Development and application of energy saving evaluation system based on energy consumption management platform

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Abstract. Based on energy consumption management platform, this system can do performance monitoring, energy consumption analysis, operation optimization, optimal load dispatching, information statistics, on line evaluation of energy saving reconstruction and comprehensive analysis of power plant. This system adopts open, standard and distribution structur, it also supports data long-distance supervise, management and long-distance upgrade and servicing. It makes sharing of the whole enterprises production management information possible, each de partment can access the overall information timely in order to make the right judgment and decision. This system has become a sharp tool of digital Working method advocated by a power generation company, and the company has carried out a lot of effective energy saving and consumption reduction work, and improve the economy, safety and management level.

1. Introduction

With the further development of the competition mechanism in the power market, UHV power grids have been gradually built, and wind power, solar power, nuclear power and other clean energy sources have been accessed on a large scale, the utilization hours of thermal power units have been declining year by year, and the operating pressure of thermal power enterprises has been further aggravated. So thermal power enterprises need to reducing power generation costs and saving energy, improving the economics of unit operation.

Aiming at the current actual situation of thermal power enterprises, construct an energy-saving evaluation system based on energy management platform that integrates data monitoring and analysis, operation optimization, load optimization scheduling and energy-saving evaluation of power plant production processes, and finds scientific and reasonable evaluation of power-saving direction of power plants. The main elements and methods form a simple and practical scientific evaluation system to meet the needs of energy-saving management of power plants, realize effective economic improvement of the unit, green power generation and sustainable development.

Two 1030MW ultra-supercritical units put into commercial operation at the end of 2010. Since its inception, the energy management platform and energy-saving assessment system have become the weapon of the “digital work method” advocated by the power generation company. With this system as the support, the company has carried out a lot of effective energy-saving and consumption-reducing...
work, and improved the operation management level and Economic benefits, reducing net coal consumption about 1.2g/kW.h.

2. Domestic and foreign technical status

2.1. Status of foreign technology
At present, the focus of foreign research is on constructing the mathematical model of power plant equipment, successfully developing monitoring technology based on mechanistic mathematical model, and on this basis, it has developed into a software platform for power station performance monitoring, so as to monitor and optimize the performance of power plants. The power plant that use mechanistic model monitoring technology has obtained significant economic benefits. This monitoring technology has become the mainstream method for performance monitoring of foreign power stations.

Foreign technology is mainly used in control integrated power generation in China. Its performance and optimized analysis data directly serve the DCS system. The advantage of the foreign technology is that the energy saving effect is relatively straightforward; the disadvantage is that the system updating is difficult after the measuring point or equipment is changed, the function is relatively simple, and the system security requirement is higher.

2.2. Status of domestic technology

2.2.1. Platform. Although most products or technologies have a publishing platform, there are not many independent computing platforms and matching distributed modeling methods, and there is not enough support for model maintenance, post-expansion and sustainable maintenance.

2.2.2. Application. The products or technologies applied by most thermal power enterprises mainly focus on performance monitoring and analysis, optimization of operating parameters, and there are not many functions in unit operation mode optimization and energy conservation assessment, while the latter has more importance and potential in energy saving and consumption reduction.

In addition, due to the defect of source data and update late of the optimized reference value caused by the update of the measuring point and the equipment modification, the system cannot be stably operated for a long time. There are some other problems, such as the product is immature, the utilization rate of the functional module is low, and the subsequent maintainability is poor. So, specialized, platform-based, standardized and open technologies is the key of the project.

3. Technical principles and characteristics
Domestic and foreign research on the thermal system monitoring and optimization of coal-fired units began with the energy-saving theory of power station systems. There are three main types of methods currently used:

The first type is the conventional heat balance method. The cyclic function method and matrix method are all developed on the basis of this method. The method is characterized by reliable results and complicated calculation, but local quantization is difficult;

The second type is the equivalent enthalpy drop method, which is based on the principle of thermodynamic thermal work, taking into account the characteristics of equipment quality, thermal system structure and parameters, to study the thermal conversion and energy utilization degree. The equivalent enthalpy drop method can be used for the calculation of the overall thermal system, or for the local analysis and quantification of the thermal system.

The third category is the theory of thermal economic perturbation. Its main idea is graph theory. Each device component is regarded as a node, and the two nodes are used to represent various flows, but the internal information of the node and some details are ignored. This method which based on economic theory has a wide range of versatility. Although it can guarantee the accuracy of calculation mathematically, it cannot give a physical explanation.
The technology adopts the heat balance method and the equivalent enthalpy drop method. The heat balance method is mainly used for the calculation of the performance index. The equivalent enthalpy drop method is mainly used for the energy consumption analysis of the operating parameters and performance indicators and the energy conservation evaluation of the equipment and system.

4. System structure
It includes data acquisition layer, data analysis layer and data display layer. It adopts open, standard and distributed structure, B/S mode deployment, and supports remote monitoring and management of data and remote upgrade service and maintenance of the system.

The data acquisition layer adopts PI real-time database with large storage capacity and advanced data compression method, which is used to store and manage real-time data and performance calculation and analysis data of all production processes, and implement unified management. It is the basis of real-time information.

The data analysis layer adopts an open NCE network computing platform. The professional model is separated from the application. There is an independent model editing and operating environment. The professionals in the development phase and later operation and maintenance do not need to understand complex software programming. Only configuration is required. Apply the model to completely distinguish the black box model from other systems.

The data display layer uses the configuration tool of the database to create the screen, the report management system produces the report, and finally publishes it to each terminal computer through the web to realize the sharing of production management information of the whole enterprise. All management and production departments can make accurate judgments and decisions based on the production management information. The system structure is showed in Figure 1.

5. Main functions
According to the current technical conditions of the power plant and relevant industry standards, the sharing of production information and management information is realized. The system is completely platform-based and easy to configure, use and extend. The main functions of the system are as follows:

5.1. Data Detection and Processing
Data is the core of informatization, affect the results of online performance calculations and the value of the system directly. This function can meet the requirements of data continuity and eliminate abnormal data timely through filters, statistics, simulation and other processing on real-time parameters,
and automatically replaces and alarms of measuring point anomalies and parameter over-limits. Abnormal data is automatically saved in a relational database and can be queried at any time.

5.2. Performance calculation and real-time monitoring
According to the DCS data and offline data, the boiler, steam turbine and unit operating parameters and performance indicators are calculated and monitored in real time, and the reasons for the deviation of the main performance indicators from the design value or target value are comprehensively analyzed. This function includes data sheets, flow charts, histograms and trend graphs of main operating parameters and performance indicators.

5.3. Energy consumption analysis
Analyze and evaluate the energy consumption caused by parameter changes, abnormal working conditions, improper operation, equipment start-stop, etc., and calculate a reasonable target value according to the current operating conditions of the unit. The operating personnel calculate the energy saving potential of the thermal system according to the deviation of actual value and target value, and adjust to ensure that the unit operates in the best way to achieve energy saving.

The key of the energy consumption analysis is to determine the target values of the operating parameters and performance indicators of the unit under variable operating conditions. This system uses design values (such as main steam temperature and reheat steam temperature), theoretical calculation values (such as condenser vacuum), and working condition analysis method, and the working condition analysis method is the main method.

In order to comprehensively analyze the energy consumption status of the unit, the energy consumption navigation function was developed. The difference between the positive and negative consumption is determined by the color of the data. The various indicators and operating parameters affecting the coal consumption of the unit are analyzed. Calculate the distribution and size of energy consumption, to find the potential of energy saving and consumption reduction.

5.4. Energy consumption distribution
The power plant is a black box for converting primary energy (raw coal) into advanced energy (electric). Produce the largest amount of electric energy with the minimum amount of standard coal consumption is the target of the power plant.

The energy consumption distribution mainly includes the main engine energy consumption and the auxiliary machine energy consumption. It can intuitively understand the main engine energy distribution and the power consumption rate of the main auxiliary machine.

5.5. Low-pressure economizer economic evaluation
The low-pressure economizer adopts the hybrid mode, and the water is taken from the #8 low-pressure heater inlet and the #7 low-pressure heater outlet, and is heated back to the #6 low-pressure heater inlet by the flue gas of the boiler.

The low-pressure economizer is used as a comprehensive utilization of flue gas waste heat, and the boiler thermal efficiency will not be affected. The heat of the exhaust gas is recycled to the thermal system by the low-pressure economizer, which is a standard external heat entry problem, and its economy is analyzed by the equivalent enthalpy drop. The low-pressure economizer absorbs the waste heat of the flue gas, which will squeeze the steam turbine to extract steam and increase the steam turbine's function. The influence of the change in the resistance of the induced draft fan and the condensate pump on the static pressure difference is calculated to evaluate the impact on the power consumption of the plant.

The thermal economy of the low-pressure economizer depends on the heat load and the extraction efficiency of the heater. Under the premise that the unit load and the supply and return points have been determined, the extraction efficiency of the heater does not change much. Therefore, the main factor affecting the economics of the low-pressure economizer is the heat load. Figure 2 is a characteristic
curve of a low pressure economizer. It can be seen from Fig.2 that with the increase of the water flow Gdsm of the low-pressure economizer, the outlet flue gas temperature Jdsmo is gradually reduced, and the outlet water temperature tdsmo is also gradually reduced, resulting in the economizer consumption difference Δbgdsm first decreasing and then increasing. The Gdsm at the lowest point of Δbgdsm is the optimum economizer water flow.

Figure 2. Characteristic curve of low pressure economizer

The optimal economizer water flow is related to the unit load. Under the premise of ensuring the safe and stable operation of the unit, the opening of the low-pressure economizer bypass door is adjusted according to the change of the unit load, so that the economizer water flow reaches the optimal value. Optimize the operation mode of the low-pressure economizer to make the unit operate economically the highest.

5.6. Analysis of working conditions

The functions of main operating parameters and performance indicators and load correlation analysis are provided based on optional factors such as load change rate, load stabilization time, circulating water inlet water temperature, etc. The load characteristic curve and the coefficient of the polynomial are determined to determine the economic load of the unit. Provide a basis for optimizing parameter target values and load optimization allocation.

5.7. Soot blowing optimization

The ash buildup on heating surface is an important factor affecting the safety and economy of the boiler. After the ash buildup on heating surface, the heat transfer efficiency is reduced, the heat absorption at each level is reduced, the temperature of the flue gas is increased, and the thermal efficiency of the boiler is reduced. On the other hand, the wall temperature of the heated surface is increased, which may cause the heated surface to burst. At present, most power plants use regular soot blowing based on operating experience. This kind of soot blowing method lacks the necessary flexibility, which may cause excessive purging to increase the erosion of the heated surface metal, shorten the service life of the tube bundle, or cause the flue gas to be insufficient due to soot blowing. As the temperature rises, the thermal efficiency of the boiler decreases.

It is difficult to formulate an optimized soot blowing scheme based on experience, so it is necessary to use a visual soot blowing method to calculate the cleaning factor and ash pollution factor of low-temperature-superheater, low-temperature-reheater, economizer and air preheater.

5.8. Condenser cold junction optimization

Condenser vacuum has a great influence on the heat consumption of the steam turbine and the output of the unit. Through the real-time monitoring and analysis of the cold junction, it is judged whether the
main economic indicators such as vacuum, terminal temperature difference, undercooling, cleaning coefficient and circulating water temperature rise are whether normal. Quantitative analysis of the main factors affecting the performance of the cold junction, proposed performance diagnostic methods of equipment or systems, combined with the operation of the cold junction system to optimize the operation mode of the condenser.

5.9. Circulating pump operation mode optimization
The optimal operation theory of the circulating water pump is that the unit increases the flow rate of the circulating water to increase the output of the steam turbine unit under the condition that the electric load and the circulating water inlet water temperature are constant. The increase of circulating water flow requires to increase the number of circulating water pumps, which will result in an increase in the power consumption of the circulating water pump. The vacuum when the difference between the output increase of the unit and the increase of the power consumption of the circulating water pump is the largest is the optimal operating vacuum. At this time, the pump operation mode is the best operation mode.

The circulating water pump of a power plant has five kinds of adjustment methods: single pump high speed, one high one low, two high, two high one low and three high. According to the relationship between the vacuum of the condenser and the operation of the pump, by analyzing the relevant influencing factors, the optimal operation mode of the pump according to the current load and the ambient temperature is automatically given to achieve the purpose of energy saving.

5.10. Load optimization allocation and economic dispatch
Under the conditions of meeting the load regulation requirements of the power grid, the maximum and minimum output of the unit, and the load response capability, the safety operation status of the main and auxiliary equipments is comprehensively considered. The numerical analysis method and the working condition analysis method are used to determine the power supply of each unit. The load characteristics of coal consumption rate, reasonable distribution of the output of each unit in the transport unit, so that the whole plant power consumption or comprehensive power generation costs are the lowest. Its main functions include: data acceptance, load distribution, data release, power generation security monitoring and assessment modules.

In view of the fact that the current grid dispatching is mainly based on the “scheduling to unit” mode, when the system is in the “scheduling to plant” mode, the total output data of the whole plant is obtained from the real-time database, and optimized according to the performance, coal price and constraint conditions of each unit. The total output of the whole plant is distributed to form the optimized output of each unit, and the result is written into the real-time database to realize optimal load distribution and economic dispatch. The Load Distribution Module does not work when the system is in the Schedule to Unit mode.

5.11. Statistical Analysis of Information
Multi-dimensional analysis and mining of real-time data and historical data, and the combination of real-time data and management data to form comprehensive decision support information and plant-wide production data reports. Keep abreast of the current, daily, monthly and annual report indicators of the whole plant and each unit, quickly benchmark the thermal economy and important thermal parameters of each unit, and find the differences between the units to save energy and reduce emissions. Provide evidence.

6. Technical characteristics

6.1. Openness and standardization
Strictly follow national standards and industry standards, and pay attention to the standardization and standardization of software and hardware selection and interface. In the network architecture, software
and hardware platform, data communication, security control, etc., it fully reflects the advanced and open system, and at the same time selects standard and mature technology to ensure that the basic platform and application software are open, interoperable and Scalability and manageability.

6.2. Platform modeling method
With the help of the expert modeling and debugging functions provided by the NCE network computing platform, it has the characteristics of simple use, high modeling efficiency, good openness, and convenient expansion and maintenance.

6.3. Data acquisition is real-time, complete, accurate and reliable
Real-time, complete, accurate and reliable data collection is the fundamental requirement of the system. Only by satisfying these four factors can the application software be trusted and available.

6.4. Application software mature and practical
Application is the key. The system integrates many experts' thoughts and experiences in power plant operation and management, and the degree of practicality and energy saving effect are excellent.

6.5. LAN (or INTERNET) remote maintenance and operation guidance
Through the LAN (or INTERNET) and developers to achieve remote maintenance and expert operation guidance, fully embodies the developer's purpose for production, service for power production.

6.6. Extremely scalable
Full consideration of the applicability of the system, providing space for future system expansion, while considering the secondary development and service of the product, is the key to successful implementation.

7. Conclusion
The establishment of an energy-saving evaluation system based on the energy management platform should be based on the overall situation of the enterprise, comprehensively consider and plan the whole plant data, embody the close combination of application and management, and highlight the openness, standardization and functional practicability of the technology. At the same time, we must select standard and mature technology to ensure the interoperability, scalability and manageability of the basic platform and application software. As a system of cross-departmental application and multi-disciplinary cooperation, only the leadership attaches importance to management, the management is in place, the multi-level technical training, and the systematic application of the system application into the daily work process is the key to the success of the project.

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