APPLICATION OF ARTIFICIAL INTELLIGENCE CONTROL IN THE CONTROL SYSTEM OF COOLING AND HEATING ENERGY STATIONS

by

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In order to understand the application of artificial intelligence in the control system of cold and hot energy station, the author proposes a research based on artificial intelligence control in the control system of cooling and heating energy station. The author first introduces artificial intelligence technology on the basis of heating and precision heating, relies on the "Internet plus" and IoT platform, applies indoor temperature measurement technology, intelligent control and information docking technology, and establishes a heating system based on artificial intelligence technology. This system has improved the level of enterprise management, promoted the further development of heating and intelligent energy conservation, reduced energy consumption, reduced pollution, and achieved the need for precise heating of the pipe-line network. Secondly, combined with the application case of a district, this district is selected as the application pilot to describe the role and effect of this system in the Hydronics. The experimental results indicate that the heat consumption of the residential area is 27.07 W/m², while the heat consumption of the comparison residential area is 28 W/m². Through indoor temperature measurement, it was found that the average indoor temperature of the comparison residential area is 22 °C. Therefore, the application of artificial intelligence heating systems has improved the thermal comfort of residents, bringing users a high quality heating experience while relatively reducing energy consumption. The intelligent application of the Hydronics can more accurately grasp the heating situation, timely and efficiently adjust the heating scheme, achieve heating balance, and improve the utilization efficiency of heat sources. At the same time, it can also effectively improve the troubleshooting ability of the hydronics, prevent safety risks, improve management efficiency, and will certainly provide more powerful support for the energy-saving society and environment-friendly society.

Key words: *artificial intelligence, heating energy, control system*

Introduction

Artificial intelligence, is a new technological science that studies and develops theories, methods, technologies, and application systems for simulating, extending, and expanding human intelligence. The AI attempts to understand the essence of intelligence and produce a new kind of intelligent machine that can respond in a similar way to human intelligence. Research in this field includes robots, language recognition, image recognition, natural language processing and expert systems. Since its inception, artificial intelligence has become increasingly mature in theory and technology, and its application fields have also expanded. The *artificial intelligence* theory and technology are introduced into the heating industry to realize the *self-learnin*g mode of heat ex-

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change station operation in winter, guide the operation of heat exchange stations, combine the IoT platform, and use big data cloud platform technology to achieve low carbon, automated, intelligent heating industry chain, and achieve user side precision heating, unattended heating stations, remote adjustment of pipe network operating parameters, intelligent energy consumption analysis, balance*, etc.* With the continuous development of technology, the application range of artificial intelligence is also becoming increasingly widespread, and the heating field is no exception. The widespread application of artificial intelligence technology has brought a series of advantages in productivity, economy, and environmental protection the heating industry. The application of artificial intelligence in heating is mainly achieved through the implementation of intelligent control systems. Through the introduction of artificial intelligence technology, the heating pipe-line network can operate more efficiently, accurately, and reliably. Firstly, the most direct benefit of the application of artificial intelligence in heating is the improvement of energy-saving effects. By collecting and analyzing data from the heating network, artificial intelligence technology can autonomously adjust the operating status of the heating network and achieve the optimal allocation of network resources. This technology can achieve more efficient and precise regulation through continuous learning and adjustment, effectively reducing energy consumption expenses during heating, reducing production costs, and improving the economic benefits of heating enterprises. Secondly, the application of artificial intelligence technology is also improving the safety of the heating industry. The heating pipe-line network has an extremely complex operating environment, and any negligence may lead to safety risks. The artificial intelligence technology can monitor various conditions in the heating pipe-line network in real-time, timely and accurately identify and solve potential safety hazards, ensuring the stable operation of the heating pipe-line network and the safety of people's lives. Finally, the application of artificial intelligence technology can also bring convenience to heating services. The artificial intelligence technology can facilitate communication and communication with users through means such as the internet, providing personalized heating services based on their actual needs, allowing users to enjoy more close to life, thoughtful and convenient services during their living process. Of course, the application of artificial intelligence technology also faces some challenges. For example, intelligent control systems require a large amount of data support and possess certain learning and exploration abilities [1, 2]. Heating enterprises cannot do without information construction. Accurate monitoring and data management require a large amount of cost support, which puts higher requirements on the cost level, resource reserves, and talent team of heating enterprises, fig. 1.

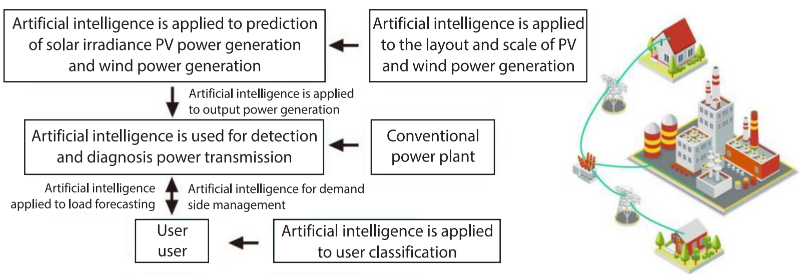

Figure 1. The artificial intelligence control in heating energy

Literature review

With the continuous development of artificial intelligence technology, its application in heating is becoming increasingly widespread. The artificial intelligence technology can help heating enterprises better manage the hydronics, improve heating efficiency, reduce heating costs, and improve user satisfaction. By analyzing the data of hydronics. The artificial intelligence can predict the operation status of the hydronics, find problems in time and deal with them. At the same time, artificial intelligence can also automatically adjust the operation mode of the hydronics according to user needs, weather conditions and other factors to achieve the best heating effect. The artificial intelligence technology can improve heating efficiency and reduce heating costs. Through the analysis of the data of the hydronics, artificial intelligence can optimize the operation mode of the hydronics, reduce the waste of energy and improve the heating efficiency. At the same time, artificial intelligence can also automatically adjust the operation mode of the hydronics according to user needs, weather conditions and other factors to achieve the best heating effect, thus reducing heating costs. The artificial intelligence technology can improve user satisfaction. Through the analysis of user needs, artificial intelligence can automatically adjust the operation mode of the hydronics to meet user needs. At the same time, artificial intelligence can also continuously optimize the operation mode of the hydronics according to user feedback, and improve user satisfaction. With the continuous development of artificial intelligence technology, it is believed that its application in heating will become increasingly widespread, bringing more convenience and comfort to people's lives. Zhou *et al.* [3] established a dynamic mathematical model for typical rooms in buildings and used MATLAB for simulation analyze the effects of outdoor temperature, solar radiation, wind speed, and water supply temperature on heating load and indoor temperature delay characteristics. It was found that solar radiation has a significant impact on the delayed heating load of buildings. Changing the water supply temperature has almost no effect on the delay law of heating load. For buildings with good window sealing performance, the increase in wind speed has little effect on the delay of heating load. Giudicessi *et al.* [4] studied the effects of the properties of composite and insulating materials on heating delay, and analyzed the thermal delay time and its influencing parameters of E-CCRP. They found that the water supply temperature has a greater impact on time delay than the initial indoor temperature.

With the continuous growth and development of the urban heating industry and the maturity of various technologies, thermal power enterprises are increasingly paying attention the linkage regulation of the primary and secondary networks, as well as the fine balance regulation of the secondary network. Due to the high completeness of hardware facilities in the primary network, strong relative closure, complex hydraulic conditions in the secondary network, and relatively poor closure, the regulation effect of the secondary network is poor. In response to this problem, the concept of *smart heating* is applied, based on the intelligence and automation of the heating industry, the information technology system and physical system are integrated, and the technologies of artificial intelligence, big data and simulation modelling are used to analyze various data as a whole, so as to optimize and control the overall pipe network. On the basis of heating and precision heating, the author introduces artificial intelligence technology, relying on *Internet+* and the IoT platform, applies indoor temperature measurement technology, intelligent control and information docking technology, and establishes a heating system based on artificial intelligence technology. Combined with the application case of a residential area, the role and effect of the system in the hydronics are described in detail [5, 6].

Methods

Establishment of system model

In traditional heating modes, manual control is the dominant method, and the establishment of hydraulic or thermal models is only in an ideal environment, and unpredictable external disturbances and changes cannot be considered. The artificial intelligence model is based on an

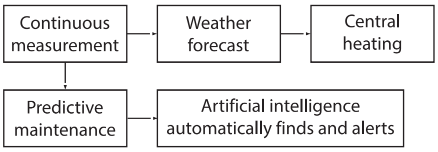

Figure 2. Functional diagram of artificial intelligence heating system

accurate thermodynamic model, while fully considering various external disturbances and changes. As shown in fig. 2, the artificial intelligence control system combines the important physical thermodynamic equations with the statistical black box model. The physical model uses recognized physical equations to describe the system. These equations will describe important characteristics that can be regarded as scientific facts. However, physical equations can generally only roughly estimate complex realities, assuming a thorough understanding and measurement of the entire system, without considering many real phenomena that may have a significant impact on the system, such as the behavior of residents. The black box model is highly flexible and does not directly explain from a physical perspective. They use data to understand correlations and impacts, so that they can understand complex phenomena that are unknown or cannot be described through physical equations. However, the performance of the black box model is not ideal when the system data transmission range is small or the data quality is poor. The artificial intelligence model generated by combining the black box model with the physical model can maintain accuracy under all conditions and can also be used to understand complex features that cannot be reflected by physical equations.

Construction and implementation of the system

The artificial intelligence system is a new management and regulation mode that achieves intelligent control, optimizes management strategies, integrates resource allocation, and reduces labor costs. The seamless connection between the big data cloud and the heat exchange station control system and the user's indoor temperature monitoring is realized through the application server, forming multi-level linkage and intelligent control from the user secondary network primary pipe network of the heat exchange station heat source.

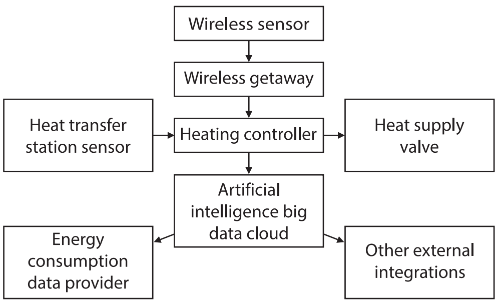

Figure 3. Composition architecture of artificial intelligence heating system

As shown in fig. 3, the indoor temperature of users is usually collected using wireless IoT sensors, which are battery based wireless sensors used to measure indoor temperature and RH. The artificial intelligence system is compatible with any temperature sensor connected to the internet. With the gradual improvement of wireless IoT sensors in terms of availability, quality, and cost-effectiveness, artificial intelligence control systems have become a very eye-catching and easily modifiable management and control mode suitable for existing buildings. Usually, 10-100% of apartment building residents need to install indoor temperature sensors. The high installation rate of sensors reduces the risk of incorrect readings caused by sensor errors or household behavior. However, for large buildings, a 15% sensor installation rate is sufficient to reliably reflect the building's condition. Sensor readings are collected through a gateway device, which is installed by IoT operators based on the type of sensor. The gateway device then communicates with Big data Cloud directly or indirectly through the heat exchange station controller*, etc.* Big data Cloud will collect all measurement data and other input signals, complete all calculations and send all control signals.

For actual heating control, artificial intelligence systems can use existing controllers from heat exchange stations. The controller is responsible for receiving the set values generated by the operation of the artificial intelligence system and ensuring that the hydronics control follows these set values. The artificial intelligence Big data Cloud provides various data analysis, problem detection, heating parameter control and artificial intelligence performance monitoring tools. Big data Cloud can help to monitor the measured values of apartment buildings and heat exchange stations in real time, adjust the set values of heat exchange station parameters, and view and analyze all historical data by realizing the visualization of building scenes or using general graphical tools. At the same time, the Big data Cloud server stores and manages all the data, and transmits them to the artificial intelligence system. Then the system receives the optimized control signals. The server transmits these control signals to the heat exchange station control system and then automatically sends them to the heat exchange station field controller, which is responsible for the realization of control goals according to its own control logic.

Self learning and prediction of the system

The establishment of artificial intelligence models provides assurance for the accuracy and diversity of control systems. The artificial intelligence system considers the dynamic changes of many related variables on heat exchange stations and buildings. For example, outdoor temperature, sunlight, rainfall intensity, wind and other weather conditions will have an important impact on the indoor environment of buildings. The heating and energy consumption status of the heat exchange station can be described by the temperature of the supply and return water, as well as the flow rate and pressure of the primary and secondary supply and return water. At the same time, indoor conditions can be monitored by measuring the actual indoor temperature and relative humidity of building occupants. The artificial intelligence control system will collect and analyze information, input it, and send the optimized optimal control signal to the heat exchange station. The artificial intelligence models dynamically learn about heat exchange stations and use model predictions to find the optimal heating control scheme. The model uses weather data and measurement data from heat exchange stations, combined with heat metering data from the heating metering platform for estimation, and regularly updates with the latest data, enabling continuous adaptation and improvement. Learning models can identify the optimal control scheme based on weather forecasts and different heating control strategies. Considering the actual situation, it is usually impossible or impossible to measure all these heat exchange stations and building variables in a cost-effective manner. It is precisely for this reason that the artificial intelligence system uses a *self-learning* mode for analysis and calculation through the collection of various types of information, avoiding the process of manual consideration, and adding references to the dynamic changes of many variables, innovating the manual control strategy in traditional heating modes.

In addition referring to different variables for system dynamic learning, the artificial intelligence system can automatically understand how different variables affect the indoor temperature and heating demand according to the available data, and accurately predict the future indoor conditions and heating demand to optimize the regulation and management system. Usually, unpredictable changes in heat load due to residential behavior or other factors can lead to significant fluctuations in indoor temperature. Despite this issue, as shown in fig. 4, the artificial intelligence system can predict indoor temperatures for the next 24 hours with an average accuracy of 0.2 °C. The accuracy of predicting the temperature difference between the secondary supply and return water has also reached a high level, with a 24 hour prediction error of only 0.26 °C. This means that the artificial intelligence control system can predict the

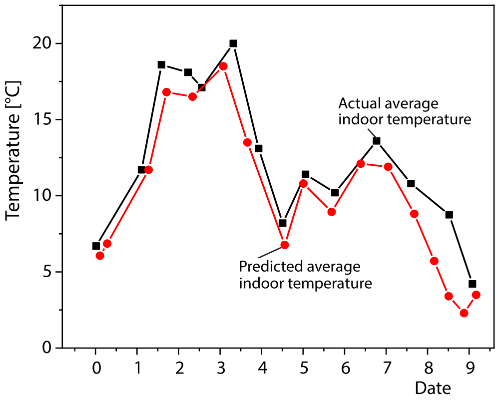

Figure 4. Comparison between predicted indoor temperature and actual temperature

24 hour heating demand, and with accurate weather forecasts, the prediction accuracy is usually as high as 98%.

Due to the ability to predict control optimization, the model can identify the optimal control plan for a long time by considering future events such as heating demand in the coming days. The prediction and optimal control plan need to be continuously updated so that the control plan can take into account new heat exchange station measurement data and the latest weather forecast information. The optimal control scheme can also consider different user preferences, including indoor temperature settings [7, 8] .

Experiments

System application and analysis

Select a certain community as the application pilot, which was built in 2019, with a total construction area of 18520 m^2 and involving 180 households. The community is located at the end of the primary pipe-line network, and the heating and hydraulic balance effects are poor. The heat exchange station in this community is divided into two sets of units: high zone and low zone. Before the 2019-2020 heating season, the community will undergo artificial intelligence heating system transformation and data analysis will be conducted after the heating season ends. Install hardware equipment and install indoor temperature wireless sensors for all 180 residential units in the community, achieving a 100% installation rate. This greatly reduces data error and ensures data accuracy. At the same time, Wireless network interface controller is installed to collect indoor temperature data, debug and dock the artificial intelligence system big data cloud communication system, and seamlessly dock with the existing controller in the heat exchange station ensure smooth data transmission and communication.

Data analysis

Through testing the operation of the artificial intelligence heating system in the community, the results are

Set the indoor temperature target value to 24 °C, and the artificial intelligence system will automatically issue the secondary side water supply temperature setting value through model calculation. According to tab. 1, it can be seen that the indoor temperature is between the upper and lower limits of the set value through statistical analysis of the heat exchange station units and residential data. From fig. 5, it can be seen that the set value of the secondary water supply temperature, the actual secondary water supply temperature, and the valve opening fit are basically the same.

On the basis of ensuring that the indoor temperature of the residential building meets the set value, comparative calculations are conducted on the energy consumption of the heat exchange station. Due to the fact that this heat exchange station is operating for the first time during the 2019-2020 heating season, a heat exchange station located in the pipe-line network location with the same heating method, building age, and insulation performance, and similar heating area, was selected for heat consumption comparison. It was found that the heat consumption of the community was 27.07 W/m^2, while the heat consumption of the compari-

Table 1. Screenshot of comprehensive data statistics table

Date	Outdoor average temperature	Maximum setting value	Minimum setting value	Indoor average temperature	Secondary water supply temperature	Valve opening	Secondary temperature supply setting value	Communication status
2020.1.17	–3	24	21	22.05	42.6	37.36	38.56	Normal
2020.1.18	1	24	21	22.4	42.02	39	38.47	Normal
2020.1.19	2.8	24	21	22.38	42.38	36.08	39.5	Normal
2020.1.20	0.6	24	21	22.56	39	37	36.42	Normal
2020.1.21	1	24	21	22.35	37	34.52	36.45	Normal
2020.1.22	2.7	24	21	22.41	38.62	36	36.42	Normal

son community was 28 W/m^2. Through indoor temperature measurement, the average indoor temperature of the comparison community was found to be 22 °C. Therefore, the application of artificial intelligence heating systems has improved the thermal comfort of residents, bringing users a high quality heating experience while relatively reducing energy consumption.

The application of artificial intelligence technology in the heating system has greatly improved the heating effect, enhanced the ability to regulate and manage indoor temperature for users, and optimized the hydraulic balance performance of the entire building. Simultaneously improving users' thermal comfort and reducing the complaint rate of hot users. Better maintain the operating conditions of heat exchange station equipment in an efficient range, reduce the energy consumption indicators of the secondary network system, and reduce the impact of outdoor temperature changes on indoor temperature fluctuations [9, 10].

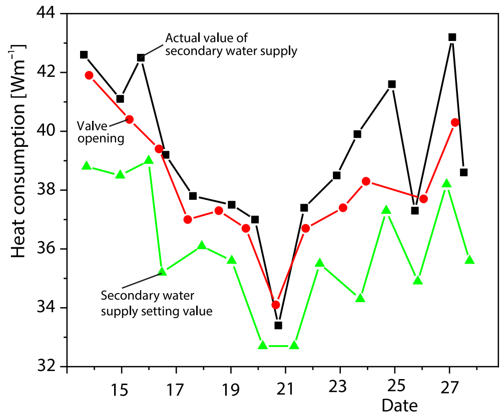

Figure 5. Secondary supply temperature setting and measured values, valve opening

Conclusion

In recent years, with the widespread promotion of heating throughout the country, various advanced technologies have been continuously applied to pipe-line inspection work, thereby achieving a trend towards intelligence and convenience in work. With the development of artificial intelligence technology, people's requirements for the quality of life are constantly improving, and higher requirements are also put forward for the supply system. Therefore, in the development process of the future hydronics, it is necessary to strengthen the research on intelligent control of the hydronics, reduce waste in the heating process by using advanced intelligent equipment, improve the heating efficiency of the city, and provide better services for residents, at the same time, this is also a requirement for establishing an energy saving society.

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