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Statistical modeling of an integrated boiler for coal fired thermal power plant

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Abstract

The coal fired thermal power plants plays major role in the power production in the world as they are available in abundance. Many of the existing power plants are based on the subcritical technology which can produce power with the efficiency of around 33%. But the newer plants are built on either supercritical or ultra-supercritical technology whose efficiency can be up to 50%. Main objective of the work is to enhance the efficiency of the existing subcritical power plants to compensate for the increasing demand. For achieving the objective, the statistical modeling of the boiler units such as economizer, drum and the superheater are initially carried out. The effectiveness of the developed models is tested using analysis methods like R^2 analysis and ANOVA (Analysis of Variance). The dependability of the process variable (temperature) on different manipulated variables is analyzed in the paper. Validations of the model are provided with their error analysis. Response surface methodology (RSM) supported by DOE (design of experiments) are implemented to optimize the operating parameters. Individual models along with the integrated model are used to study and design the predictive control of the coal-fired thermal power plant.

Keywords: Chemical engineering, Applied mathematics

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1. Introduction

Electricity is the most essential thing in the day-to-day life of everyone in this active world. Without electricity this contemporary world cannot last even for a moment. The difference between energy source and demand is always present and it requires foremost consideration. To overcome the scenario of the difference between the supply and demand, the efficiency of the existing power plants need to be taken care and also the newer power plants need to be established with the supercritical technology. Nearly 41% of power is obtained through coal-fired thermal power plants. Efficiency of the subcritical plants can be improved in the following ways: a) to improve the quality of coal; b) proper air fuel ratio for the combustion; c) to avoid pressure drop between the oiler units etc. To achieve this, proficient simulations of individual units need to be built to examine the reliability of the variables of interest on a set of independent variables. Boiler of the subcritical power plant consists of combustion chamber, economizer, drum, superheater and reheater. All these units are interrelated to each other such that changes in one unit affect the performance of the another unit. Statistical analysis of the units of power plant is not well established and this motivated to build the regression model for the individual boiler unit (economizer, drum and superheater) and the integrated unit. Data driven models based on real time data can be helpful in analyzing performance of the existing plant. This type of model is based on computational intelligence for investigating the state variables of system without the awareness of their physical behavior.

Modeling of the boiler drum of the coal-fired thermal power plant through the mass balance and energy balance was initiated by Astrom and Bell [1] and Astrom and Eklund [2]. The different control configurations for the developed model was studied and compared by them.

Richard [3] proposed for the improvement of the components of the prevailing plant to increase the efficiency of the coal-fired power plant instead of swapping it with the new skills. Flynn [4] discussed the types of thermal power plant and their individual component. The modeling and the computer simulation with different control structures for the power plant model are analyzed by the author. The overview of the modeling of individual units and the integrated units of coal-fired and gas-fired thermal power plant and several simulation methods have been presented by Lu [5]. The derivation of pressure equation and the temperature equations of boiler units using physical laws are presented in [6] and [7]. Data driven model based on artificial neural network (ANN) has been proposed by Smrekar et al. [8] and [9] for the estimation of power output and main steam properties of the power plant. It was proved that the proposed model can provide better results with minimal number of parameter compared to the physical model.

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