linearity and time delays. The complexity of these problems and the difficulties in implementing conventional controllers to eliminate variations in PID tuning motivate the use of other kind of controllers, such as model-based controllers and intelligent controllers.

This paper proposes a model-based controller such as Dynamic Matrix Controller (DMC) and an intelligent controller based on fuzzy logic as an alternative control strategy applied to regulate the steam temperature of the thermal power plant. The temperature regulation is considered the most demanded control loop in the steam generation process. The steam temperature deviation must be kept within a tight variation rank in order to assure safe operation, improve efficiency and increase the life span of the equipment. Moreover, there are many mutual interactions between steam temperature control loops that have been considered. Other important factor is the time delay. It is well know that the time delay makes the temperature loops hard to tune. The complexity of these problems and difficulties to implement PID conventional controllers motivate to research the use of model predictive controllers

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such as the DMC or intelligent control techniques such as the Fuzzy Logic Controller (FLC) as a solution for controlling systems in which time delays, and non-linear behavior need to be addressed [3,4].

The paper is organized as follows. A brief description of the DMC is presented in Section 2. The FLC design is described in Section 3. Section 4 presents the implementation of both controllers DMC and FLC to regulate the superheated and reheated steam temperature of a thermal power plant. The performance of the FLC controller was evaluated against two other controllers, the conventional PID controller and the predictive DMC controller. Results are presented in Section 5. Finally, the main set of conclusions according to the analysis and results derived from the performance of controllers is presented in Section 6.

2. Dynamic matrix control

The DMC is a kind of model-based predictive control (Fig. 1). This controller was developed to improve control of oil refinement processes [5]. The DMC and other predictive control techniques such as the Generalized Predictive Control [6] or Smith predictor [6] algorithms are based on past and present information of controlled and manipulated variables to predict the future state of the process.

The DMC is based on a time domain model. This model is utilized to predict the future behavior of the process in a defined time horizon (Fig. 2). Based on this precept the control algorithm provides a way to define the process behavior in the time, predicting the controlled variables trajectory in function of previous control actions and current values of the process [7]. Controlled behavior can be obtained calculating the suitable future control actions.

To obtain the process model, the system is perturbed with an unitary step signal as an input disturbance (Fig. 3).

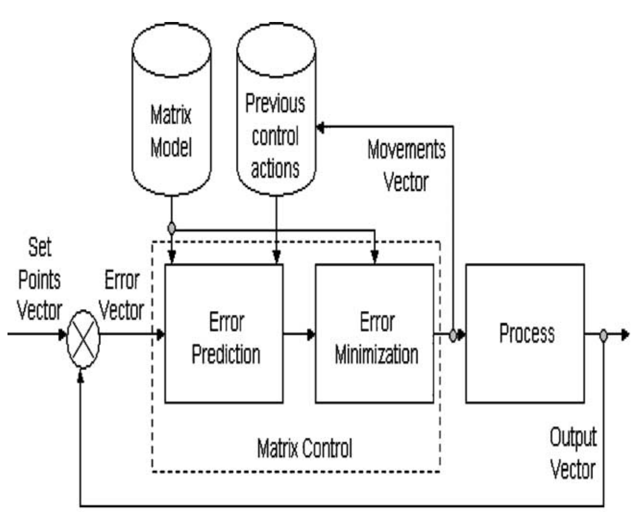

Fig. 1. Architecture of a DMC controller.

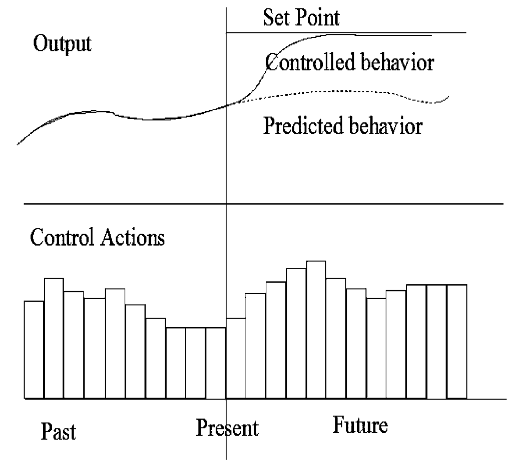

Fig. 2. Prediction of future behavior of a variable.

This method is the most common and easy mean to obtain the dynamic matrix coefficients of the process.

The control technique includes the followings procedures:

(a) Obtaining the Dynamic Matrix model of the process. In this stage, a step signal is applied to the input of the process. The measurements obtained with this activity represent the process behavior as well as the coefficients of the process state in time. This step is performed just once before the operation of the control algorithm in the process.

$$\underline{A} = \begin{bmatrix} a_1 & & & \\ a_2 & a_1 & & \\ \cdots & & & \\ a_n & & \cdots & a_1 \end{bmatrix} \tag{1}$$

(b) Determination of deviations in controlled variables. In this step, the deviation between the controlled variables of the process and their respective set points is measured.

(c) Projection of future states of the process. The future behavior of each controlled variable is defined in

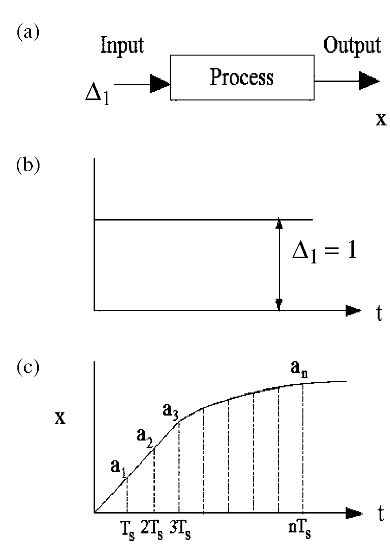

Fig. 3. Dynamic matrix coefficients of a process.