Research on Smart Energy Saving Method of Central Air Conditioning System Based on Big Data

Ming Li[a,*], Jian Li[b]

Technical Service Department of Yihong Electromechanical Equipment Installation Engineering Chengdu Co., LTD., Chengdu, Sichuan, China

[a]825182196@qq.com, [b]43403050@qq.com

*Corresponding author

Keywords: Big data, Intelligent energy saving, Central air conditioning, Optimization algorithm

Abstract: Aiming at the problems of large load variation range, low overall efficiency and high energy consumption of central air conditioning, a control optimization method of cooling water system and chiller based on data analysis was proposed. Different optimization algorithms are used to build a data-driven prediction model. Random equipment combination, the lowest energy consumption. The feasibility and effectiveness of the proposed method are verified by actual running data.

1. Introduction

Central air conditioning is the main source of building energy consumption. Central air conditioning in more than 90% of the time is in partial load operation, resulting in low overall system efficiency, generating a large amount of energy waste. In order to save energy and reduce emissions, it is necessary to study the intelligent optimization control method of central air conditioning based on the principle of big data.

Data-driven method, which applies artificial intelligence algorithm to energy saving, has fewer parameters, high model accuracy, simple implementation and strong adaptability, and is widely used in energy consumption prediction and optimization in the field of air conditioning energy saving. Tian Jingjing [1] established the regression prediction model of equipment by using global optimization and particle swarm optimization algorithm, and obtained the optimal control parameters of air conditioning. Li Xuebin [2] proposed a unit load distribution optimization model considering the optimal performance coefficient and energy consumption, and used the improved genetic algorithm to find the optimal solution of the optimization model, and achieved ideal energy-saving effect. Andrew et al. [3] used dynamic neural network to establish the nonlinear relationship between controllable variables, uncontrollable variables and energy consumption, and then adopted particle swarm optimization method to carry out multi-objective optimization of air conditioning system.

Data-driven method A method of problem solving. Starting from the initial data or observed values, the heuristic rules are used to find and establish the relationship between the internal features. This paper combines the data-driven method with the relevant theories of big data mining, designs the concrete implementation of intelligent control, and puts forward an optimization control strategy based on the data-driven method.

2. Central Air Conditioning System Energy Consumption Reasons

2.1. Its Own Design Problems, Resulting in Energy Waste

Central air conditioning system according to the maximum load, will retain 10%-20% design margin, most of the time is operated under partial load, full load occupies a small part of the time. The chilled water pump and cooling water pump of the central air conditioning system need to rely on the valve and bypass to adjust, which will cause the inevitable large closure loss and large flow

  DOI: 10.25236/iche.2022.048

rate, high pressure, low temperature difference phenomenon, so that the power consumption increases. The central air conditioning system itself design problems, resulting in the central air conditioning system energy consumption.

Bad use of electricity, resulting in energy waste. In the air conditioning temperature setting is extremely unreasonable, in a long time no one has been allowed to run the air conditioning, central air conditioning is not suitable for the situation, did not turn off the power plug, generate unnecessary power consumption.

Daily management is not reasonable, resulting in energy waste. In strict accordance with the site requirements, the use of standards to ensure that the central air conditioning can be reasonable use. Most of the central air conditioning system management depends on human feeling, many central air conditioning system has not completed the technical transformation, the lack of system scientific and reasonable monitoring, can not realize the reasonable deployment of operation quantity, resulting in a lot of energy consumption.

2.2. Energy-Saving Renovation Measures of Central Air Conditioning System

Optimization of central air conditioning water system technology. Optimizing the technology of central air conditioning water system and reducing the energy consumption of circulating pump motor can reduce the power consumption of air conditioning system by 1.5-30%. Water system control can achieve the role of energy saving of the main engine, and the energy saving potential is very large, reducing the energy consumption. Cooling water system equipment has the characteristics of a large number of units, low energy consumption per unit, so the energy saving point of the system is to find the best combination of equipment.

The data of chiller collected from the site were selected and preprocessed, and the cooling water system state and energy consumption model were established by using the optimization algorithm. The model evaluation index was used to verify the model effect. The state model and setting point were taken as the constraint conditions of the optimization model to find the optimal solution of the equipment start-stop state combination, so as to minimize the system energy consumption under the condition of ensuring the operation requirements of the cooling water system. The verification results show that the data driven method of the proposed PSO algorithm can effectively reduce the energy use of the chiller.

3. Energy Saving Control System of Central Air Conditioning

3.1. The Composition And Energy-Saving Principle of Central Air Conditioning

A complete set of central air conditioning system, taking water-cooled units and summer working conditions as examples, can be divided into two parts: water system and wind system. According to the working principle of the system, the water system is further divided into refrigeration units, chilled water system and cooling water system, and the wind system is mainly composed of fan coil and other air supply equipment [4-5].

Refrigeration unit is the heart of the whole central air conditioning system, its main components are compressor, evaporator and condenser. The main component of the chilled water circulation system is the chilled water pump, which transmits the chilled water cooled by the evaporator to the front fan coil through the chilled water pipe and the chilled water pump, and the fan coil can exchange heat with the indoor air through the air supply.

The main energy consumption in the central air conditioning system lies in the refrigeration unit, each water pump in the water circulation system, the end fan coil system and the outdoor cooling tower. The energy saving needs to properly adjust the running state and running frequency of the above energy consumption equipment to achieve, which is the variable flow control method of the water system. In the energy saving control system, the measured data of the field environment monitoring sensor is generally compared with the set value. If there is a difference, the system will control the operating frequency and quantity of the equipment according to the data difference size to maintain the best running state of the system and avoid unnecessary energy loss in the operation process.

3.2. Central air conditioning distributed control system

Distributed control system (DCS) is a distributed control system based on intelligent controller, which carries out centralized monitoring, operation, management and decentralized control on the front field equipment. The distributed control system with direct digital controller as the core and RS485 bus as the communication link has become the best choice for energy-saving control of central air conditioning.

Direct digital controller to collect real - time data. A/D converter is used to convert analog signals into switching signals for computer reception. After computer calculation, the calculation result is obtained.

RS485 bus adopts balanced multi-point and differential transmission to achieve communication, and the bus is twisted pair, based on the combination of these three points, RS485 bus has strong anti-interference ability and ultra-long signal transmission distance. It is widely used in distributed control systems.

4. Research on Algorithm Calculation Strategy of Control System

4.1. The Energy Consumption Model of the System is Established

For energy saving of chiller, it is to meet the cooling load demand of front end with the minimum power consumption of unit operation, which can be judged by partial load rate (LR) of unit under the premise of not exceeding the operation limit. According to literature [6], the power of chiller can be expressed as a functional relation related to LR:

$$P = a + b \times LR + c \times LR^2 + d \times LR^3$$

Where a,b,c and d are performance coefficients of chiller respectively. In this paper, the chiller, chilled water pump and cooling water pump optimization can be regarded as a whole, so the energy consumption of these three kinds of equipment can be regarded as the objective function Pmin. Water chiller unit:

$$Q_{need} = \sum_{i=1}^{n} LR_i \times Q_{zi}^e$$

Q_{zi} - energy consumption of the first chiller, kw;LR_i - partial load rate of the first chiller;

Q^e_{zi} - cooling capacity of the No. i chiller, kw;Q_{need} - Actual load demand, kw.

For energy saving optimization of fan coil units, the building can be partitioned according to the equipment functions to monitor the fan coil units.

$$\min(Q_p) = \min(Q_{pi}^1) + \min(Q_{pi}^2) + \cdots \min(Q_{pi}^n)$$

In this equation, the minimum energy consumption of Fan-coil units is divided into the sum of the minimum energy consumption of Fan-coil units in each zone. In the process of FAN-coil unit operation, it is necessary to meet the human body's demand for indoor temperature. The variable air volume control method is adopted to control the indoor temperature within a comfortable range by changing the air supply volume. Therefore, the constraints on indoor temperature can be transformed into constraints on the air supply volume.

4.2. Particle Swarm Optimization Algorithm

Dr. Eberhart and Dr. kennedy invented Particle Swarm optimization (PSO), which is also translated as particle swarm optimization, particle swarm optimization, or particle swarm optimization. It is a random search algorithm based on group cooperation developed by simulating the foraging behavior of birds. It is often considered a form of swarm intelligence. It can be incorporated into multi-agent optimization systems.

PSO draws inspiration from this model and is used to solve optimization problems. In PSO, the solution of each optimization problem is a bird in the search space. We call them "particles". All particles have an adaptive value determined by the optimized function, and each particle has a speed that determines the direction and distance they fly.

The PSO is initialized with a population of random particles (random solutions) and then finds the optimal solution through iteration, at each iteration the particles update themselves by tracking two "extreme values". The first is the optimal solution found by the particle itself, which is called the individual extremum, and the other extreme is the optimal solution found by the whole population, which is the global extremum. Alternatively, instead of using the whole population, you can use only the neighbors of some of the optimal particles, and then the extreme value among all the neighbors is the local extreme value.

5. Data Acquisition and Processing

5.1. The Data Collection

When analyzing the existing monitoring system, it is found that the parameter information under the current operating condition of the system is incomplete, so the external sensor method is adopted to complete data collection, and the external electric meter used for energy consumption is collected. The electric meter transmits the collected data to the data terminal of each device through RS485 communication bus. Then the data is transferred to the total data acquisition terminal through Lora wireless transmission protocol, and the total terminal uplodes the data to the industrial computer through TCP/IP protocol.

The relevant parameters of chiller are collected by external sensor. The data is collected by the sensor and sent to the switch through the serial port server, and then the switch transmits the information to the industrial computer. Of course, no matter energy consumption or other parameters are carried out under the stable operation condition of the air conditioning system, so as to ensure that the collected original data can reflect the state of the air conditioning system.

Information gain is the degree to which the information of a feature in the data set reduces the uncertainty of the total information, which is one of the most widely used methods for feature selection before modeling [7]. In short, in the absence of the feature, the reduced part of the total information is the information gain of the feature.

The so-called information quantity refers to the concept of entropy in statistical theory. entropy is a concept that measures the uncertainty between random variables. It is defined as:

$$H(X) = -\sum_{i=1}^{n} p_i \log p_i$$

In the information gain, and compare their sizes, the criterion of feature selection is: calculate the information gain of each feature in the data set, and the classification power of the feature can be reflected by the information gain value. The larger the information gain value, the more information it brings, and the more important the feature is to the data set..

5.2. Data Preprocessing Analysis

Data preprocessing is a processing method that plays a very important role in neural network and the whole field of machine learning, and it is also a key step [9]. Therefore, before learning the system state and energy consumption, it is necessary to conduct a series of pre-processing operations on the original data, so as to improve the quality of the data and improve the speed and accuracy of model training. The following is the data preprocessing method used in this article.

Data standardization refers to the reduction of data samples according to a certain proportion, so that the results fall into a predetermined interval, in order to solve the adverse impact of the original data on the model due to the trend or magnitude difference. Different orders of magnitude result in larger order of magnitude parameters dominating the modeling process, while lower order of magnitude parameters are overridden by the former.

6. Energy Consumption Optimization of Chiller by Genetic Algorithm

6.1. Establishment of Optimization Model

The energy consumption of cooling water system and chiller accounts for more than 80% of the energy consumption of the whole system. From the perspective of modeling and actual operation, to minimize the total energy consumption of air conditioning and ensure room temperature, it is actually necessary to solve the optimization problem of the objective function of the system. In order to minimize energy consumption, variable optimization should be carried out within the constraint conditions to find the appropriate control decision variable, namely, the load of each chiller..

The optimization objective function model constructed according to the optimization process is:

$$obj = \min_{PLRi} \sum_{i}^{n} EC_{chiller,i} = \min_{PLRi} \sum_{i}^{n} f\left(PLR_i, T_{RCWT}, T_{SCWT}\right)$$

ECchiller, i Energy consumption of the ith chiller, load ratio PLRi, T_{SCWT} chilled water supply temperature, T_{RCWT} chilled water return temperature.

Figure 1 directly shows the comparison of energy consumption of chiller before and after optimization. As can be seen from the chart, before and after the optimization, the partial load ratio of each chiller has changed, and the refrigeration efficiency has been improved, and the larger the total load, the more obvious the energy-saving effect. The validation data show that when the total load ratio is in the range of 55%-95%, the total energy consumption of each chiller is reduced by 5.05%-21.05% by optimizing the load of each chiller.

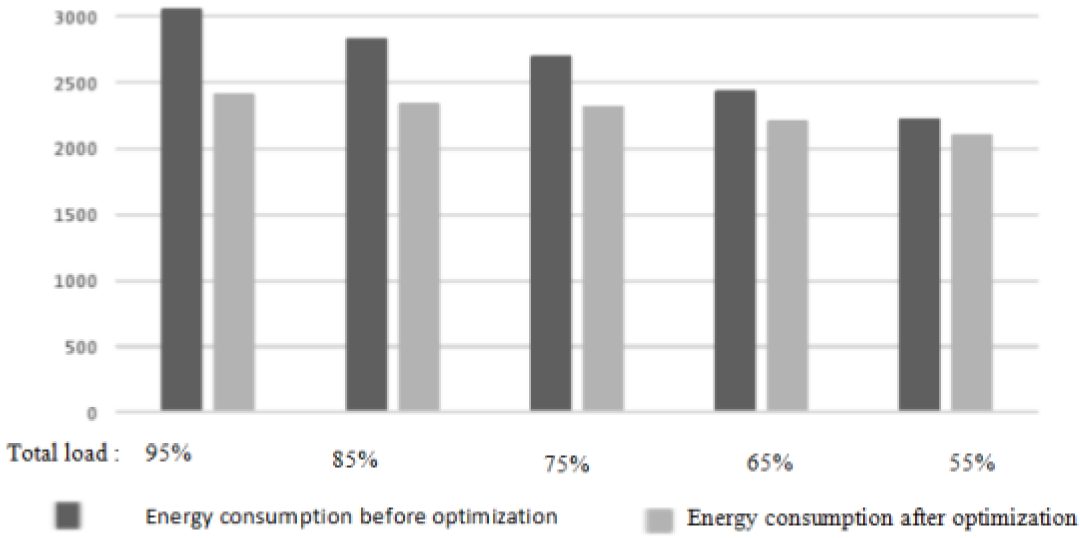

Figure 1 Comparison of energy consumption of chiller before and after optimization.

6.2. Analysis of Optimization Results

Through the analysis of the historical energy consumption data of each part of the central air conditioning system, it is concluded that the energy consumption of the cooling water system and the chiller accounts for more than 80% of the whole system energy consumption. In order to minimize the system energy consumption, different data-driven algorithms are used to optimize the energy consumption. Using the optimization method to determine the best combination of equipment, so as to give the lowest energy consumption of the system equipment control scheme.

The data of cooling water system and chiller under stable operation conditions were collected, and the collected data were preprocessed by standardization, outlier processing and missing value completion to improve the data quality and reduce the impact of data defects on the model.

By analyzing the optimization effect of cooling water system and chiller, it is proved that the energy consumption optimization strategy based on data-driven method proposed in this paper has a good application prospect in the field of energy conservation of central air conditioning system.

7. Conclusion

According to the equipment composition and working principle of the central air conditioning system, the system energy consumption composition and energy-saving control methods are analyzed.

To improve the existing energy-saving control system, mainly from the control system architecture, load distribution and control algorithm three aspects of the design of a new control system.

According to the system improvement method, for the point-to-point control of the system equipment, the minimum energy consumption of each unit is considered to meet the actual cooling load demand, so the minimum energy consumption model of equipment energy consumption is established. For the selection of control algorithm, the genetic particle swarm optimization algorithm is selected. According to the characteristics of point-to-point master-slave control system, the distributed parallel calculation of the algorithm is carried out. Finally, intelligent load distribution is realized to improve the operating efficiency of the unit.

Matlab and Simulink were used to simulate the curve tuning of PID algorithm respectively. The results show that the response speed of genetic particle swarm optimization algorithm based on distributed parallel computing is obviously faster than PID algorithm, and it is more stable than PID algorithm, and the energy-saving optimization effect is better.

In the aspect of intelligent load distribution, the regional controller selects the unit operation matching mode according to the energy consumption optimization results, which can greatly improve the unit operation efficiency and achieve excellent energy-saving effect.

Acknowledgements

The authors greatly appreciate the following sponsors for their support to the study:

The natural science foundation of education committee of Sichuan province, "Research on Control System of large bridge bearing testing machine" (08zb070)..

References

[1] Tian Jing Jing. Research on Energy Consumption Prediction and Optimal Control Model of Central Air Conditioning System [D]. Wuhan: Wuhan University of Science and Technology,2019..

[2] Li Xuebin. Research on multi-objective optimization of load distribution for joint operation chiller "J". Cleaning and Air Conditioning Technology, 2008,04:85-87...

[3] Andrew. K, Xu. G. L. Modeling and optimization of HVAC systems using a dynamic neural .network[J].Energy, 2012, From 1-250.

[4] L. Kang, G. Wang, Y. Wang et al, The Power Simulation of Water - Cooled Central Air - Conditioning System -based on Demand Response field. In The IEEE Access, 2020, 67396-67407.

[5] Chen Yang, Yao Hua. Energy saving control of large central air conditioning system based on Longniuxue-particle swarm optimization algorithm. Journal of Refrigeration, 2021,42(04):43-49.

[6] Wang J Y, Ashour M, Lagoa C et al. Non-concave network utility maximization in connectionless networks: a fully distributed traffic allocation algorithm [C], American Contral Conference(ACC), 2017:3980-985.

[7] LI Hang. Statistical Learning Methods [M]. Beijing: Tsinghua University Press, 2013:71-76.

[8] XUE W. Statistical analysis and application of SPSS [M]. Beijing: China Renmin University Press, 2014:236-239. (in Chinese)

[9] Tan Yaowen, Tan Yihong, Li Xueyong. Application of data mining technology in statistical preprocessing [J]. Mining Engineering Research, 2015, 27 (2):76-78.