The Critical Technical Research on the Intelligent Control Management System of the Energy Station

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Abstract. According to the currently equipment characteristics and process requirements of the refrigeration system of the energy station, we implement intelligent control energy-saving renovation project, which realized the automatic and intelligent control and operation of the refrigeration system related equipment. The system uses distributed control system, and provides systematic solutions for scientific decision-making, reasonable dispatch, energy management, energy efficiency analysis and energy-saving control. Simultaneously, to improve energy efficiency, this system can make full use of the electricity price policy, maximize the economic benefits of water storage, and operate in the lowest cost mode of energy supply.

1. INTRODUCTION
In currently refrigeration system equipment, all pumps adopt frequency conversion and bypass control. The inverter adopts manual control, the bypass control adopts manual switching, the cooling tower adopts the direct control method to control the start and stop of the fan. According to the currently equipment characteristics and process requirements of the system, the intelligent control management system in the energy station combines the air conditioning automatic control system with the energy management system. According to the characteristics of the hybrid energy station, the system provides systematic solutions for scientific decision-making, reasonable dispatch, energy management, energy efficiency analysis and energy-saving control, which can realize the automation and intelligent control of the refrigeration system, improve the system comprehensive COP value, and ensure that the system runs at the lowest unit energy supply cost.

2. System structure
The intelligent control and management system manages the air-conditioning system equipment of the energy station. The design concept followed by the overall system architecture is: Distributed control, centralized management, interconnection, and smart operation. The system is composed of Energy Production Decision and Management Center (Management layer), Energy efficiency integrated monitoring platform (Control layer), and Intelligent control module (Device layer).

2.1. Management layer of the energy station
Management layer of the energy station was centered on the commercial computers, which managed all the devices of the system integratedly, to realize the monitoring and data exchange of the water system equipment for the central control room.
Management layer was connected with energy efficiency integrated monitoring platform through the bus Ethernet, it was responsible for the centralized monitoring and management of the entire energy station system. Management layer made the system's power on and off decision, and carried out the energy dispatch in the station, which was based on the principle of the lowest production cost per unit cooling capacity.

Management layer realized full-energy, full-process, and full-system supervision for customers, launched the refined management of energy for customers, which can achieve the intelligent control of self-adaptation, self-learning, and automatic evolution.

2.2 Control layer of the energy station
Control layer of the energy station was designed with computer intelligent control technology, which is based on intelligent fuzzy control software, with centralized monitoring, system optimization, efficient operation, adjustment control, comprehensive data collection, authority management, one-key start functions. Through comprehensive parameter collection and real-time monitoring of the air-conditioning system, it can generate the corresponding optimized control plan, and issue execution.

Control layer has an independent man-machine interface. According to independent algorithms and control strategies, it can achieve efficient and optimized control of devices. Thus, energy consumption is reduced.

2.3 Device layer of the energy station
Device layer of the energy station is composed of unit intelligent control module for dual working conditions, refrigeration unit intelligent control module, cool storage pump intelligent control module, cooling tower intelligent control module, on-site collection box. The intelligent control module adopted frequency conversion control for the chilled water pump, cooling water pump, cold storage water pump, cold water pump.

Every module control unit has independent and complete functions, and completes monitoring and control functions independently.

All equipment at device layer is stable and reliable, and the system has strong anti-interference ability, the same type of intelligent control module unit can realize fault compensation function, to ensure the continuous availability of the system.

3. Research on the critical technologies of the system
The characteristics and importance of the refrigeration system was combined in this research that the energy-saving optimization control of each operation link of the system is carried out to improve the operation efficiency of the system[2].

3.1 Energy saving between water chiller and water pump
Chilled water fuzzy predictive control based on load forecasting is mainly used for energy saving between chillers and pumps. Fuzzy control is a kind of computer intelligent control based on fuzzy set theory, fuzzy linguistic variables and fuzzy logic reasoning, especially suitable for such complex, nonlinear and time-varying systems.
A fuzzy prediction algorithm was used in the system to control the chilled water system. According to the characteristics and cycle of chilled water system, the short-term load of chilled water in the future is predicted. According to the trend of load change, the operation parameters of the system in the future are speculated, and the operation frequency of the pump set is dynamically adjusted. On the premise of ensuring the service quality, make the supply and demand of cooling capacity match, minimize the waste of cooling capacity and reduce the transmission energy consumption, and realize the energy-saving control of the chilled water system.

A prediction can be obtained clearly from the software based on fuzzy prediction algorithm, and compared with the current load. While the outlet temperature, flow rate or water pressure difference between supply and return of chilled water is abnormal during the operating system which will send out alarm signal and take corresponding protection measures to ensure the safe and normal operation of the air conditioning host. Because the chilled water system adopts the dynamic control of output energy, the refrigerant flow of the air conditioning host follows the demand supply of the end load, which greatly improves the carrying efficiency and the efficiency cost ratio of the cooling load. Under various load conditions, the air conditioning system can not only ensure the demand of the end load, but also save the energy consumption of the system to the maximum extent.

3.2. Energy saving between chiller and cooling system
The energy saving between chiller and cooling system is mainly divided into the energy saving between chiller and cooling water pump, chiller and cooling tower.

Considering the energy consumption of water chiller, cooling water pump and cooling tower fan, a middle point temperature of cooling water corresponding to the highest cooling system efficiency can be found under each load condition, environmental parameters and evaporation side temperature, that is, the best point of cooling system efficiency can be found to make the whole system have the highest energy efficiency ratio. Under the given cooling load and ambient wet bulb temperature, there must be an optimal temperature point in the cooling system, which makes the total power of the cooling system the lowest[3].

Fig. 1. Fuzzy Prediction Algorithm used to Control the Chilled Water System.
By adjusting the frequency of cooling water pump or the number of cooling tower fans, the temperature at the cooling water outlet of the main engine can be changed, resulting in the temperature difference between the two main engines. There is always a temperature difference between the two main engines, which makes the total power of the refrigeration system the lowest under the same load. Taking the cooling system as a whole, the main engine as the basis and the temperature difference between the two devices as the evolution goal, the optimal cooling system can be found by continuously controlling the frequency of the cooling water pump and the power of the cooling tower fan. When the ambient wet bulb temperature is determined, the tower power corresponding to the number of cooling towers, the pump power corresponding to the frequency of cooling water pump, and the main engine power corresponding to the temperature difference between the two devices are queried circularly, and the tower number and the frequency of cooling water pump corresponding to the minimum combined power are taken as the control objectives.

Table 1. The Best Refrigeration System.

| program       | 21:38:00 | 21:46:40 | 21:55:20 | 22:04:00 | 22:12:40 | 22:21:20 | 22:30:00 | 22:38:40 | 22:47:20 |
|---------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Load rate (%) | 84.32    | 84.26    | 84.19    | 83.95    | 84.27    | 86.49    | 84.99    | 84.26    | 83.63    |
| Wet bulb temperature (°C) | 23.04    | 23.00    | 23.01    | 22.98    | 22.97    | 23.00    | 23.14    | 22.97    | 23.03    |
| Approach temperature (°C) | 4.14     | 4.15     | 4.15     | 4.11     | 4.19     | 4.16     | 4.01     | 4.19     | 4.17     |
| Cooling tower power (kW) | 73.34    | 73.84    | 74.56    | 73.86    | 74.50    | 75.43    | 74.99    | 76.26    | 73.74    |
| Cold range (°C) | 5.54     | 5.50     | 5.49     | 5.46     | 5.49     | 5.52     | 5.57     | 5.54     | 5.43     |
| Cooling pump power (kW) | 164.20   | 162.77   | 164.02   | 163.48   | 163.39   | 163.84   | 162.77   | 164.20   | 163.12   |
| Electric power of main engine (kW) | 2026.43  | 2024.29  | 2019.29  | 2012.14  | 2015.00  | 2030.71  | 2036.07  | 2021.07  | 2007.14  |
| Total cooling capacity of main engine (kWh) | 2536.50  | 2526.50  | 2524.00  | 2523.50  | 2518.00  | 2546.00  | 2548.50  | 2536.50  | 2507.00  |
| Total power of cooling tower (kWh) | 12.83    | 12.92    | 13.05    | 12.93    | 13.04    | 1.20     | 13.12    | 13.35    | 12.90    |
| Total power of cooling pump (kWh) | 28.73    | 28.48    | 28.70    | 28.61    | 28.59    | 28.67    | 28.48    | 28.73    | 28.55    |
| Total power of main engine (kWh) | 354.62   | 354.25   | 353.38   | 352.12   | 352.62   | 355.38   | 356.31   | 353.69   | 351.25   |
| Refrigeration system EER (kWh) | 6.40     | 6.39     | 6.39     | 6.41     | 6.39     | 6.41     | 6.40     | 6.41     | 6.38     |
| Cooling water inlet temperature (°C) | 27.1     |          |          |          |          |          |          |          |          |
| Cooling water outlet temperature (°C) | 32.44    |          |          |          |          |          |          |          |          |
| Wet bulb temperature (°C) | 23.10    |          |          |          |          |          |          |          |          |
| Load rate of main engine (%) | 83.06    |          |          |          |          |          |          |          |          |
| Temperature difference (°C) | 28.09    |          |          |          |          |          |          |          |          |
| Target cooling (°C) | 5.85     |          |          |          |          |          |          |          |          |
3.3. Energy saving of chillers and chillers
The energy saving between chillers mainly uses the group control strategy based on the optimal efficiency of the main engine. The chiller is the most energy consuming equipment in the operation of central air conditioning system. The running energy consumption of refrigeration engine is related to the performance of refrigeration engine, and the performance of refrigeration engine includes full load performance and part load performance.

Based on the knowledge base of "temperature difference load rate cop", the system automatically optimizes the optimal temperature of cooling water to achieve the minimum comprehensive energy consumption of unit, cooling water pump and cooling tower fan, and obtains the optimal system energy utilization rate (COP value) under a certain load.

The core of the optimal efficiency group control technology of chillers is to establish and refresh the load / efficiency characteristic database of chillers in real time. In the actual operation process, the system will sort out the parameters of the energy efficiency monitor installed on the pipeline of each chiller, obtain the cop of each host and the cop of the unit combination, and then use the cop to compare with the current total load rate of the system. The current temperature of condenser and so on are used to learn and revise the historical database. According to the current load rate and condenser temperature of the air conditioning system, the system can find a unit combination mode with the highest cop in the current working condition in the database to make the chiller run in the high cop load area, realize the dynamic matching of unit efficiency and load, and make the overall efficiency of the operating unit group the best and the total energy consumption the lowest.

Based on the chiller group control technology of the efficiency load characteristics of the main engine, the best combination of chillers is selected to make the chiller group in a higher efficiency range and ensure its efficient operation.

3.4. Energy saving strategy of cool storage unit
The chilled water thermal storage technology is to store the cold energy in the form of cold water with electric refrigerator in the night when the power load is low. Through the comprehensive energy efficiency measurement and collection of air conditioning system equipment and process parameters, the system analyzes the operation cost of each system under different working conditions, makes scientific and reasonable decision-making and management, and provides full and detailed basis, so as to achieve the scientific management of energy.

The key of the cool storage is to accurately predict when and how much to cool by using electricity price policy and load forecasting. According to the forecast load table, cold storage cost, cold storage capacity and the principle of next day discharge, the total amount of cold storage is verified.

The key of cooling release is to calculate the cost of cool storage and release, and compare it with the load forecast cost of the day, and release the cool storage effectively at the maximum unit energy supply cost (yuan / kWh) of the day, so as to obtain the maximum cost replacement rate. So that the advantages of cool storage can be maximized.

3.5. Energy saving strategy of the best combination of direct supply and cool storage and discharge for chillers
Through the establishment of energy cost database under various working conditions of the system, when the system is running, the total hourly load of the system is predicted first, so as to provide basic data basis for the start-up of the system. The system can get the corresponding energy consumption according to the energy efficiency measurement under different energy sources, and calculate the operation cost of different energy sources under different prices according to the predicted load.

On the premise of taking the lowest unit energy supply cost as the decision criterion, the basis of system decision-making is the statistical analysis of energy supply cost under various working conditions, and according to the statistical results, the best energy supply combination mode under current working conditions is reasonably selected. Then the system is sorted according to the unit refrigeration cost under the current working conditions. First, put the system with low refrigeration
cost into operation. When the refrigeration capacity can not meet the demand, then add the second
low-cost cold source, and so on, to ensure the lowest operation cost of the whole energy station[4].

4. System function

4.1. Monitoring function
The energy station decision control system can monitor the whole air conditioning control system. Through unified integration, all control systems are centralized under the same platform for unified monitoring and control.

4.2 Functional quality
According to the output energy quality of each kind of energy, the qualified time, cumulative time and guarantee rate of energy supply can be obtained.

4.3. Measurement and energy consumption statistics
The system can count and measure the output cooling capacity and heat of the refrigeration station, display the statistical results in various forms (table, histogram, curve chart, etc.), and provide the energy consumption comparison chart of different controlled equipment in the specified period and the same controlled equipment in different periods, so as to generate intuitive energy consumption comparison chart or report.

4.4. Control function
It can realize unattended and intelligent operation of the whole energy station. It can realize one key start stop function of corresponding refrigeration (heating) equipment in energy production decision and management center[5].

4.5. Load forecasting
According to the external wet bulb temperature and the actual cold / heat consumption, the cold / heat demand of each load area in each period of the day is predicted. The system can also summarize the cold / heat demand of each load area as the total cold / heat demand of each period of the whole ring network system to guide the energy scheduling module to carry out energy scheduling.

4.6. Centralized alarm function
The system software realizes the centralized alarm processing of the equipment fault, sensor parameter crossing, communication interruption and other information.

5. Conclusion
Firstly, according to the characteristics of building load, the first-class management and energy scheduling level of the system was achieved through scientific decision-making and reasonable operation. Secondly, multiple energy systems were used to achieve the goal of long-term green operation as well as making full use of the electricity price policy to achieve the goal of energy saving and consumption reduction. Then the control technology and strategy of control should reach the first class level in the world to realize the efficient operation in the system. In addition, while the control logic is correct, and the operation is convenient, the labor intensity of the operation and maintenance personnel will be reduced, as well as the unattended operation will be realized. As a result the safe production will be achieved by using reliable and stable operation of highly reliable hardware equipment and comprehensive security protection. In briefly, intelligent operation of the system has been realized through perfect self-control ability, independent and complete functions, automatically modifies control methods and control strategies.
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