Optimization and transformation of 300MV units steel ball coal mill Pulverizing System

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Abstract. Comprehensive treatment, we should have a test on the 300 MV unit steel ball coal mill pulverizing system. At the same time, analyze the main operating parameters before modification. Transform the pulverizing system and optimize the run mode of the pulverizing system by comprehensive treatment. So we can control the pulverizing unit consumption under 30KWh/t. It makes the pulverizing system in the best state. Then we can ensure its economic and safe operation.

1. Introduction
Most of the thermal power generating units in China adopt ball mill intermediate storage pulverizing system. The advantages of using steel ball mill are: It is safe and reliable, easy to operate and maintain coal with low grindability and high moisture content. But it also has its shortcomings: The equipment consumes a large amount of metal, and the initial investment cost is high. The energy consumption is high. The power consumption of grinding pulverized coal per ton is 26-37 kWh. It is not suitable for low-load operation. The complex system of intermediate pulverized coal bunker must be adopted. In recent years, with the increase of installed capacity and the improvement of unit safety, the problems of intermediate storage pulverizing system of ball mill are particularly prominent. At present, there are many problems in drum ball mill. The pulverizer has insufficient output and long-term low load operation[1]. The power consumption of pulverizing is high. The phenomenon of powder leakage is common and the phenomenon of grinding blockage occurs from time to time. The unreasonable fineness of pulverized coal results in excessive coarseness of pulverized coal when treated, which seriously affects the combustion in the furnace. It is easy to cause problems such as high temperature corrosion, slagging, flue gas temperature deviation and poor burnout. The excessive fineness of pulverized coal increases the power consumption of pulverized coal. The system configuration is unreasonable, especially the selection of crude powder separator can not match the system, which makes the coal return large, fineness difficult to adjust, system output insufficient and efficiency low; The automatic control ability is poor and the operation is tedious. Therefore, the pulverizing system must be reformed and optimized so as to keep the pulverizing system in the best condition[2].
2. Pulverized Coal System of Steel Ball Mill for 300MW Unit

In modern pulverized coal boilers, pulverizing system has become an indispensable part of the common composition of boiler combustion equipment. In order to improve the economic operation of the boiler unit, the boiler combustion adjustment test must be carried out to improve the operation mode and to improve the necessary equipment after the selection of equipment and the determination of the unit operation. The pulverizing system test is the main content of the adjustment test of the boiler unit and the basis of the whole combustion adjustment.

A 300 MW unit boiler in a power plant is a DG1025/18.2-II4 subcritical pressure, intermediate reheating and natural circulation drum furnace designed and manufactured by Dongfang Boiler Factory. The boiler is designed to burn Mengxi bituminous coal (designed low calorific value of coal Qar, net = 21.34MJ/kg, dry ash-free volatile Vdaf = 29.2%), tangential combustion, two rotary air preheaters and two electrostatic precipitators in the tail flue, and four DTM350/700 steel ball mills in the intermediate storage pulverizing system. Each boiler is equipped with two ANN-2180/1000N adjustable axial-flow fan and two D413-1884-631 axial-flow fan. It adopts exhaust gas powder feeding, ball mill and intermediate storage pulverizing system[3]. For various reasons, the unit consumption of pulverizing system has been around 33.0kWh/t. It is obvious that the energy consumption of pulverizing system of this furnace is too high, so it must be reformed.

2.1. Pre-treatment Test of Pulverizing System

2.1.1. Characteristic test of coal feeder. In coal feeding measurement, the moving speed of scraper is measured under different speed of coal feeder, and the actual speed of motor of coal feeder is measured by photoelectric tachometer. At the same time, the thickness of coal seam is measured, and a length of raw coal is weighed to determine the relationship between speed of coal feeder and coal feeding quantity[4]. The output test results of coal feeder are shown in Table 1. Formula for calculating coal feed B:

\[ B = m v 1000 L \]

B - coal feed, T / h; m - the quality of a fixed length of raw coal on the scraper, kg; V - coal feeder measured scraper speed, M / h; L - the length of raw coal on the scraper, M.

| Serial Number | Project                          | Unit   | Data     |
|---------------|---------------------------------|--------|----------|
| 1             | Chain perimeter of coal feeder  | mm×mm  | 200×88   |
| 2             | Width of coal feeder            | mm     | 630      |
| 3             | Thickness of coal seam          | mm     | 350      |
| 4             | Coal feeder chain turning time 100r/min | 11’53”56 |
| 5             | Coal feeder chain turning time 200r/min | 6’8”88 |
| 6             | Coal feeder chain turning time 300r/min | 4’8”38 |
| 7             | Stacking density of coal feeding| t / m³ | 0.85     |
| 8             | A Coal feeder output(100r/min)  | t / h  | 16.63    |
| 9             | A Coal feeder output(200r/min)  | t / h  | 32.18    |
| 10            | A Coal feeder output(300r/min)  | t / h  | 47.79    |

2.1.2. Calibration of the inlet air volume of the pulverizer. The flow coefficients of exhaust backrest pipes are calibrated by pitot tube under 2 ~ 3 wind speeds, and the ventilation rate of the system is determined. The flow coefficient of the backrest pipe is 0.881, and the ventilation capacity of the system is 126794.69 m³/h under the normal operation condition.

2.1.3. Separation efficiency test and resistance test of crude powder separator. The efficiency and resistance of A crude powder separator were tested. Maintain the original operation status of the system. The baffle opening of separator is 30%. The results are shown in Table 2.
Table 2. Test results of efficiency and resistance of A crude powder separator.

| Number | Project                                      | Unit | Source | Data   |
|--------|---------------------------------------------|------|--------|--------|
| 1      | Current of A coal mill                      | A    | Meter  | 72.6   |
| 2      | Current of A pulverizer                     | A    | Meter  | 61.7   |
| 3      | Export pressure of A pulverizer             | Pa   | Meter  | 4.3    |
| 4      | Inlet pressure of A pulverizer              | Pa   | Meter  | -8694  |
| 5      | Valve opening of return air door A          | %    | Meter  | 37     |
| 6      | A Flow Rate at the entrance of flour discharger | t/h | Meter | 168 |
| 7      | A pulverizer inlet temperature              | °C   | Meter  | 202    |
| 8      | A pulverizer outlet temperature             | °C   | Meter  | 62     |
| 9      | Negative pressure at inlet of A pulverizer  | Pa   | Meter  | -733   |
| 10     | Negative pressure at exit of A coal mill    | Pa   | Meter  | -1807  |

2.1.4. Coal quality characteristics and pulverized coal fineness during the test. Because of the change of coal market, the coal quality deviates from the original designed coal quality, the operating parameters of pulverizing system must be determined according to the existing coal quality. The industrial analysis of coal into furnace during the test period is shown in Table 3.

Table 3. Industrial Analysis of Furnace Coal.

| Project | Mt | Mad | Aad | Vdaf | FCad | St,ad | R200 Fineness of pulverized coal | R90 Fineness of pulverized coal |
|---------|----|-----|-----|------|------|-------|---------------------------------|---------------------------------|
| Unit    | %  | %   | %   | %    | %    | %     | %                               | %                               |
| Reality | 10 | 3.4 | 16.73 | 31.69 | 54.56 | 0.66 | 9.4 | 32.8 |

2.1.5. Characteristic curve of ball loading of coal mill (Test of relationship between ball loading and current). From no-load to 90% of the design value, the current of the mill and the amount of steel balls in the mill are recorded every time with steel balls. Six working conditions are tested, the diameter of the ball is 60. Running on two coal mills A and C, taking the average value, the test data are shown in Table 4.

Table 4. Test data of ball loading characteristics of coal mill.

| Project                      | Data |
|------------------------------|------|
| Actual ball loading (t)      | 0    |
| 10                           | 20   |
| 30                           | 40   |
| 50                           | 60   |
| Coal mill current (A)        | 36.5 |
| 43                           | 49.4 |
| 57.6                         | 71.2 |
| 83.5                         | 90.5 |
3. Optimizing Reform of Pulverizing System

3.1. Comprehensive Reform of Pulverizing System

3.1.1. According to the grounding test, the existing problems of the equipment were found. The system is checked and eliminated to solve the air leakage of pulverizing system, including the air leakage of the pulverizer body and the air leakage of the air lock, the air inlet door and the air valve in the system. Strengthen the maintenance of the powder conveying winch, improve the operation management system, and prevent the occurrence of powder and spontaneous combustion[5].

3.1.2. Steel ball throwing. The original steel ball has only two kinds of big balls, ø60 and ø40, and the best proportion of adding balls is ø60:ø40:ø30=4:3:3, in order to ensure the filling coefficient of the steel ball in the coal mill, the steel ball is preliminarily added 58T to carry out the optimization adjustment test after repairing.

3.1.3. Deficiency elimination of folding baffle in crude powder separator. The baffle opening of crude powder separator is chaotic and inconsistent inside and outside. The defect of baffle is eliminated to ensure that the baffle opening is consistent inside and outside, and the overall opening is uniform and adjusted to 50 degrees[6].

3.1.4. Reform of Coarse Powder Separator. The original separator structure has bigger problems, especially in inner cylinder structure. When the baffle opening of separator decreases (e.g. the opening is about 30%), it increases the chance of air short circuit, which makes the fineness of pulverized coal difficult to control, the uniformity is poor and the separation efficiency is low[7].

After retrofitting the crude powder separator, anti-wear treatment is done on the outside; the inner cone change into a closed structure, and the vertebral body is made of 16Mn steel plate with 8 mm thickness, and the outer part is made of anti-wear treatment; the crude powder separator adopts an entrance ring guide with twice carrying mode, and the outer part is made of anti-wear treatment, with the thickness of anti-wear layer of 15-20 mm. The aim is to increase the ability of air flow to carry pulverized coal, reduce the content of qualified pulverized coal in the return pulverized coal, and increase the output of the system[8].

After modification, there is no short-circuit phenomenon in the pulverized coal of the crude pulverized coal separator. The baffle opening of the separator can be adjusted to 40%-60%, which can reduce the resistance of the separator and the ventilation rate of the system. Pulverized coal fineness R90 is controlled below 30% and R200 is controlled below 6%.

3.2. Optimization of Operation Mode of Pulverizing System

3.2.1. Increase the inlet temperature of coal mill. Before harnessing, the outlet temperature control of the coal mill is on the low side, which makes the output of drying low. According to the analysis of coal quality, the outlet temperature of the coal mill is controlled in the range of 66-71 degrees C, which does not affect the safe operation, so that the output of the system can be properly increased.

By adjusting the way, the inlet temperature of the mill can be increased to more than 200℃. The output of pulverizing system can be increased and the unit consumption of pulverized coal can be reduced by increasing the coal feed rate, controlling the outlet temperature of the pulverizer not to exceed the temperature and keeping the differential pressure between the inlet and outlet of the pulverizer not less than 1800Pa.

3.2.2. Reduce the outlet air pressure of the pulverizer. According to the experiment, the energy saving potential of the pulverizer is the biggest. The main problems are that the outlet air pressure of the pulverizer is too high (about 4.3 kPa) and the primary air speed is too high (35-39 m/s). High primary
air speed not only increases power consumption, but also causes serious pipeline wear. At the same time, excessive air volume causes coarsening of pulverized coal fineness and poor uniformity. Excessive recirculating air volume and large amount of low temperature air circulating in the pulverizer are unfavorable for increasing the output of the system and greatly increasing the power consumption of the pulverizer.

Adjustment methods: The outlet pressure of the discharger is controlled from 3.5 kPa to 3.8 kPa, and the primary air speed can be controlled at about 30 m/s. Close the opening of the recirculating valve and increase the hot air volume of the system. The opening of the recirculating valve can be controlled at about 10%.

3.2.3. Increase the speed of coal feeder. At present, the stable output of the pulverizing system is 40 t/h. Through equipment improvement and optimization adjustment, the speed of the coal feeder is increased to 300 r/min and the stable output of the pulverizing system is increased to 45 t/h under the condition of constant ball loading.

3.2.4. Determine the fineness of economic pulverized coal. The economic fineness of pulverized coal for burning bituminous coal in a solid slag-discharging pulverized coal furnace is as follows:

\[ R_{90} = 4\% + 0.5nV_{daf} = 4 + 0.5 \times 1.1 \times 31.69\% = 21.4\% \]

Therefore, the fineness of raw pulverized coal (32.8%) is obviously larger, which should be reduced to be close to 21.4%. Considering the actual operation situation, 25% is appropriate.

3.2.5. Determine the optimum load of steel balls.
The optimum filling coefficient is:

\[ \Psi_j = 0.12 \left( nD^{4.23} \right)^{1.75} = 0.1866 \]

Optimum loading capacity of steel balls is:

\[ G_j = \rho g \Psi_j V = 4.9 \times 0.1866 \times 67.35 = 61.6 \]

Before optimization, the loading capacity of steel balls is obviously lower than 45 tons, and the optimum loading capacity of steel balls is 60 tons.

3.2.6. Reduce the air volume of the system. According to the formula of optimum ventilation rate of coal mill, the calculation is as follows:

\[ q_v,z_j = 38V_n D_{10003KV_{T1}} + 36R_{90} KV_{T13} \Psi_j (101.3p)0.5 = 38 \times 67.35 \times 1.75 \times (100031.01 + 36 \times 25) 1.01 \times 30.186 = 118362 \]

The ventilation rate of the original pulverizer is 126 795 m³/h, which is obviously too large, resulting in the coarseness of pulverized coal. The optimum ventilation rate of coal mill is 118 000 m³/h.

3.2.7. Optimizing the operation parameters after modification. After optimization and transformation of the pulverizing system, the optimum operating parameters are shown in Table 5.

| Number | Project                              | Unit | Data |
|--------|--------------------------------------|------|------|
| 1      | Ball loading capacity of coal mill   | t    | 60   |
| 2      | Idle current of coal mill            | A    | 90   |
| 3      | Load current of coal mill            | A    | 105  |
3.3. Revamping Result

3.3.1 The efficiency of crude powder separator is improved. Under the condition of maintaining optimal operation of pulverizer and pulverizer, the efficiency test of the crude powder separator was carried out. The test results showed that the separation efficiency was significantly improved, from 45.5% to 61.8%.

The opening of the original baffle is 30%, the opening of the modified baffle is 40%–50%, and the resistance is reduced from 850 Pa to 600 Pa. The economic performance has been significantly improved.

3.3.2 The system treatment is improved and the unit consumption of coal mill is reduced. Before transformation, the speed of coal feeder is 220-270 r/min and the output of coal mill is 34-43 t/h. By optimizing ball loading and operation mode of coal mill, increasing inlet temperature and differential pressure between inlet and outlet of coal mill, the treatment of coal mill has been improved obviously. The speed of coal feeder is 320-350 r/min, the output of coal mill is 51-55 t/h, and the output of coal mill is increased by more than 30% on average.

3.3.3. The unit consumption of pulverizing is reduced. Reduce the opening of recirculation valve, control the opening within 10%, close the return valve, control the outlet pressure of the powder discharger at 3.5 ~ 3.7 kPa, and the current of the powder discharger obviously decreases. According to the actual operation results, the unit consumption of pulverized coal discharging decreased from 16.15kWh/t to 13.28kWh/t, and that of coal grinding decreased from 17.08kWh/t to 12.70kWh/t.

3.3.4. Reduce primary wind speed and reduce pipeline wear. Reducing the ventilation volume of the system, the inlet air volume of the pulverizer reduces from 126 000 m³/h to 118 000 m³/h, without affecting the output of the pulverizer, and the speed of the coal feeder can run steadily from 320 to 350 r/min.

4. Conclusion

Through the adjustment test of the pulverizing system, the controllable parameters and control mode are changed in a planned way, the operation parameters of the pulverizing system are tested comprehensively, and the economic and safety test results are compared to determine the optimal economic operation mode of the pulverizing system, so that the pulverizing system is always in the best state. In addition, through reforming some equipment of the existing pulverizing system, air leakage is reduced, separator efficiency is improved, and the whole pulverizing system runs economically and safely.
Reference

[1] Li, Q. Gao, S. Xue, Y. (2013) Manual of Energy Conservation and Emission Reduction for Thermal Power Plants [M]. China Electric Power Co. Ltd., Beijing.

[2] Xi'an Institute of Thermal Engineering. (2014) Energy Consumption Analysis and Energy Saving Diagnosis Technology for Coal-fired Generators [M]. China Electric Power Co. Ltd., Beijing.

[3] Xi'an Institute of Thermal Engineering. (2009) Energy Saving and Consumption Reduction Technologies for Power Generation Enterprises [M]. China Electric Power Co. Ltd., Beijing.

[4] Liu, Z. Global Energy Internet [M]. China Electric Power Press, Beijing. pp. 10-39.

[5] Xu, C. (2009) Hybrid Modeling and Optimization of Boiler Efficiency and NOX Emission in Power Station [D]. North China Electric Power University, Beijing.

[6] Gu, L. Li, Y. Li, L. (2015) Prediction of combustion optimization mixing model for utility boilers [J]. Chinese Journal of Electrical Engineering. pp. 35 (9): 2231-2237.

[7] Simon, T.Daphne, K. (2012) Support vector machine active learning with applications to text classification[J]. Journal of Machine Learning Research. pp. 2(1): 45-66.

[8] Asdrúbal, L. Xiaouou, L. Wen, Y. (2014) Support vector machine classification for large datasets using decision tree and Fisher linear discriminant[J]. Future Generation Computer