Optimization of Air-Coal Distribution System for 1000MW Thermal Power Unit Based on Data Mining

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Abstract. At present, the operation adjustment of the power distribution system of the power station boiler mainly relies on the experience of the operators and the optimization and adjustment test, neither of them can be economically and flexibly adapted to the current situation of complex boiler combustion conditions and strict environmental protection indicators. To reduce the NOx generated by pulverized coal combustion in the furnace, this paper effectively combines the big data mining technology with the boiler combustion system based on the best ratio of coal-air. Taking the double-cut circular boiler designed by a 1000MW thermal power unit as an example, we use Apriori algorithm to mine the association rules in historical operation data and develop software to guide the operation of the operator. By calculating, the NOx content of the SCR inlet after adopting the optimization scheme is reduced by about 17%. Combined with the “cost-benefit analysis of denitration technology” spectrum, the denitration cost is reduced by about 200,000 yuan per month.

1. Introduction
In the power distribution system of power plant boiler burners, the unreasonable air distribution and powder distribution method will not only reduce the economic efficiency of the unit operation, increase the coal consumption of power supply, but also increase the emission of pollutants such as NOx. The industry is actively seeking new ways to optimize the operation of wind and coal. The deep integration of automation and intelligence provides new ideas for the operation optimization of power plant boilers. Datang Nanjing Power Plant cooperated with Southeast University [1]. The intelligent optimization platform launched in 2017 has been launched. The combustion optimization operation management module combines mathematical models and thermal tests. JD used “AI+ Big Data” to reduce costs and increase efficiency for the thermal power industry. In 2019, the first pilot project was carried out at the National Energy Group Nanning Power Plant, which increased the boiler thermal efficiency by 0.5%.

In the power station burner air and powder distribution system, the unreasonable air and powder distribution mode will not only reduce the economic operation of the unit, but also increase the coal consumption of powder supply. At present, most thermal power plants still adopt the following air and powder distribution optimization adjustment mode [2].

a. Rely on the experience of the operating staff. However, the adjustment range fluctuates greatly and has regulation lag.
Through boiler combustion and pulverizing system optimization adjustment test. The effect is good, but time and energy consumption, and as time goes by, many factors change, the adaptive adjustment ability is not good.

In view of the above shortcomings, to decorate with double tangential burner in the four corners of a certain power plant 1000 MW thermal power unit as an example, using Apriori algorithm, from the historical data mining operation, the best wind coal ratio optimization scheme, and develop software, online guide for optimal operational personnel, in order to improve the running efficiency, reduces the power supply coal consumption and emissions of nitrogen oxides.

2. Data mining algorithm

In the historical operation of the database from DCS system, data preprocessing and data coding are firstly carried out, data mining is conducted through Apriori algorithm [3], and finally, the performance index of air and powder distribution is used to judge the optimization scheme of air and powder distribution, thus forming a benchmark database.

2.1. Data pre-processing

1. Unsteady data rejection: When the load variation is greater than 50MW, reject this condition.
2. Bad point data rejection: When the temperature of the superheater is greater than 600 degrees, reject the short-time over-temperature condition; if the sensor measurement error occurs, data with less than 0 is regarded as 0.

3. Data symbolization coding: traverse data samples to find the maximum and minimum parameters, then discretize and program continuous data. The rough partition is divided into five, and the fine partition is divided into ten.

| original data | 1      | 2      | 3      | 4      | 5      | 6      | 7      |
|--------------|--------|--------|--------|--------|--------|--------|--------|
| Symbol       | 1001   | 1001   | 1002   | 1003   | 1004   | 1005   | 1004   |

2.2. Apriori algorithm optimization process

With the SCR inlet NOx content as the optimization condition, the support degree and confidence are the evaluation criteria of the degree of association.

Set variables: N-SCR inlet NOx content record, M-6 coal mill output record, F-25 damper opening record, R-burner swing angle record, S-SOFA wind swing angle record.

i. Screen out all lower N operating conditions;
ii. Associate $N$ and $M$, filter out frequent itemsets that satisfy the support and confidence, and use them as candidates for the next step $\{S, M\}$;

iii. Associate $\{N, M\}$ and $F$, and filter out frequent itemsets that satisfy the support and confidence, and serve as candidates for the next step $\{N, M, F\}$;

iv. Associate $\{N, M, F\}$ and $R$, and filter out frequent itemsets satisfying support and confidence, and as candidates for the next step $\{N, M, F, R\}$;

v. Associate $\{N, M, F, R\}$ and $E$, and filter the frequent itemsets that satisfy the support and confidence, and get the benchmark values $\{N, M, F, R, E\}$. The benchmark value $\{N, M, F, R, E\}$ is used as the optimal air distribution formula for this specific load, coal type and ambient temperature.

2.3. Selecting the best conditions

Finally, the benchmark value is obtained from multiple sets of qualified optimization combinations through comprehensive criteria, and a three-level database is established to store the benchmark value.

| Table 2. Three-level benchmark database |
|----------------------------------------|
| load | 60% | 80% | 100% |
| Coal type | Coal A | Coal B | Coal A | Coal B | Coal A | Coal B |
| Ambient temperature | T1 | T2 | T1 | T2 | T1 | T2 |
| Air-coal ratio | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 |

3. Software development

![Software system structure diagram](image)

Figure 2. Software system structure diagram

The overall structure of the software is shown in Figure 2.6 and Figure 2.7. The system adopts the layered design idea, which is divided into data layer, processing layer and display layer in a macroscopic way, and adopts modular development, and finally provides operational guidance and optimization suggestions for the operating personnel.

i. Data processing module

This module realizes the receiving, converting, filtering and storing of real-time data, and calls the benchmark database under similar working conditions. Finally, the real-time data and optimized data are simultaneously displayed to the visual interface.

ii. Timing module

When the software is initialized, a timing process is created, and the data processing module and the data display module are controlled by the timing process, thereby realizing dynamic calling and dynamic display of data.
iii. Data display module
The data display module includes two parts: form beautification and data display. The data display mainly uses the chart control, the label control and the custom control, and the form beautification inherits the CSkin interface library.

4. Innovation
The data mining algorithm big data technology is ingeniously coupled with the wind power distribution system of the thermal power plant.
1. Using quadratic coding, 34 variables are converted into 5 variables, which reduces the processing load of the computer and improves the mining speed.
2. Set a small degree of support, the optimal working condition is generally a small probability event. If the support degree is too large, it will filter out the better working conditions, which is a major feature different from other areas of data mining.

5. Application

5.1. Functional simulation test
1. Applicability considerations: Data mining is applicable to pit-mouth power plants with less fluctuations in coal types or large units with less load changes and infrequent peaking. The 1000MW thermal power unit generally does not need to participate in peak shaving, and the load operation is about 60% 80% 100%. The same load can be maintained for several hours, which is relatively stable, which is good for data mining.
2. Accuracy considerations: Reject the severe unsteady conditions, divide the load variation greater than 50 MW into two operating conditions. Because of the large variable operating conditions, safety is prioritized rather than economical and environmentally friendly.
3. Safety considerations: Considering the start and stop of the unit and eliminating the hidden dangers such as unstable combustion and overheating of the superheater during the data cleaning process.
4. Feasibility considerations: Since denitrification is a process with a certain reaction time, the adjustment has hysteresis. (The lag time is about seven minutes), the optimization is given for a certain data range, rather than for a certain data. If the interval setting is too small, the adjustment would be too frequent, while if the interval setting is too large, the accuracy is poor.
Sample boiler equipment parameters: Shanghai Superbial Transformer DC Pulverized Coal Furnace, model SG-3103/27.46-M536, type: single furnace, double tangent, one intermediate reheat, π type coal powder In the case of BMCR, the main and reheat steam temperature is 605 °C / 603 °C, and the main and reheat steam pressure is 27.46 MPa / 5.86 MPa. The boiler can carry the basic load and participate in peak shaving, and the design coal type is Wangzhuang lean coal.
The sample data is derived from the DCS system: the historical operation data of the power plant units from December 2018 to February 2018 is used for mining.

5.2. Comprehensive benefit assessment
5.2.1. Environmental benefits

\[ \text{NOx production amount} = \text{NOx density} \times \text{smoke flow rate} \times \text{time} \]

According to the above formula, the 1000MW thermal power unit is under lean coal, 850MW load, and the ambient temperature is 25°C. According to the data of three months, the NOx reduction before and after optimization is 17%, and the monthly emission reduction is 204.168 tons.
5.2.2. Economic benefits. According to the literature [4], the denitrification rate is 90%, the SCR inlet NOx concentration is 600mg/Nm3—400mg/Nm3, and the denitrification cost is reduced by about 1,000 yuan per ton, saving 200,000 yuan per month.

6. Conclusion
Data mining is one of the feasible methods for boiler operation optimization. For different application environments and different types of boilers, the software has wide adaptability and popularization. Through the comprehensive application of big data mining technology to achieve intelligent optimization control, intelligent decision support, etc., the enterprise assets are optimally distributed, the production quality is optimally controlled, and economic and social benefits are optimally realized.

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