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Analysis and Research on Influencing Factors of Unscheduled Shutdown of Coal-Power Units

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Abstract: *This paper makes statistics on the unplanned outage and output reduction of coal-fired power generation units directly transferred to a provincial power grid, analyzes the main influencing factors leading to unplanned outage of coal-fired power generation units, and puts forward targeted improvement measures, which lays a foundation for ensuring that the coal-fired power generation units play a role in ensuring supply under the new power system.*

Keywords: *Unplanned outage, Unplanned output reduction, Coal power unit, Influence factor*

1. Introduction

In the process of building a new power system, coal power will be transformed to both basic guarantee and system regulatory power supply[1]. Due to the volatility and randomness of new energy power generation, as well as the small number of pumped storage and new energy storage units, coal motor units are the main force for peak shaving at this stage. At present and in the long run, with the increase of the times of startup and shutdown and deep peak shaving, the safety and operation reliability of coal power units will be greatly affected[2]. Therefore, it is very necessary and urgent to study the factors affecting the operation reliability of thermal power units under the condition of large-scale new energy grid connection.

Based on the statistical analysis of the "unscheduled outage" and "unscheduled output reduction" fault factors of coal power units in a provincial power grid in China in 2019, this paper establishes a set of boiler side fault factors that affect the reliability of coal power units, and makes a special analysis of the main faults, which helps to reduce the occurrence of similar accidents and ensure the safe and stable operation of the power grid.

2. Unplanned Outages of Coal fired Power Generation Units

2.1 Unplanned outage type

Unplanned shutdown can be divided into "trip" and "emergency shutdown". Tripping refers to the deterioration of unit operation status, triggering shutdown conditions and requiring immediate disconnection from the grid. Emergency shutdown refers to the abnormal operation state of the unit, which needs to be shut down within a certain period of time. The time requirement for grid disconnection is relatively loose compared with the trip event. In 2019, 263 unscheduled outages of the provincial grid direct thermal power units occurred, of which "tripping" and "emergency shutdown" accounted for 29.7% and 70.3% respectively. Fig 1 and Fig 2 show the number and proportion of the two.

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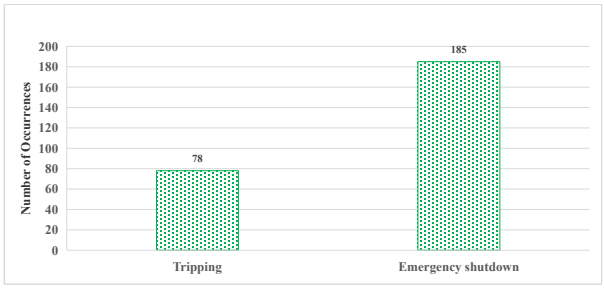

Figure 1: Number of unplanned outage events of different types

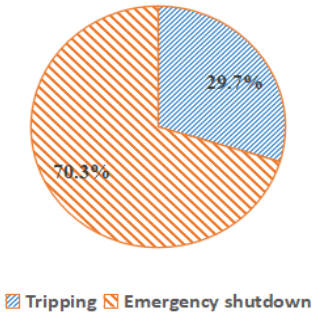

Figure 2: Proportion Number of unplanned outage events of different types

2.2 Statistical analysis of tripping events

Statistical analysis is made on the tripping events of direct thermal power units in 2019. The main reasons for the tripping of thermal power units can be classified into steam turbine, boiler, electrical system and thermal control system according to the equipment ownership. Fig 3 and Fig 4 show the frequency and proportion of all types of events.

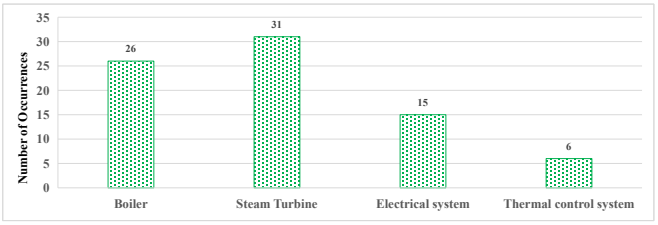

Figure 3: Number of trips of different types

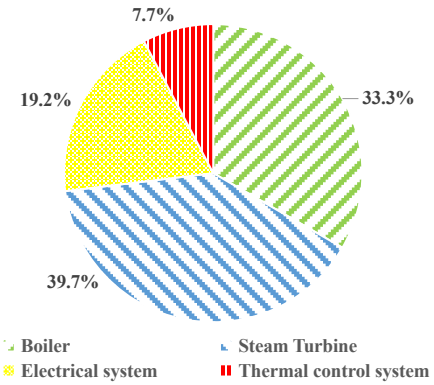

Figure 4: Proportion of different types of tripping events

It can be seen from Fig 3 and Fig 4 that steam turbine causes the largest proportion of unit tripping events, accounting for 39.7%, which is mainly caused by turbine vibration; The tripping events of thermal power units caused by equipment at the boiler side accounted for 33.3%, mainly due to equipment of pulverizing system, combustion system, steam water system and flue gas and air system.

Fig 5 and Fig 6 show the number and proportion of tripping events caused by various systems on the

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boiler side. It can be seen that the combustion system accounts for the largest proportion of the tripping events caused by the boiler side, accounting for 46.2%, which is mainly caused by the fire extinguishing of the boiler and the large fluctuation of the furnace pressure caused by coking and coke loss in the furnace; Secondly, steam water system is the second largest cause of unit tripping at boiler side, accounting for 30.8%, mainly due to unstable water level of steam drum and leakage of heating surface; The unit trip caused by the boiler air and flue gas system is mainly due to the boiler MFT caused by the fan trip, and the unit trip caused by the pulverizing system is mainly due to the imbalance of the boiler water coal ratio caused by the pulverizer trip and coal blockage, the low feedwater flow protection action, and the boiler MFT.

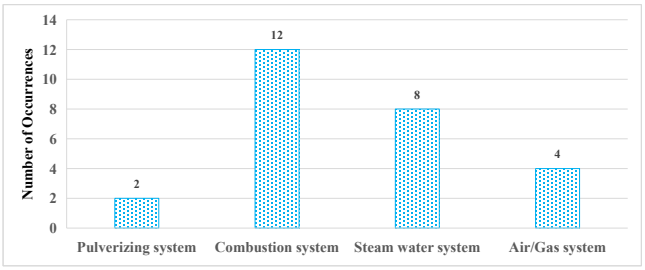

Figure 5: Trip events caused by boiler systems

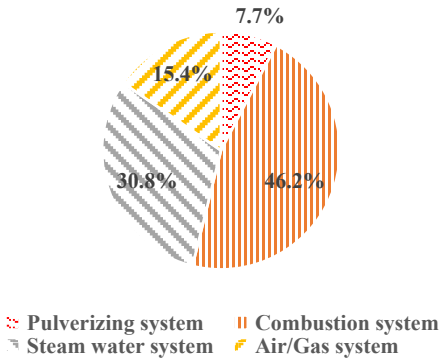

Figure 6: Proportion of tripping events caused by various systems on the boiler side

Through comprehensive analysis, it can be seen that the causes of unit tripping at the boiler side, including coking in the boiler furnace, tripping of pulverizer in the pulverizing system and coal blockage, are mainly caused by poor coal quality.

2.3 Statistical Analysis of Emergency Shutdown Events

Statistical analysis is made on the emergency shutdown events of coal generating units in 2019. Fig 7 and Fig 8 show the frequency and proportion of various types of events.

It can be seen from Fig 7 and Fig 8 that different from the trip events of coal power generation units, the boiler side factor causes the most emergency shutdown events of coal power generation units, accounting for 59.5%. The main faults on the boiler side are caused by leakage of pressure parts and emergency maintenance of equipment.

Fig 9 and Fig 10 show the number and proportion of emergency shutdown caused by boiler side factors. It can be seen that the leakage of pressure parts is the main factor causing the emergency shutdown of the unit at the boiler side, accounting for 74.5%.

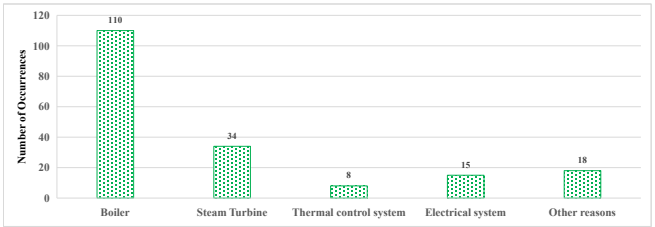

Figure 7: Number of emergency shutdown events

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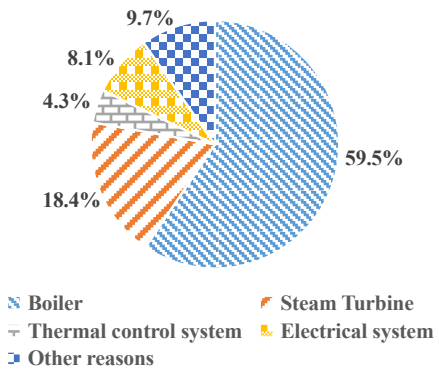

Figure 8: Proportion of emergency shutdown events

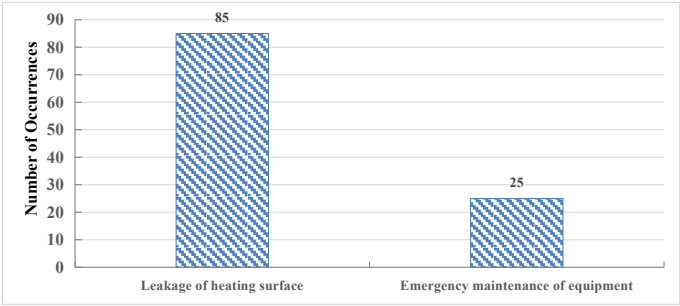

Figure 9: Number of emergency shutdowns caused by different faults on the boiler side

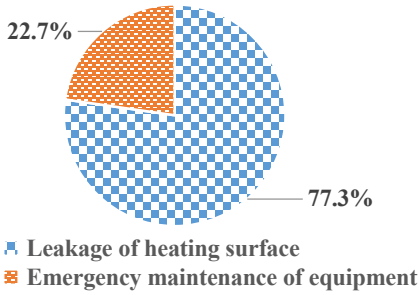

Figure 10: Proportion of emergency shutdown caused by different faults on boiler side

Fig 11 and Fig 12 show the number and proportion of leakage on heating surfaces at different parts of the boiler. It can be seen that the water wall leakage has the highest frequency and proportion, followed by superheater and reheater. Water wall leakage is easy to occur at the location of high temperature corrosion, which is generally related to high sulfur content in coal and strong reducing atmosphere during boiler operation [3-4].

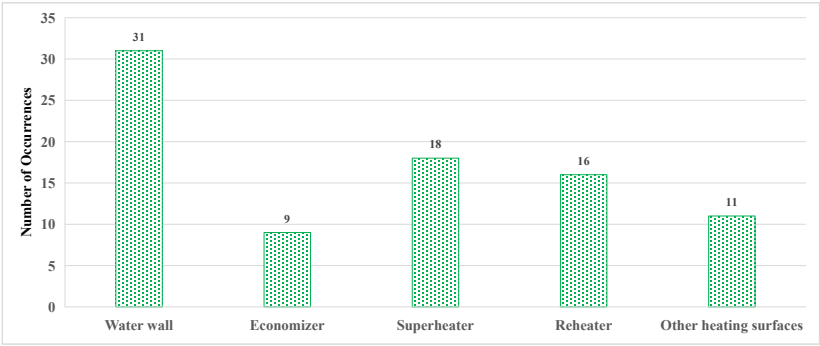

Figure 11: Leakage quantity of different pressure parts of boiler

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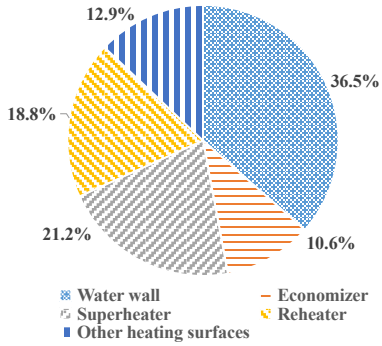

Figure 12: Leakage ratio of different pressure parts of boiler

3. "Unplanned output reduction" event of coal power units

3.1 Statistical Analysis of Factors Affecting the Output Reduction of Coal fired Power Generating Units

In 2019, 664 output reduction events occurred to coal power units in the provincial grid, including 395 output reduction events caused by residential heating and industrial heating, accounting for 59.5%. Fig 13 shows the proportion of output reduction of coal power units caused by other factors except heat supply.

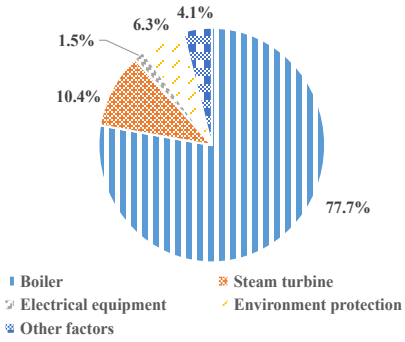

Figure 13: The proportion of output reduction of coal power units caused by other factors except heat supply

It can be seen from Fig 13 that in addition to the output reduction events caused by heating factors, the number of output reduction events caused by boiler side factors is the largest, accounting for 77.7%. Further statistical analysis shows that the boiler side fault factors mainly include pulverizing system equipment, air and flue gas system equipment, coal quality, air preheater and other factors. Figure 14 shows the proportion of output reduction events caused by various fault factors on the boiler side.

It can be seen from Figure 14 that among the fault factors on the boiler side, the number of unit output reduction events caused by coal quality is the largest, accounting for 33.0%; Then the air and flue gas system (25.8%), air preheater blockage (20.1%) and pulverizing system (14.8%); The output reduction event caused by the combustion system in the boiler mainly occurs in the unit equipped with circulating fluidized bed boiler (CFB), because the bed temperature is too high during the operation of the circulating fluidized bed boiler. In order to ensure the safe operation of the boiler, the load reduction operation is required.

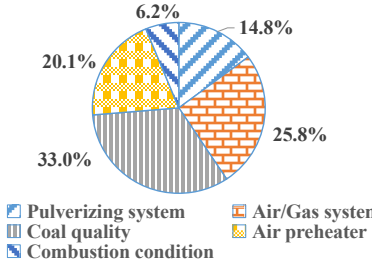

Figure 14: Proportion of output reduction events caused by various fault factors on the boiler side

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3.2 Analysis on the influence mechanism of various fault factors on the boiler side

1) Coal quality

The coal quality is the main factor affecting the unit output reduction at the boiler side. When the coal quality is poor, especially when the calorific value of the coal used is far lower than the design coal, the output of the pulverizer is limited, and the coal required for full load of the unit cannot be met.

In addition, the variable coal quality will also bring the following impacts to the boiler operation: the rise of sulfur content may lead to: a. High temperature corrosion of the boiler and increased coking on the heating surface. b. The low temperature corrosion of the boiler tail heating surface is intensified. c. With the increase of SO_3 generation and ammonia bisulfate generation, the risk of air preheater blockage increases. d. The risk of blockage and low temperature corrosion of low temperature economizer increases. The increase in moisture may result in: a. The combustible components of coal are relatively reduced, the calorific value is reduced, and the ignition heat is increased, so that the ignition is delayed, the temperature in the furnace is reduced, the ignition is difficult, the combustion is incomplete, and the heat loss of mechanical and chemical incomplete combustion is increased. b. With the increase of flue gas volume, the resistance of the tail flue increases, and the output of the induced draft fan increases or even overloads. c. The increase of power consumption for pulverizing may also lead to the binding and blocking of raw coal bunker, coal feeder and coal chute, as well as the reduction of pulverizer output and other adverse consequences.

Since the cost of coal accounts for more than 70% of the operating cost of the power plant, the current situation of coal from multiple sources will not change fundamentally in a short time. Therefore, adopting reasonable coal blending and burning mode is one of the effective means to solve the problem that the coal quality affects the load capacity of the unit.

2) Air/Gas system

The fan and flue gas system account for 25.8% of the failure factors at the boiler side that lead to the unit output reduction, mainly because the fan output is limited or fails, including induced draft fan, forced draft fan, primary fan and booster fan of desulfurization system. Fig.15 shows proportions of unit output reduction caused by various fans.

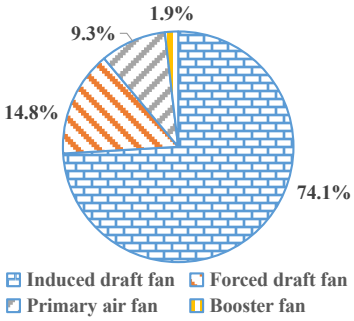

Figure 15: Proportions of unit output reduction caused by various fans

It can be seen that the induced draft fan is the main factor causing the unit output reduction of the air and flue gas system, accounting for 74.1%, followed by the forced draft fan and primary fan. The reasons for the unit output reduction caused by induced draft fan mainly include insufficient output, large vibration, high bearing temperature, and short-term faults (oil leakage, temporary maintenance, moving blade jamming, hydraulic coupler maintenance, frequency converter fault, bearing replacement, etc.). The proportion of various faults is shown in Figure 16.

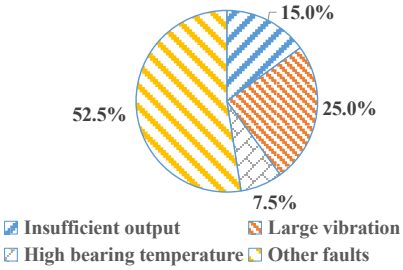

Figure 16: Proportion of various faults of induced draft fan

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It can be seen from Figure 16 that the induced draft fan has the largest number of short-term failures, accounting for 52.5%, followed by fan vibration (25%), insufficient output (15%), and high bearing temperature (7.5%).

Through comprehensive analysis of the above data, it can be seen that the induced draft fan is the main cause of the boiler side air and flue gas system that causes the unit output reduction, and the key is the short-term failure of the induced draft fan, which is highly related to the quality of daily maintenance and repair. In addition, fan vibration is often closely related to the operating point of the fan. When the flue resistance increases and the operating point of the fan deviates from the optimal operating range, the risk of fan vibration will increase; Insufficient output of induced draft fan is also one of the key factors that cause load reduction of the unit, especially when the air preheater is seriously blocked and the resistance of the tail flue is large, the induced draft fan will have full load or overload output for a long time, which will increase the number of short-term failures of the induced draft fan[5].

3) Air preheater

Blockage of air preheater is the third boiler side fault factor affecting unit output reduction, accounting for 20.1%.

Many studies have shown that the main reasons for serious blockage and high differential pressure of air preheater are the performance degradation of upstream SCR denitration system, unreasonable ammonia injection strategy and excessive ammonia escape. The ammonia escape at the outlet of denitration device will react with SO_3 to generate ammonia bisulfate. When the flue gas temperature is lower than the dew point of ammonia bisulfate (generally 147 ℃), the viscous ammonium bisulfate will adhere to the heat storage element of the air preheater, and the air preheater will be blocked due to the adhesion of fly ash. The larger the product of ammonia escape and SO_3 concentration, the easier it is to generate ammonia bisulfate. Therefore, the most effective way to solve the problem of air preheater blockage is to improve the comprehensive performance of SCR denitration system and reduce ammonia escape[6].

4) Pulverizing system

The pulverizing system is another boiler side factor that affects the unit output reduction. The main reasons that the pulverizing system affects the load are the failure maintenance of the pulverizer (large vibration, high bearing temperature), the failure maintenance of the coal feeder and coal blockage.

The main factor causing the unit output reduction of the pulverizing system is the pulverizer failure, followed by the coal feeder failure, and finally the coal blockage of the coal pipe under the raw coal bin (which is greatly related to the moisture content of the coal). Therefore, the effective means to reduce the pulverizing system failure mainly include: strengthening the maintenance of the pulverizer and coal feeder, strengthening the coal blending management, and controlling the external moisture of the coal entering the furnace[7].

4. Conclusion

Large vibration of turbine equipment is the main cause of unit trip. Among the boiler side fault factors that cause unplanned shutdown of the unit, leakage of pressure bearing parts is the main factor that causes emergency shutdown of the unit, and the occurrence of such events can be reduced by strengthening anti wear and explosion-proof management. Residential heating and industrial heating are the main reasons for unit output reduction. The poor coal quality is the main fault factor that causes unit tripping and output reduction at the boiler side. Blockage of air preheater and insufficient output of induced draft fan are closely related to excessive ammonia escape of SCR system. Therefore, optimizing the coal blending method and improving the comprehensive performance of SCR denitration system can effectively reduce the occurrence of unplanned output reduction events.

Acknowledgments

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