Optimizing coal burning caused by coal breaking in recirculating vulcanization bed unit based on fuel control strategy

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Abstract. Recirculating fluidized bed has high efficiency, low pollution and good coal adaptability. It can burn all kinds of quality fuels, such as peat, bituminous coal (including high sulfur coal), anthracite, gangue, coke, industrial waste, municipal waste, etc. Direct addition of desulfurizer such as limestone in the bed results in small investment and high desulfurization efficiency. International and domestic circulating vulcanization bed has entered the stage of large-scale and commercial production. Recirculating fluidized bed combustion is a new technology. The burning mode of special coal in boiler structure is essentially different from that of pulverized coal furnace. There is a certain gap in domestic installation technology compared with pulverized coal furnace. It is easy to cause coal cut-off in operation of circulating fluidized bed forming unit. The occurrence of coal cut-off is easy to cause bias burning and unbalanced combustion of boiler. In serious cases, MFT action of boiler will be triggered. Therefore, it is necessary to optimize the existing fuel control strategy to prevent coal burning caused by coal breaking in the circulating vulcanization bed unit.

1. Introduction
Recirculating fluidized bed boiler (CFB) has developed rapidly in recent years due to its cleaner combustion mode, wide fuel adaptability and wide load regulation ratio. The large-scale subcritical CFB (evaporation capacity 1025t/h) developed independently has been put into commercial operation, and the CFB in China has entered the development stage of subcritical parameters. The large-scale CFB developed independently has become one of the optimal technologies for thermal power plants. The self-developed large-scale circulating fluidized bed boiler adopts the single-chamber structure with large width/depth ratio and multi-point coal feeding. In this way, the balanced coal feeding is very important for the normal operation of such units. Also to ensure the left and right side of the coal balance, to maintain the bed temperature throughout the furnace uniform change, do not cause local overheating coking. Previous control strategies were difficult to meet these requirements.
2. Optimization method

2.1. Deficiencies of typical fuel control strategies

A typical fuel control idea is to control 8 coal feeders through a fuel master controller. When the output of the fuel master controller changes, all 8 coal feeders change the coal feed at the same time, as shown in figure 1 below.

![Figure 1. Typical fuel control strategy.](image)

On both sides of the circulating vulcanization bed unit, four coal feeders are arranged on each side (A side and B side). When coal failure occurs on one of the coal feeders (arranged on the A side for example), the total fuel quantity decreases. The fuel master controller is used to control the coal feeding quantity of the remaining seven coal feeders to maintain the balance of the total fuel quantity. Therefore, when A coal feeder on one side (side A) breaks coal, it will increase the coal supply on the other side (side B). Frequent coal break often leads to unbalanced coal supply on both sides, which makes the boiler prone to partial combustion and unbalanced combustion, and triggers boiler MFT action in severe cases. In view of the shortage of typical fuel control strategy in the application of circulating fluidized bed, an optimization scheme of fuel control strategy is proposed, which is used to balance the coal supply on both sides to prevent the unbalanced combustion of circulating sulphurized bed unit caused by frequent coal cutting.

2.2. Optimization strategy

For the typical fuel control strategy, according to the actual operation of the circulating sulfur bed unit, the typical fuel control method was invented and improved. The control strategy mainly includes three parts: the fuel master control loop, the fuel control loop on side A, and the fuel control loop on side B, as shown in figure 1 below.
Figure 2. Optimized fuel control strategy.

The first part is the fuel master control circuit. The output value of boiler master control is used as the command value of fuel master control. The sum of A side coal feeding instruction and B side coal feeding instruction is the feedback value of fuel master control. The output value of fuel master control is used as the instruction value of A side and B side fuel control circuit respectively.

The second part is the a-side fuel control loop. The output value of fuel master control is used as the instruction value of the a-side fuel control circuit. The sum of the total feed coal of A side feeder is used as the feedback value of A side fuel control loop. The output value of side A fuel control circuit is used as the coal feeding instruction value of side A coal feeder.

The third part is the b-side fuel control circuit. The output value of fuel master control is used as the instruction value of the b-side fuel control circuit. The sum of the total coal fed to the coal feeder on side B is the feedback value of the fuel control loop on side B. The output value of the b-side fuel control circuit is used as the coal feeding instruction value of the b-side feeder.

This optimization scheme takes into account the phenomenon of unit bias caused by frequent coal breaking of circulating vulcanization bed unit. Single PID controllers on both sides (A and B sides) control the coal feed on one side respectively. When the coal feed on A side breaks coal, the PID controller on A side increases the coal feed on A side, but does not increase the coal feed on B side, in order to maintain the constant coal feed on A side, and keeps the stability of the total fuel. It can provide coal in A balanced way and effectively prevent the boiler from burning out due to the unbalanced coal supply in A and B side caused by frequent coal breaking by the coal feeder.

In this optimization scheme, different from the conventional control idea, the fuel master control feedback adopts the sum of A side and B side coal feeding instructions, instead of the total coal feeding quantity. Here is one of the highlights of the design, but also difficult to think of the place. If the total amount of coal is used as the feedback, when A coal feeder on side A frequently breaks coal, the actual total amount of coal will be greatly reduced due to the actual total amount of coal given to the coal master control feedback, so that the output of the coal master control will be increased, and the output of the coal master control will be used as the command value of the control loop on both sides of the coal supply. Both sides received the main control instruction of coal supply. Because the coal supply machine on side A broke off, the output of coal supply machine on side A was greatly increased, and that of coal supply machine on side B was slightly increased. So that the total amount of coal to match the command. For a long time, one side of the coal machine broken coal, because the other side will be a small increase each time, will continue to accumulate, will eventually lead to the boiler bias. It is impossible to prevent the partial combustion caused by coal breaking.
3. Test results

3.1. Implementation of unit overview
The optimized control strategy is applied to a 2*300MW pithead coal gangue heat and power plant, and the load-changing test is carried out. The boiler is equipped with 8 coal feeders, which are divided into A and B coal feeders. Limited by the installation process and equipment, the coal feeder on both sides of A and B breaks coal frequently, and at least one coal feeder breaks coal in 5 minutes.

3.2. Control effect
The optimized control strategy was applied to a 2×300MW coal gangue thermal power plant in a power plant and the variable load test was carried out. The relevant parameters of fuel master control are shown in table 1, 2 and 3.

| Table 1. PID parameters of fuel master control. |
|-----------------------------------------------|
| Gain (K) % : | Proportion (KP) : | Integral gain: |
| 1           | 0.5              | 4             |

| Table 2. Automatic parameters of side A coal feeding. |
|------------------------------------------------------|
| Gain (K) % : | Proportion (KP) : | Integral gain: |
| 1           | 0.26              | 1.3           |

| Table 3. Coal feeding automatic parameters of side B. |
|------------------------------------------------------|
| Gain (K) % : | Proportion (KP) : | Integral gain: |
| 1           | 0.26              | 1.3           |

In the process of variable load, side A breaks coal frequently, and the process response curve is shown in figure 3 below. The coordinated control response curve based on the optimized fuel strategy is shown in figure 4 and 5 below.

Figure 3. Process response curve
It can be found from figure 3 that during the process of load change, side A frequently breaks coal, while side B does not break coal. When side A breaks coal, side A's coal instruction increases rapidly to supplement side A's coal loss due to coal break.

As can be seen from figures 4 and 5, the coordinated control loop based on the optimized fuel control strategy can well perform the tasks assigned by the coordinated control loop during the process of variable load and pressure.

When A coal feeder on side A frequently breaks coal, because the fuel master control feedback adopts side A and side B to give feedback to the coal instruction, the fuel output does not change, and the fuel output is the instruction of the fuel control loop on side A and side B. The fuel control circuit of side A detects the decrease of the actual coal supply to side A, so as to increase the output of side A coal feeder, rapidly increase the coal supply to side A, and supplement the broken coal supply of A coal feeder. The command and feedback of the fuel control loop in side B do not change, and the output of the coal feeder in side B does not change. Therefore, only side A can be adjusted without side B, which can prevent side feeder from frequently breaking coal and causing partial combustion of boiler.

4. Conclusion
In a power plant 2×300MW coal gangue thermal power plant at the pit mouth, in order to prevent the frequent coal breaking of large circulating vulcanization bed unit, resulting in unbalanced coal feeding on both sides, partial firing in boiler chamber, triggering MFT. The fuel control strategy was optimized, and A and B sides were used to feed coal separately to solve the above problems. It lays a
good foundation for AGC investment and ensures that AGC control can be put into operation effectively for a long time.

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