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Soft sensing of coal moisture

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ABSTRACT

This study presents a soft sensing model of coal moisture for utility boilers. The model is based on the energy and mass balance of matter in the inlet and outlet of a positive-pressure, direct-firing, MPS-type mill. Compared with the results obtained with a proximate analysis method, the results calculated with the soft sensing method are consistent with proximate analysis data. Meanwhile, the accuracy and reliability of the soft sensing method can be improved by data fusion of the calculated coal moisture from other running mills.

1. Introduction

The conflict between coal price and electric power price has become increasingly prominent with the continued development of China. The source and composition of coal used for power generation are complex and changeable. In particular, some plants use blended coal, with a large proportion of low-quality coal, to reduce fuel cost. As a result, the quality of coal in furnaces varies and the values of main indicator parameters fluctuate within a large range. Different types of coal result in a series of problems in pulverising, ash and slag handling and combustion adjustment systems. Accordingly, the online monitoring of coal quality in furnaces is important.

Moisture content is an important quality parameter of coal because of its effect on the safety and the economic operation of thermal power plants. This significance of moisture content is mainly reflected in the following conditions: (1) An increase in coal moisture affects coal calorific value, whereas water evaporation consumes heat and thus reduces boiler efficiency. (2) An increase in coal moisture content leads to the poor mobility of the coal powder. Coal powder will then block the mill and transportation pipeline if drying is not sufficient. As a result, the safe operation of a unit is compromised.

To address these problems, coal moisture must be monitored online, and compensation in the control system of a mill must be conducted. A change in the moisture content of fuel needs to be detected within seconds, so that the control system can correctly adjust the combustion air supply and the fuel feed system [1]. At present, moisture content can be measured through conventional laboratory analysis and online measurement methods. The traditional method of measuring coal moisture involves a large delay; the measurement results, which are often obtained after coal combustion, cannot be used to guide production and adjust combustion accordingly.

The online measurement methods of moisture can be categorised into two types, namely, direct hardware sensing and indirect soft sensing. Direct measurements include methods such as microwave [2], near infrared spectroscopy (NIR) [3], terahertz spectroscopy [4], radio frequency (RF), nuclear magnetic resonance (NMR), and dual-energy X-ray absorptiometry (DXA). These methods, however,

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require expensive hardware. Most plants use offline laboratory testing methods without the conditions of the real-time online measurement of coal quality.

The indirect soft sensing method mainly utilises easily measured process variables (secondary variables) according to the mathematical relationship (soft sensing model) between these variables and the process variables (primary variables), which are difficult to measure directly. Nevertheless, the latter variables can be measured through a variety of mathematical calculations and estimation methods. Such methods do not require expensive hardware; they only need to use the existing sensor measurements of the system and obtain measurement results which are consistent with those of the hardware sensing method [5]. In this regard, soft sensing technology has been developed rapidly in recent years. Many applications to test coal quality and monitor boiler emissions have also been developed, and these applications include neural networks, multiple regression, state estimation and Kalman filtering [6–9]. Odgaard and collaborators have conducted extensive research to estimate coal moisture online and apply control optimisation and fault diagnosis [10–13]. They introduced a method based on the simple dynamic energy model of a coal mill to estimate coal moisture. Jianguo Liu built a coal moisture analysis model for coal fed into boiler basing on milling system operation parameters measurement, and they calculated the coal moisture M_{ar} by complex iterative calculation [14].

The rest of this paper is organised as follows. Section 2 describes the basic situation of the unit described in this study, as well as the properties and working processes of the positive-pressure, direct-fired pulverising system and medium-speed roller mill. Section 3 derives a quadratic equation which includes coal moisture according to the energy and mass balance of the mill system, as well as presents the online solution method for coal moisture. Section 4 presents the data fusion theory, by which the measured value from different sensor can be processed and the optimal estimated value can be got. Section 5 calculates coal moisture with the use of actual plant operating data and analyses and compares five cases. Section 6 concludes this study.

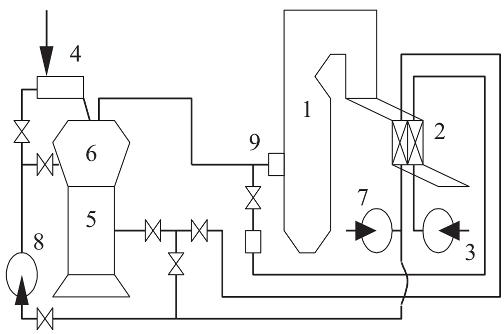
2. Coal mill

This research examines the ZGM-123-type medium-speed roller mill of China Datang Panshan Power Generation Co., Ltd. The method which the company utilises is universal and suitable for other types of mills. The company is equipped with two 600 MW turbine generators. The boiler is an HG-2023/17.6-YM4 made in Harbin Boiler Plant and has the properties of sub-critical, single reheat, controlled circulation boiler drum, single furnace and Π-type layout. The turbine is N600/16.7/537/537/-F made in Harbin Steam Turbine Plant and has the properties of sub-critical, single reheat, uniaxial with four cylinders and four exhaust-steam reaction types. Each unit is equipped with six sets of positive-pressure, direct-fired pulverising systems. The coal feeder is an EG-24, belt weighing-type coal feeder. The mill is a ZGM-123 medium-speed roller mill. The system structure is shown in Fig. 1.

A positive-pressure, direct-fired pulverising system mainly consists of a primary fan, sealing fan, coal feeder and coal mill. The grinding and drying of raw coal are conducted simultaneously in the mill. The air which comes out of the primary fan is categorised into two channels: one channel which comes out through the air preheater is called hot primary air, whereas the other channel which does not come out through the air preheater is called cold primary air. The two channels of primary air mix before they enter the mill, in which the opening degree of the hot primary air door controls the outlet temperature of the mill, and the opening degree of the cold primary air door controls the primary air flow. The unit requirements of the output and coal drying are satisfied by the two channels of primary air. Each mill is equipped with a sealing fan; sealing air is used for mill sealing to prevent coal powder leaking.

3. Theoretical formula for the online calculation of coal moisture

Because coal is fed into the mill by a conveyor belt, the coal heats up and dries during grinding and thus incurs



1.boiler furnace, 2.air preheater, 3.air blower, 4.coal feeder, 5.coal mill
6.coarse, pulverised coal separator, 7.primary fan, 8.sealing fan, 9.burner

Fig. 1. Schematic of a medium-speed mill, positive-pressure, direct-fired pulverizing system.