Engineering Technology Trends Vol 2 Issue 5 2024

Original Research Article

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Research on the Application of Intelligent Control in Thermal Automation of Thermal Power Plants

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Abstract: This paper delves into the application of intelligent control in the thermal automation of thermal power plants, focusing on its role in optimizing boiler combustion, superheat temperature control, and full-range control of boiler feedwater. By integrating high-precision sensors, data processing algorithms, and intelligent decision-making logic, the intelligent control system achieves real-time monitoring, precise analysis, and intelligent decision-making for the entire production process of thermal power plants, significantly enhancing operational efficiency, energy-saving capabilities, and economic benefits. Additionally, the paper proposes specific application measures for intelligent control in boiler combustion control, such as data-driven model construction, real-time monitoring and feedback adjustment, and predictive control strategies, providing references for the intelligent development of thermal power plants.

Keywords: Intelligent control; thermal automation of thermal power plants; application

1. Overview of Thermal Optimization Control

In the map of energy conversion and supply, thermal power plants occupy a pivotal position, they use coal as the main fuel, through the complex thermal cycle process to convert chemical energy into electrical energy, supplying electricity demand in all areas of society. However, this conversion process is often accompanied by huge energy consumption and environmental pollution problems, especially in the increasingly tight coal resources today, to improve the operational efficiency of thermal power plants and energy saving and emission reduction capacity has become a key issue to be resolved. Thermal optimization control, as an important technical means to achieve this goal, its core lies in the production process of thermal power plants through the fine regulation of thermal parameters and intelligent management, in order to optimize the combustion efficiency, reduce energy losses, and improve the quality of power generation. These thermal parameters include, but are not limited to, boiler efficiency, unit load distribution, main steam pressure and temperature, feedwater flow and speed, etc., which are directly related to the overall operational efficiency and economy of thermal power plants. Traditionally, thermal power plants have used distributed control systems (DCS) to manage the production process. Although automated control has been achieved to a certain extent, its limitations have

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gradually emerged in the face of increasingly complex and changing power generation demand and energy saving and emission reduction targets. With the rapid progress of information technology, especially the integration of big data, cloud computing, artificial intelligence and other cutting-edge technologies, thermal optimization control has ushered in unprecedented development opportunities. The modern thermal optimization control system realizes real-time monitoring, accurate analysis and intelligent decision-making of the whole production process of thermal power plants by integrating advanced sensing technology, data acquisition and processing technology, model prediction and optimization algorithms[1]. It is not only able to dynamically adjust the control strategy according to the real-time operating data, optimize the boiler combustion process to ensure that the main steam parameters are in the best state, but also through the optimal distribution of load, waste heat recovery and reuse and other means to minimize energy consumption and emissions, to achieve a win-win situation for both economic and environmental benefits.

2. The Role of Thermal Automatic Control System in Thermal Power Plant

2.1 Expansion of Management Information System

One of the primary roles of thermal automatic control systems in thermal power plants is to significantly expand the functions and scope of the management information system. By integrating advanced sensors, data acquisition and processing units, and intelligent control algorithms, the system can collect and process massive amounts of data from the operation of thermal power plants in real-time and accurately, including but not limited to boiler combustion status, steam parameters, and equipment operating conditions. This data provides operators with an intuitive monitoring interface and helps management gain insights into potential issues in the production process, optimize resource allocation, and improve decision-making efficiency through advanced analysis functions. Moreover, the thermal automatic control system can seamlessly connect with enterprise ERP, CRM, and other management systems, achieving deep integration of production data and management information, further enhancing the overall operational management level of thermal power plants.

2.2 Application of Thermal Automatic Regulation Theory

The core of thermal automatic control system lies in the application of automatic regulation theory. The theory is based on thermodynamics, cybernetics and other interdisciplinary knowledge, through the construction of accurate mathematical models and algorithms, to achieve the automatic regulation and optimization of the production process of thermal power plants. In actual operation, the system is able to automatically adjust key parameters such as boiler combustion intensity, steam flow rate, water feed rate, etc. according to the preset control objectives and current operating status, ensuring that the unit operates in a safe, economic and efficient state. This automatic adjustment ability not only reduces the labor intensity of the operating personnel and improves the work efficiency, but also significantly reduces the risk of human error and ensures the safe and stable operation of the thermal power plant.

2.3 Contributing to the Accumulation of Advanced Algorithm Modules

The continuous operation and optimization of thermal automatic control systems contribute to the accumulation of valuable advanced algorithm module resources for thermal power plants. These algorithm modules are the core of the system's intelligent decision-making and automatic regulation capabilities. Based on a large amount of historical operational data and expert experience, they are continuously optimized and upgraded through advanced technologies such as machine learning and data mining. As algorithm modules accumulate and improve, the system can more accurately predict the performance changes of units, detect potential faults in advance, and formulate effective preventive measures[2]. At the same time, these advanced algorithm modules provide strong support for the customized transformation and technological innovation of thermal power plants, promoting the development of thermal power plants towards intelligent and refined management.

3. Application of Intelligent Control in Thermal Automation of Thermal Power Plants

3.1 Boiler Combustion Process Control

The application of intelligent control in the thermal automation field of thermal power plants is increasingly widespread, particularly in the control of the boiler combustion process. The boiler combustion process in thermal power plants is a highly complex and variable aspect that directly affects the overall operational efficiency and environmental emission levels of the power plant. Traditional boiler combustion control methods mainly rely on the experience and adjustments of operators, making it difficult to achieve optimal control. The introduction of intelligent control provides a more refined and efficient control method for the boiler combustion process. By integrating advanced sensors, data processing, and artificial intelligence technology, the intelligent control system can monitor various parameters such as temperature, pressure, and gas composition within the boiler in real-time and automatically analyze the current combustion state based on this data to quickly make control decisions. For example, by adopting neural network algorithms or fuzzy control logic, the system can dynamically adjust combustion parameters such as air-fuel ratio and furnace purge intensity based on changes in external conditions such as fuel quality and load demand to achieve optimal combustion efficiency and emission standards. During system operation, historical data and operational experience are continuously collected and learned, gradually optimizing control strategies, making boiler combustion process control more precise and reliable. This not only helps reduce energy consumption and pollutant emissions of the boiler but also significantly improves the production economic efficiency and environmental protection level of the thermal power plant.

3.2 Boiler Superheat Temperature Control

The application of intelligent control in thermal automation of thermal power plants, especially in boiler superheat temperature control, demonstrates its outstanding performance and advantages. Boiler superheat temperature is a critical parameter in thermal power generation, directly affecting the operational efficiency and safety of steam turbines. Traditional superheat temperature control methods often rely on PID controllers, but their regulation effects are often suboptimal when dealing with complex and variable conditions. By integrating advanced sensor technology, real-time data processing capabilities, and intelligent algorithms, the intelligent control system can monitor the temperature at the boiler superheater outlet in real-time, comprehensively considering multiple influencing factors such as fuel quantity, feedwater quantity, and air quantity for precise calculation and analysis[3]. Based on this data, the system can automatically adjust control methods such as desuperheating water flow and burner tilt to achieve precise control of the superheat temperature. It can automatically adjust control strategies based on historical operating data and current operating conditions to meet different operating needs. At the same time, through predictive models, the system can anticipate changes in superheat temperature in advance and take control measures in advance to avoid adverse effects of temperature fluctuations on unit operation.

3.3 Full-Range Control of Boiler Feedwater

The in-depth application of intelligent control in the thermal automation field of thermal power plants, particularly in the full-range control of boiler feedwater, has greatly enhanced the system's stability and operational efficiency. Boiler feedwater control is a key link in the thermal system of thermal power plants, aiming to ensure stable boiler water levels, meet the demand for steam load changes, and minimize the energy consumption and wear of feedwater pumps. Traditional boiler feedwater control systems mainly rely on PID controllers, but they often struggle to respond accurately and quickly when faced with complex conditions such as rapid load fluctuations or changes in fuel quality, resulting in significant water level fluctuations and suboptimal control effects. The introduction of intelligent control provides an effective solution to this problem. The intelligent control system integrates a high-precision sensor network, advanced data processing algorithms, and intelligent decision-making logic, achieving comprehensive monitoring and precise control of the boiler feedwater process. The system can collect multiple key parameters such as boiler water level, steam flow, and feedwater flow rate in real-time and use data analysis and predictive models to accurately assess current operating conditions and future trends. Based on this information, the system can automatically adjust the speed of feedwater pumps or valve openings to ensure that the boiler water level remains near the set value while optimizing the distribution of feedwater flow, improving the overall efficiency and response speed of the thermal system.

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It can continuously accumulate historical operational data, learn and identify optimal control strategies under different conditions, gradually optimizing control parameters and algorithms to adapt to the changes and needs of long-term operation in thermal power plants. This continuous optimization capability makes full-range control of boiler feedwater more intelligent, efficient, and reliable.

4. Application Measures of Intelligent Control in Thermal Automation of Thermal Power Plants

4.1 Boiler Combustion Control

The application of intelligent control in the thermal automation of thermal power plants is crucial for enhancing the precision and efficiency of boiler combustion control.

4.1.1 Data-Driven Model Construction

Using big data technology and machine learning algorithms, historical data from the boiler combustion process is deeply mined and analyzed to construct precise mathematical models of the combustion process. These models can accurately reflect how factors like fuel characteristics, burner layout, and air-to-fuel ratio impact key indicators such as combustion efficiency and pollutant emissions.

4.1.2 Real-Time Monitoring and Feedback Adjustment

An advanced sensor network is integrated to monitor various parameters of the boiler combustion process in real-time, including furnace temperature, flue gas composition, and fuel flow. The intelligent control system evaluates the current combustion state based on real-time data and compares it with preset targets, automatically adjusting control parameters like fuel supply, air-fuel ratio, and burner angle to achieve optimal combustion outcomes[4].

4.1.3 Predictive Control Strategy

By combining historical data with current operating conditions, predictive control algorithms are used to forecast the boiler's combustion state over a future period. Based on these predictions, control strategies are adjusted in advance to effectively manage uncertainties such as load changes and fuel quality fluctuations, ensuring a stable and efficient combustion process.

4.1.4 Self-Learning and Optimization Mechanism

The intelligent control system features self-learning and self-optimization capabilities. During operation, the system continuously collects and analyzes operational data, identifying optimization potential and automatically adjusting control algorithms and parameters to meet combustion needs under various conditions. This ongoing optimization mechanism helps improve combustion efficiency and reduce pollutant emissions.

4.1.5 Fault Prediction and Diagnosis

Through real-time monitoring and data analysis, the intelligent control system can detect potential faults in the boiler combustion process, such as burner blockages or damper jams, and issue early warning signals. Additionally, using fault diagnosis algorithms, the system can quickly locate the cause of the fault, providing accurate information to maintenance personnel, reducing downtime, and minimizing production impact.

4.2 Improving the Emergency System Mechanism

In the thermal automation of thermal power plants, the application of intelligent control brings revolutionary changes to boiler combustion control. The intelligent control system first integrates high-precision sensors to collect key parameters such as temperature, pressure, oxygen concentration, and fuel flow within the boiler in real-time. Through advanced data processing and analysis technology, the system can deeply analyze this data and establish dynamic models of the combustion process. These models not only reflect the current combustion state but also possess the ability to predict future trends. Based on real-time monitoring data and predictive models, the intelligent control system can automatically adjust combustion strategies. For example, the system can quickly adjust parameters like fuel supply, air-fuel ratio, and burner angle according to changes in fuel quality and load demand to maintain optimal combustion conditions. By precisely controlling the air-fuel mixture ratio during the combustion process, the system can reduce incomplete combustion, improve combustion efficiency, and significantly lower emissions of pollutants like nitrogen oxides and sulfur dioxide. Over long-term operation, the system continuously accumulates operational data and analyzes it using machine learning algorithms to identify optimization opportunities in the combustion process. Over time, the system gradually adjusts its control strategies to better match actual operating conditions, achieving simultaneous improvements in combustion efficiency and environmental performance. Through real-time monitoring and analysis of various parameters during combustion, the system can promptly detect signs of potential faults and issue early warnings. Once a fault occurs, the system can quickly locate the source of the problem and provide corresponding handling suggestions, offering strong support to maintenance personnel and ensuring the continuous and stable operation of the boiler combustion process.

Conclusion

The application of intelligent control in the thermal automation of thermal power plants provides strong support for achieving efficient and clean thermal power generation. As information technology continues to advance and integrate, intelligent control systems will be continuously optimized and upgraded, driving thermal power plants towards more intelligent and refined management. In the future, intelligent control is expected to play an increasingly important role in enhancing the operational efficiency of thermal power plants, ensuring energy security, and promoting environmental protection.

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