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An investigation on the efficacy of classical tuning algorithm to satisfy advanced requirements: control of main steam pressure during fuel switching and load disturbances in coal fired boilers

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Abstract: The direct application of classical tuning methods in determining the PID controller parameters warrants the determination of the intercept values in X-axis (designated as " L") and Y-axis (designated as " a ") from the open loop step response of the output (to be controlled) with respect to input signal (to be regulated). However, for complex processes, the above procedure seemed to be cumbersome and as an alternative step the researchers usually opted for the heuristic algorithms for the determination of PID controller parameters. In this paper, the authors have identified the boiler demand signal as the input signal to be regulated to control the steam pressure of utility steam generators and derived the PID controller parameters using classical tuning algorithms. Further, it has been demonstrated that with the use of these controller parameters, the transient responses obtained during fuel switching as well as load disturbances are much better than the earlier published results.

Keywords: Pressure control of steam generator, Boiler demand signal, Determination of PID controller parameters, Tuning map, embedded controller, CHR method, fuel switching, ramp variation in loads.

1. INTRODUCTION

It has been observed in recent times that the practicing control engineers and research community resort to the application of modern control algorithms, such as Fuzzy Logic Controllers, Model Predictive Controllers, State observer techniques with feedbacks etc. to control complex process variables. El-Rabaie et al. have applied generalized predictive controller to study the transient behaviour of main steam pressure of drum type boiler during the variations of fuel flow and control valve position. A modified generalized predictive control algorithm has been employed by Qiu Xuefeng et al. to improve the dynamic characteristics of main steam pressure of the boiler. Wen Tan et al. have proposed a model predictive control to improve the performance of the boiler firing rate during large load disturbances. Shi Yuanhao et al. advocated Sliding Mode Predictive Control strategy for main steam pressure control wherein internal model control coupled with Smith predictor has been used to deal with the time delay and time varying characteristics of the boiler while sliding mode controller provides necessary corrections for the model mismatch. Prasad et al. have used a constrained multi variable control strategy to regulate the main steam pressure during load cycling. Beheshti et al. have judiciously combined fixed PID and a neural network so as to have a feed forward controller to control the main steam pressure of an industrial boiler. Fernandez-del-Busto et al. applied model reference adaptive control algorithm to control main steam pressure of boiler. A fuzzy model control methodology is proposed by Cheng et al. for controlling the steam generation in a drum boiler. Hongbo Liu et al. have proposed a special subclass of fuzzy inference systems, called the Gaussian partition with evenly spaced midpoints systems and used to self-tune the PID controller parameters for steam pressure control. An optimal variable structure control (VSC) based on a coordination genetic algorithm has been deployed by Yang Yong and Luo An for controlling the main steam pressure of thermal power plant. Hongbo Lu et al. proposed a control scheme by integrating fuzzy self-tuning with adaptive control and auto-tuning techniques for main steam pressure control. Rong Panxiang et al. employed Fuzzy PI controller integrating Fuzzy Control and the PID control together and applied for the controlling of main steam pressure of boiler. Zhao Kun-long and Wang Zai-ying proposed IMC-PID, a modified PID controller based on internal model control, for the boiler superheated steam pressure control. The developments taking place so fast in this direction raise a doubt whether the application of PID controllers will survive in future. The main difficulty lies in obtaining appropriate controller parameter values. These values are normally obtained by trial and error procedure or through heuristic iterative algorithms as indicated by Dharmalingam. (2011 a, b, c).

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The application of well established classical tuning methods such as Ziegler-Nichols and Chein, Hrones, Reswick warrant the determination of the intercept values in X-axis (designated as “ L”) and Y-axis (designated as “ a “) from the open loop step response of the output with respect to input, as employed by Astrom, K.J. et al. (2001, 2004 and 2006). However, for complex multi input and multi output systems / processes, the selection of input signal which is to be perturbed for this purpose is difficult and this has been the main reason for researchers opting heuristic algorithms for the determination of PID controller parameters. In this paper, the authors have identified the boiler demand signal as the input signal to be regulated to control the steam pressure of utility steam generators and derived the PID controller parameters using classical tuning algorithms. Further, it has been demonstrated that the transient responses obtained during fuel switching as well as load disturbances are much better than earlier published results.

2. SYSTEM DESCRIPTION

A thermal power plant consists of steam generator (also known as boiler), turbine and generator. Boiler consists of furnace, heat exchangers like super heaters, reheaters, economizer and circulation system. Circulation system in turn comprises of drum, down comers and waterwalls which constitute the walls of the furnace. Coal and air are burnt in the furnace and the products of combustion become the flue gas. Chemical energy in the fuel has thus been converted into thermal energy. The flue gas formed in the furnace transfers the heat to various heat exchangers and leaves the furnace. The location of various heat exchangers in the furnace is shown in Fig. 1.

Fig. 2 schematically represents the coal, primary air (PA) and secondary air (SA) path of the boiler system. The coal is pulverized in the mill and the primary air carries the powdered coal to the furnace. The secondary air meets the additional air requirements for ensuring complete combustion. The furnace is a tangentially fired system and the number of coal burner elevations depends on the capacity of the boiler. For a typical 500 MW unit, there will be nine elevations out of which six will be functioning during full load conditions while for a typical 210 MW boiler there will be six elevations out of which four will be functional.

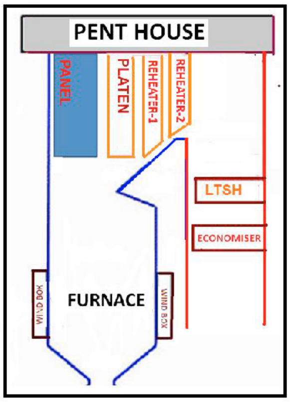

Fig.1. Schematic diagram of boiler furnace

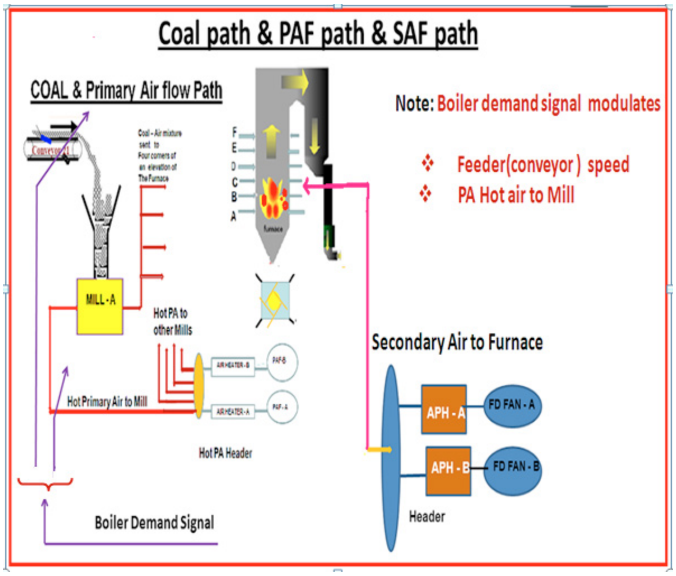

Fig. 2. Schematic diagram of Coal, PA and SA path

The heat transfer mechanism in furnace is quite complex and the furnace walls receive heat by direct radiation. The water inside the water walls (WW) get converted into steam and the two phase mixture goes to drum where the mixture gets separated as water and steam. Panel and platen super heaters and reheaters also receive heat partly by direct radiation. The coal burners can be tilted upwards and downwards. An upward tilt decreases the heat flow to waterwalls and increases the heat flow to radiant super heaters and reheaters (RH) while a downward tilt increases the heat flow to water walls and decreases the heat flow to radiant super heaters and reheaters. The feed water after being preheated in high pressure heaters and economizer enters the drum. The water level in the drum is usually kept slightly below the central axis of the drum.

The high pressure steam flow to the turbine is controlled to meet the set load demand in three different ways. These are known as Boiler following mode, Turbine following mode and coordinated mode. Depending upon the mode of selection, the boiler demand signal which ultimately regulates the combustion process is derived from the master pressure control of Boiler-Turbine-Generator unit. The method of deriving the boiler demand signal corresponding to different modes of operation is discussed in next section.

3. BOILER DEMAND SIGNAL

Fig. 3 schematically represents the steam and water path of the boiler system. The main steam (MS) pressure at the boiler outlet remains constant if the steam production in circulation system is equal to the demand of steam at the outlet of the boiler.

The boiler demand signal which regulates the combustion process is identified as the signal to be manipulated to control the main steam pressure. This boiler demand signal is derived based on three modes of the operation of the power plant. The modes of operation and the generation of the boiler demand signal are given in Table 1.