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Fuel metering and control optimization based on combustion state diagnosis

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Abstract. It is hard to accurately meter the fuel feed into the furnace for a double-in and double-out pulverizing system, which affects the fuel control quality and also the main steam pressure of a boiler. A correction method for the indirect measurement model of the coal metering feed into the furnace for double-in and double-out pulverizing system is proposed based on the combustion state diagnosis of a burner using fuzzy C-mean clustering method, of which is applied in a 620MW super critical power unit. The engineering application results suggested that the method of this work is effective to improve the fuel control quality during the mill start and stop process. By using the method of this work, the controlling deviation between the target value and the measured value of the main steam pressure is within 0.2 MPa, while it is about 0.6 MPa when the fuel control is without correction.

1. Introduction

Double-in and double-out pulverizing system is widely applied in power plant that burning inferior coal due to the good adaptability to various coal and convenient maintenance [1]. However, it is hard to accurately meter the coal feed into the furnace during the mill start and stop process, which affects the fuel control quality and results in the fluctuation of the main steam pressure of a boiler. Therefore, the boiler is hard to operate at the most economic level [2-4].

Flame radiation intensity is the most intuitive reflection of the combustion process. It is available to quantitatively describe the combustion intensity by using fuzzy C-mean clustering algorithm to conduct combustion state diagnosis based on the features extraction from flame radiation intensity [5, 6]. As a result, it is possible to correct the fuel metering feed into the furnace of a double-in and double-out pulverizing system based on combustion diagnosis.

Fuel metering and control optimization technology based on the combustion diagnosis is studied in this work, which takes a 620MW super critical unit that assembled with 6 double-in and double-out mills as an example. The combustion state diagnosing result of a single burner is integrated into the fuel indirect measurement model as a correction factor, making the fuel metering more accurate, therefore to achieve the goal of fuel control optimization.

2. Fuel metering method based on the combustion state diagnosis

2.1. Fuzzy C-mean clustering (FCM) algorithm



The FCM adopts ‘membership’ to describe the similarity of a sample to a certain category, providing a quantitative value for a fuzzy event. The basic principle of FCM is reported in reference [6]. Only the concept and expression of the membership is provided here. For a data set $X=\{x_1, x_2, \dots, x_n\}$, which is assumed that can be classified into k categories, therefore, the membership u_{ij} of the i_{th} sample belongs to the j_{th} ($1 \leq j \leq k$) category should meet the following rules:

$$0 \leq u_{ij} \leq 1 \quad (1)$$

$$\sum_{j=1}^k u_{ij} = 1 \quad (2)$$

$$u_{ij} = \frac{1}{\sum_{a=1}^k \left(\frac{p_j - x_i}{p_a - x_i} \right)^{\frac{2}{m-1}}} \quad (3)$$

Where p is the clustering center of a certain category, a and j is category subscript, u_{ij} is the membership, m is the smooth factor.

Online combustion state diagnosis technology based on flame radiation intensity FCM includes following steps, of which the detailed information is reported in reference [7]: 1) collect flame radiation intensity history data of the burner to be diagnosed, 2) ascertain the combustion state categories by analyzing the history data, 3) choose sufficient data of each category, determine the diagnosing cycle T and features vector that could represent combustion state, 4) compute the features vector of each cycle and use as a sample, obtain many samples of each category, 5) conduct clustering analysis of all the samples that includes different categories and obtain the clustering center of each category, 6) Compute the features vector in a cycle online and use as a sample, 7) compute the membership between the sample obtained in step 6) and the clustering center obtained in step 5).

2.2. Fuel metering correction method

For a double-in and double-out pulverizing system, the fuel feed into the furnace cannot be weighed directly and usually metered by indirect measurement based on an empirical formula including the opening degree of the valve where coal pass through, the mill level and the air pressure that carries coal, of which the expression is as follows:

$$R=P(x)V(x)L(x) \quad (4)$$

Where, $P(x)$ is the function of air pressure, $V(x)$ is the function of the opening degree of the valve and $L(x)$ is the function of the mill level, all these functions are set according to the characteristics of a mill, which is usually obtained by operating experience. The above formula is proved to be accurate in metering the fuel feed into the furnace in steady state. However, during the mill start and stop process, due to the lag characteristic of the mill, the fuel metering feed into the furnace needs to be corrected, of which the program is outlined as figure 1, including following steps (taking one of the mill as an example, a mill has two coal pass pipes and four burners usually):

1) Analyze the history data of the flame radiation intensity signal at different operating stages from the first ignition of the boiler to full power operation. The combustion state during all stages is classified into 4 categories, corresponding to language description of ‘good’, ‘common’, ‘poor’ and ‘bad’. Obtain the clustering center of these 4 states using FCM clustering algorithm.

2) Compute the membership degree between the real-time combustion state of one of the burner and the clustering center of state ‘good’ and state ‘common’, respectively. The results are marked as L_{11} and L_{12} . These of the other burner are marked as L_{21} and L_{22} .

3) Choose the biggest value among the $L_{11} \sim L_{22}$ that obtained in step 2 and marked as L_{1max} .

4) Use L_{1max} as an independent variable, the first, the second and the third correction factor is obtained by the mapping of functions of $f(x)$, $g(x)$ and $h(x)$, respectively. The forth correction factor is set as 1.

5) According to different conditions, choose the correction factor C from the four factors by designing rules.

6) Using the metering value R_0 obtained by formula (4) multiply the correction factor C, the result is used as the first candidate of the metering value of one coal pass pipe of the mill. According to the operating condition of the coal feeder, choose R_0 or 0 as the second candidate. The third candidate is set as 0. The final metering value of one coal pass pipe of the mill Q_1 is chosen from these three candidates.

7) Repeat steps 2) ~ 6) and obtain coal metering values of the other coal pass pipe of the mill, marked as Q_2 .

8) Compute the sum of metering values of all coal pass pipes and it is the total coal quantity feed into the furnace from the studied mill.

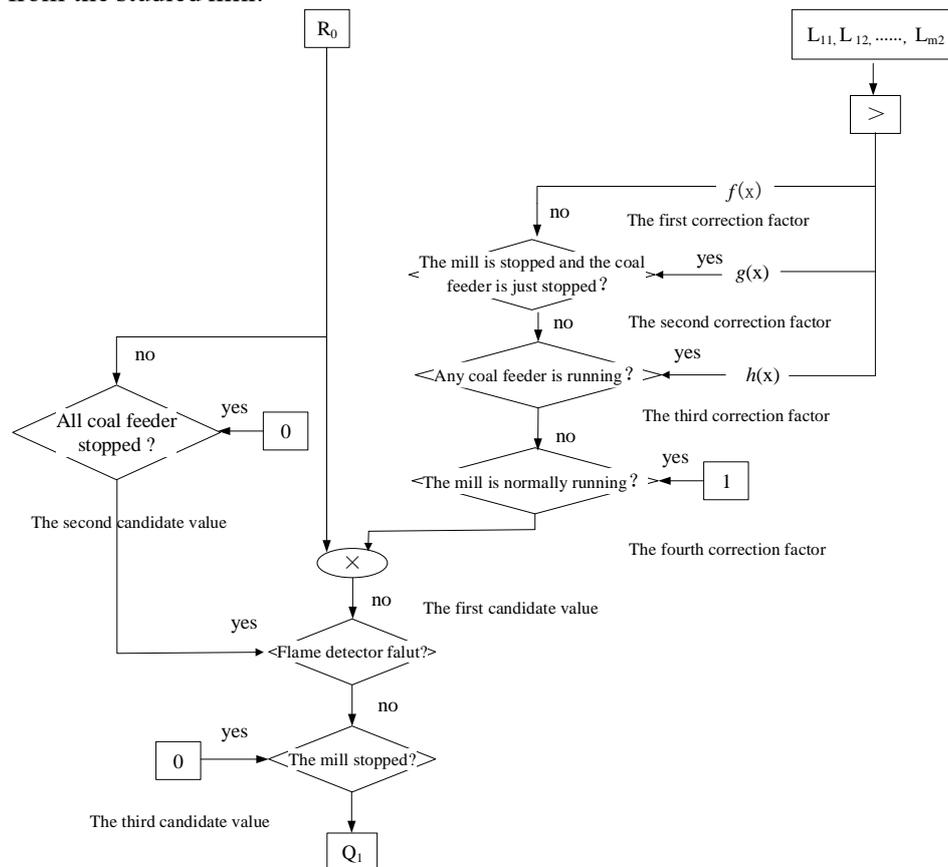


Figure 1. The principle of the fuel metering correction method.

The detailed information of $f(x)$, $g(x)$ and $h(x)$ are shown as table 1.

Table 1. Mapping relationships between L_{1max} and $f(x)$, $g(x)$ and $h(x)$

Item	Values					
L_{1max}	0	0.2	0.3	0.5	0.8	1
$f(x)$	0.2	0.6	0.85	0.95	0.98	1
$g(x)$	0.2	0.5	0.8	0.9	0.95	1
$h(x)$	0.5	0.72	0.9	0.98	1	1

3. Results and discussion

The variation trend of the main operating parameters during the mill start process is shown in Figure 2, of which the measured fuel is without correction. As shown in the figure, the main steam pressure measured value began to increase and deviated the controlling target value after the mill started about 3 min. The deviation between the two reached the biggest value of about 0.6 MPa after the mill started about 5.5 min. During the same time, the feed water flow fluctuated in a small range, which matched the variation of the mid-point temperature. It is inferred that the increase of the main steam pressure was resulted by the start of the mill. The main steam pressure gradually decreased to the target value due to the effect of the boiler master control. The above process is caused by the inaccurate of the fuel metering feed into the furnace. During a mill start process, the fuel metering feed into the furnace obtained by the indirect measurement model mentioned in section 2.1 is smaller than the real value. The reason is that the model considering that it costs time to build the mill level. However, when there is coal remained in the mill, the coal will be blown into the furnace immediately and burn after the mill start without delay. In other words, the mill has already finished the mill level building process under this condition. Due to the inaccurate metering of the fuel, the control deviation of the main steam pressure increases and the deviation amplitude increases with the increase of the coal remained in the mill.

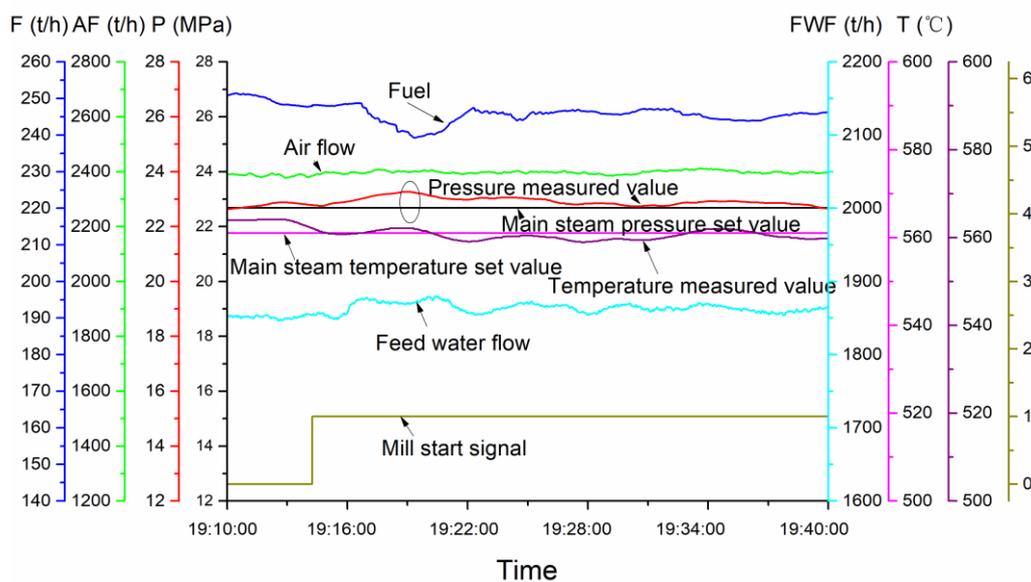


Figure 2. The variation trend of main operating parameters during a mill start process.

The variation trend of main operating parameters during the mill start and stop process are shown in Figure 3 and Figure 4, respectively, of which the fuel metering feed into the furnace are corrected according to the method mentioned section 2.2. As shown in both figures, the main steam pressure are controlled well during the mill start and stop process and the biggest deviation between the target value and measured value is smaller than 0.2 MPa, which is better than the standard value of 0.5 MPa. Using the combustion state diagnosing conclusion of the corresponding burner of a mill to correct the fuel metering value obtained by the indirect measurement model is proved to be effective to improve the fuel control quality. One need to note that the correction factor works only during the mill start and stop process, aiming to solve the problem of inaccurate metering of the fuel feed into the furnace which is resulted by the remained coal in the mill. During the stable operation process of a mill, the correction factor is set as 1.

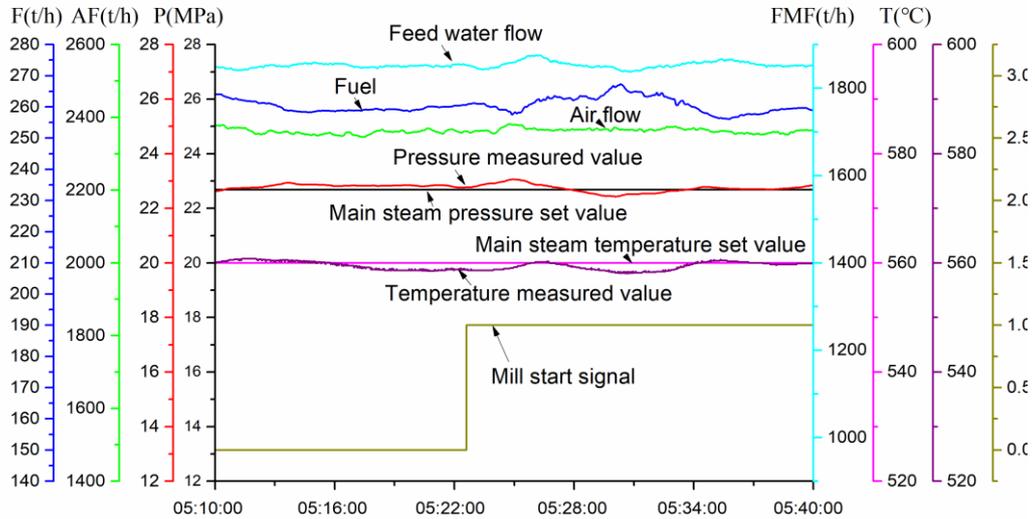


Figure 3. The variation trend of main operating parameters during a mill start process with fuel metering corrected in the fuel control.

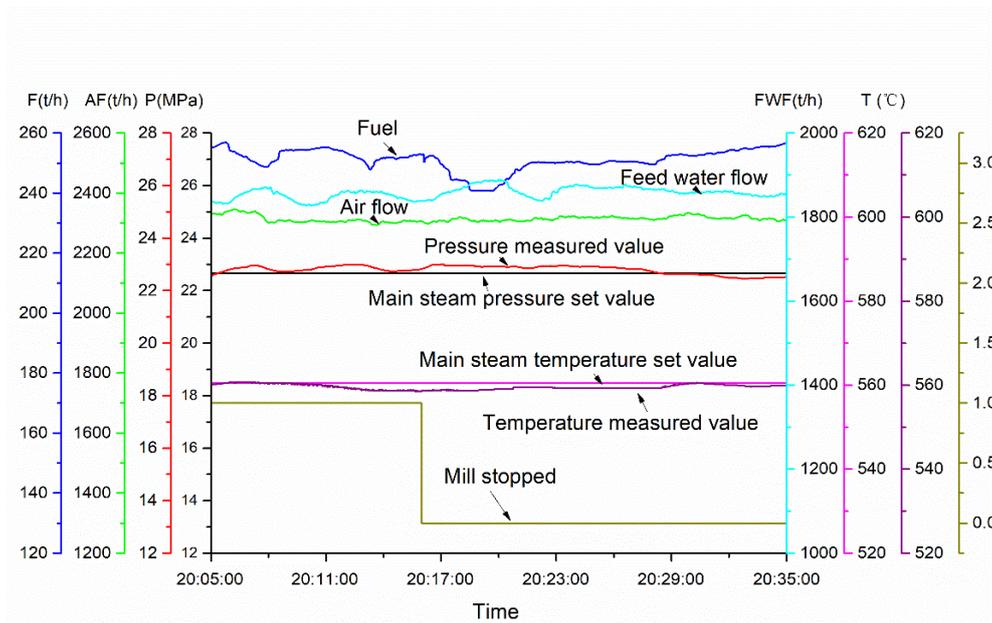


Figure 4. The variation trend of main operating parameters during a mill stop process with fuel metering corrected in the fuel control.

4. Conclusion

Based on the combustion state diagnosing of a burner, a correction method for the indirect measurement model of fuel metering feed into the furnace is proposed in this work and is applied in a 620MW supercritical unit that adopts “W” shape flame boiler and assembles with 6 double-in and double-out pulverizing systems. The results shows that the method in this work is effective. The controlling deviation of the main steam pressure is smaller than 0.2 MPa during the mill start and stop process by using the mothed of this work. It is smaller than the deviation of 0.6 MPa when the fuel control is without fuel metering correction.

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