ANALYSIS AND USE OF BUILDING HEATING AND THERMAL ENERGY MANAGEMENT SYSTEM

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Abstract: To explore the role and influence of thermal energy management system on building heating , by building a thermal energy management system based on the Internet of things, the situation of heating system and building heating is analyzed, the heat utilization rate of building heating, the stability of heating temperature, the change of heating energy consumption are mainly studied, and the energy consumption of building and the comprehensive effect of thermal energy management system and residents' satisfaction are analyzed. The research results show that through the role of the Internet of things thermal energy management system, the heat utilization rate of heating buildings has increased from about 65% to about 80%, about 15%. The fluctuation of heating water temperature is reduced from 12°C before the system is adopted to 4°C, which improves significantly. The coal consumption per hour of heating system is reduced from 63kg/h to 50kg/h, and the coal saving is about 15%. This not only saves resources but also reduces environmental pollution. The heat management system based on the Internet of things has significantly improved the heating system and building heating. Through the application of thermal energy management system, not only the heat utilization rate is increased, but also the consumption of resources is reduced and the environment is protected. Meanwhile, it solves the problem of building heating and the maximization of efficiency in the operation of heating companies. The research on building heating and thermal energy management system has a positive effect on the follow-up research.

Keywords: *heat energy; building; temperature; energy consumption; heating*

1. Introduction

With the improvement and strengthening of China's economic strength, people's material living standards have been greatly improved, but the resulting environmental pollution and energy depletion are becoming more and more serious [1]. The main reasons for this situation lie in the following aspects. On the one hand, China's population base is huge, and its dependence on energy is very high. On the other hand, the current level of energy use in China is relatively low, which not only wastes a lot of resources, but also brings serious environmental pollution [2]. At present, China pays more and more attention to environmental protection and efficient use of energy. Industries with low energy utilization and serious pollution are eliminated and closed. The government hopes to improve the environment and carry out industrial transformation through such measures [3]. For heating enterprises, they also face a very sharp test. On the one hand, heating is related to the winter for thousands of families. On the other hand, the environmental pollution caused by heating is obvious. Therefore, it is very urgent to improve the utilization of energy and the level of heat management [4]. Through the heat management system to control the heating energy, on the one hand, it can reduce unnecessary energy consumption, and on the other hand, it can also improve the heat utilization rate of heating, so as to realize the management of building heating from the whole closed-loop ecology [5]. In this study, the energy of heat supply is controlled by energy management system to reduce the consumption of coal resources and improve the efficiency of heat utilization [6]. At present, coal is the main raw material for heating in China, and the combustion of coal will bring serious haze and pollution. In particular, China's population is large, and the coal consumption is very large. Therefore, improving the level of heat utilization is very important to save coal energy and reduce pollution [7]. Resources have a very important impact on the country and everyone's daily life. No matter in military, aerospace, industry and daily life, resources can become raw materials for many things after processing [8]. In this study, through the construction of the heat energy management system based on the Internet of things, the heat utilization rate of building heating, the stability of heating temperature, and the change of heating energy consumption are studied. The energy consumption of the building, the comprehensive effect of the thermal energy management system and the satisfaction of the residents are analyzed, so that the role of energy management system in environment and energy efficiency can be analyzed qualitatively and quantitatively [9].

It is very important for all industries to improve the utilization efficiency of resources. To improve the efficiency of energy utilization, more powerful technology and management system are needed. For the improvement of environment, more advanced management system with less pollution discharge is needed. The population base of China is very large, and the heating consumption in winter is also very large. If the heat management system can be improved, and the efficiency of coal and other resources utilization can be improved, the benefits brought are obvious. At present, this field is still in a relatively primary stage. Therefore, the focus of this study is to manage the heat supply system to reduce environmental pollution and improve the heat utilization.

In this study, through the construction of heat management system based on the Internet of things, the heat utilization rate of building heating, the stability of heating temperature, and the change of heating energy consumption are studied. The energy consumption of the building and the comprehensive effect of the thermal energy management system are analyzed. The research shows that the heat energy management system based on the Internet of things has a significant effect on the improvement of the heating system and building heating, which not only improves the heat utilization rate, but also reduces the consumption of resources and protects the environment. The innovation of this study is that for both two links of suppyling heating and using heating, more comprehensive analysis and research are carried out. At present, most of the research direction lies in the optimization of heating links. Therefore, this study has a very important value for the future research on building heating and thermal energy management system.

2. Methodology

2.1. Building heating

Building heating is quite common in the north of China, which has existed for decades and has a very long history [10]. Heating system plays a very important role in the planning and construction of infrastructure in the whole city [11]. With the increasing scale and height of the building, the temperature of the external environment changes more and more frequently. As the heating system of urban heating, there are problems such as backward control system, insufficient heating, unstable temperature, and poor communication system [12].

The decision hierarchy of heating system is shown in Fig. 1. The most important thing is that at present the air environment quality is very poor, the pollution is very serious, and needs to be improved and innovated. It is the most urgent problem to improve the level of energy utilization and people's living environment [13]. At present, in terms of central heating and heating for urban residents, in some large northern cities, advanced and large-scale heating facilities have been built. In terms of residential equipment and control devices, it has also achieved the most advanced level at present. At present, the mode of urban heat supply in China mainly includes the mode of common operation of thermal power and boiler, and the mode of air conditioning, electric gas heating and heating [14].

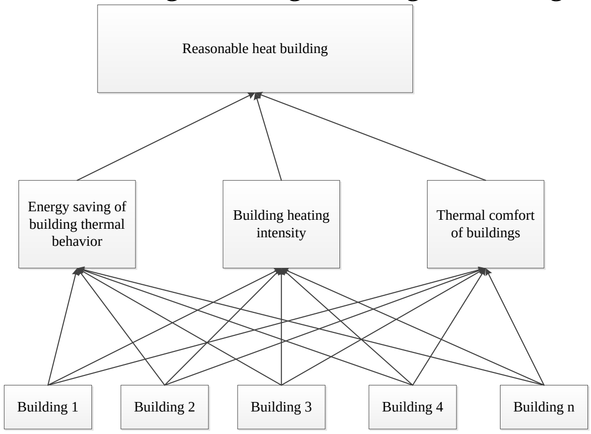

Figure. 1 Decision hierarchy of heating system

2.2. Challenges facing heating system

At present, the international advanced level can reach 85% - 90% in the utilization efficiency of heating boiler heat source. At present, the heat utilization efficiency of China's heating system can only reach about 60%, with a gap of 25% compared with the advanced level [15]. The reason for the low efficiency of heating boilers is that most of the coal used for combustion has not been processed or screened. Therefore, the energy generated by these low-quality coal combustion is not enough to meet the demand of heating boilers [16]. Therefore, most of the heating boilers in China are under the condition of low load operation. The equipment cannot fully play the role of heating, resulting in a large amount of heat is wasted, the purpose of heating the boiler is not achieved, and a large amount of smoke heat generated is wasted [17]. To some extent, the current situation is related to the low level of management personnel, backward automation equipment such as boilers, and low business operation ability of personnel [18]. For urban heating system, it needs to be reflected not only in scale, but also in heating efficiency, residential coverage, heating temperature stability, heat utilization efficiency, etc., which puts forward more stringent requirements for heating system. Only more strict requirements can improve the utilization efficiency of resources and heat. The structure of building heating energy saving control system is shown in Fig. 2.

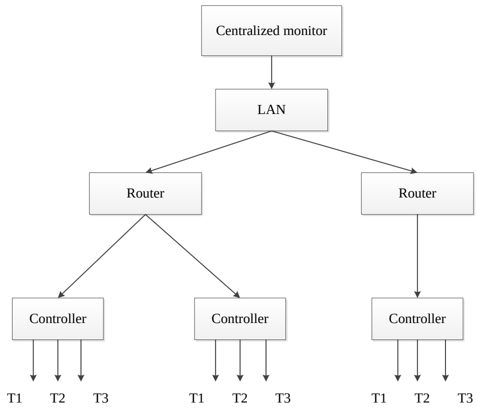

Figure. 2 Structural diagram of building heating energy saving control system

2.3. Overall structure of heating system

The whole heating system can be divided into three layers: monitoring control layer, centralized operation monitoring layer and integrated information management layer. In the monitoring and control layer, sensors and transmitters complete the data acquisition of heating process, such as supply and return water temperature, drum liquid level, furnace pressure, water supply flow, etc. The actuator directly executes the operation command and realizes the control, such as completing the opening adjustment of the valve. Different controllers on the heat source, heat network (including heat exchange station) and heat user respectively collect their process parameters and control their systems. At the same time, the controller transmits the data collected by the controller to the server in the centralized operation monitoring layer through GPRS communication. The structure of energy-saving control system of heating system is shown in Fig. 3.

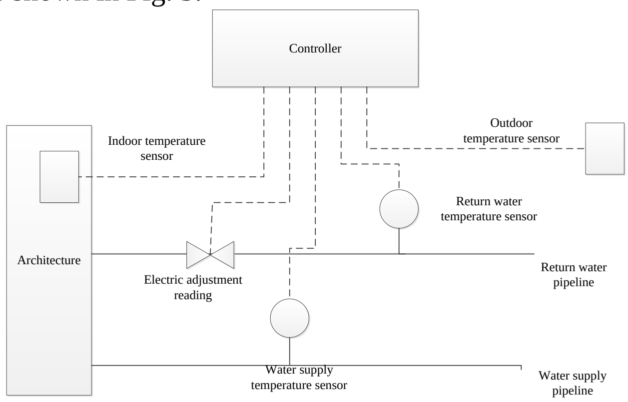

Figure. 3 Structure diagram of energy saving control system of heating system

In the centralized operation monitoring layer, the server is responsible for receiving the data from the monitoring control layer, displaying it in the form of configuration, and completing the monitoring and command release. Network users can be authorized to complete the operation, status monitoring, alarm processing, report printing and other work of human-machine interface of heating system.

In the integrated information management layer, based on the scale of DCS system and the actual needs of the industry, there will be differences in the functions realized. The higher information management layer can include the following functions: real-time information presentation, production scheduling management, cost accounting, energy management, quality management, batch management, equipment maintenance management, etc. The field controller block diagram is shown in Fig. 4. The comprehensive information management layer of the heating system mainly realizes the functions of real-time information presentation, energy management, batch management and equipment maintenance.

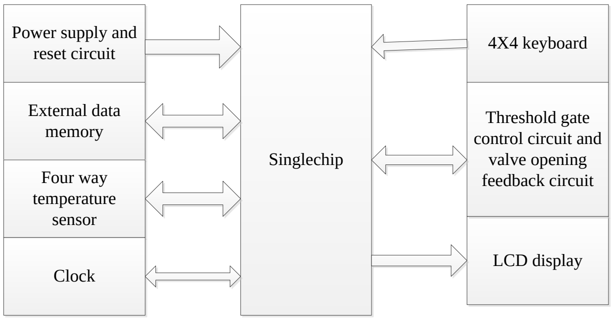

Figure. 4 Field controller block diagram

Calculation of heat loss of directly buried pipelaying trenching pipeline: The thermal resistance of soil is deduced according to the theory of heat transfer. Using the concept of equivalent thickness to consider the exothermic heat resistance of the earth's surface facing the outdoor cavity gas, the soil heat R_t (m * C / W) can be calculated by the following Eq. (1):

$$R_t = \frac{1}{\lambda_t} \mathrm{In}\left[\frac{h^{/}}{\gamma_z} + \sqrt{\left(\frac{h^{/}}{\gamma_z}\right)^2 -1}\right] \quad (1)$$

In the Eq. (1),

$$h^{/} = h + \delta = h + \lambda_1 / \alpha_0 \quad (2)$$

The above Eq. (2) can be simplified as Eq. (3):

$$R_t = \frac{1}{\lambda_t} \mathrm{In} \frac{2h^{/}}{\gamma_z} \quad (3)$$

Therefore, the calculation equation of heat loss for pipelaying without trenching utilidors is as following Eq. (4).

$$\Delta Q = \frac{2\pi\left(t - t_0\right)/\left(1+\beta\right)}{\frac{1}{\lambda_b}\mathrm{In}\frac{\gamma_z}{\gamma_w} + \frac{1}{\lambda_t}\mathrm{In}\frac{2h^{/}}{\gamma_z}} \quad (4)$$

The method of lumped parameter is used to divide the previous calculation based on the heat loss of pipe network segment by segment. The heat supply pipeline from the heat source to a heat exchange station is regarded as a unit of calculation p_i. Then, the heat loss Q_i of each calculation unit is calculated separately, then the heat loss of the primary network of the whole heating system is $\sum \Delta Q_i$. The heat loss calculation equation of pipeline p_i is given as Eq. (5):

$$\Delta Q_i = A.\left(\bar{t} - t_w\right).l \quad (5)$$

When optimizing the operation of the heating network, it is necessary to convert the heat loss of the pipeline into an economic index, that is, the annual heat loss cost of the heating network operation, as shown in the Eq. (6):

$$C_h = 3.6\times10^{-6}\Delta Q_i.n_h.j_h \quad (6)$$

The optimization objective function selects the annual conversion cost of heating network operation. The annual conversion cost of heating network operation mainly includes two parts. One is the heat loss cost of pipeline, and the other is the power consumption cost of heat medium transmission. The goal of operation optimization of heating network is to select the scheme with the least operation conversion cost on the basis of considering both effects. The optimization objective functions of heating network operation are given as Eq. (7) and Eq. (8):

$$\min M = C_h + C_c \quad (7)$$

$$H_{gr} = h_0 + q_{rh} - h_c - \sum_{r=1}^{8}\tau_r\eta_r \quad (8)$$

In the actual operation of the heating system, the high circulation flow will inevitably lead to the rise of the operation electricity cost. The increase of water supply temperature can reduce the operation electricity cost, but increase the heat loss of the pipe network. However, because the energy quality of electric energy is higher than that of heating energy, from the perspective of qualitative analysis, increasing the primary network water supply temperature will increase the heat loss of the pipe network, but its proportion is small. Increasing the temperature of the primary water supply can increase the temperature difference between the secondary water supply and return water of the heat exchange station, thus greatly reducing the workload of the circulating water pump, and the effect of power saving is obvious. To sum up, the operation scheme of heating pipe network to increase water supply temperature and reduce water supply flow can be preliminarily determined.

2.4. Internet of things thermal energy management system

China attaches great importance to the urban heating system and invests a lot of money. At the same time, the government has very strict requirements on the environmental pollution of heating boilers. However, in the actual operation process, due to the obstacles and limitations of various factors, the requirements stipulated by the government have not been achieved, mainly due to the failure to implement advanced technology and experience in the system operation process. In addition, at present, there are no clear regulations and standards for energy consumption monitoring, equipment maintenance, production records, etc. in the heating system in China, which leads to the lack of corresponding supervision by the regulatory authorities according to this standard, so the blind discharge of heating enterprises will occur. The operators only rely on relevant experience for adjustment and control, which is seriously lack of science and rationality. The main program flow of the Internet of things thermal energy management system is shown in Fig. 5. It is feasible to apply the Internet of things technology in the heating system. The whole Internet of things system is divided into three layers: perception layer, network layer and application layer.

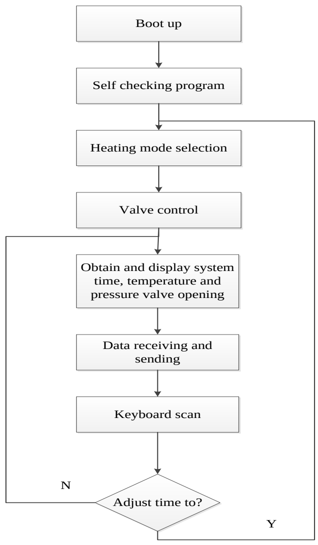

Figure. 5 Main program flow chart of Internet of things thermal energy management system

With the Internet of things technology, it can form an effective connection between "people and things" and "things and things", and promote people to obtain accurate and scientific data and information more conveniently. In order to promote the heating enterprises to achieve the goal of energy consumption reduction, it is necessary to accurately grasp the data related to energy consumption of the heating enterprises, and reasonably analyze the energy consumption data according to the overall goal of energy conservation and emission reduction, and then take the corresponding reasonable measures to promote the heating system to ultimately achieve energy conservation and emission reduction. Using the Internet of things technology, not only can real-time monitor the energy consumption of each heating pipeline and the total energy consumption of the heating system, but also can real-time monitor the water loss and pump status of the heating network. The procedure flow of heating mode selection is shown in Fig. 6. Energy consumption control of heating system, as the basic link in the specific energy conservation and emission reduction work of the whole heating system, can provide the basis and convenience for the heating enterprise and relevant departments to "take the right medicine" in time, and provide reliable support for the solution of energy conservation and emission reduction of heating system only when the most authentic and accurate information is mastered in time

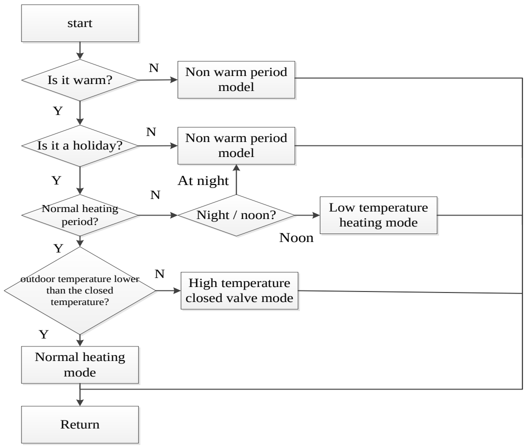

Figure. 6 Heating mode selection procedure flow chart

2.5. Application of Internet of things in heating system

The application of Internet of things technology in heating system is mainly reflected in the following three aspects:

(1) Data collection. In the heating system, the Internet of things technology mainly has two kinds of data collection ways, which are manual data collection and automatic data collection. Among them, the automatic data acquisition realize the collection of heat, flow, time and temperature and other parameters mainly through the installation of sensors on the pipe network, user heat meter, heat exchange station, thermal power plant and heat source.

(2) Information reading. The data information transmitted by the sensor is identified. According to TCPP protocol, it is converted to network transmission format, and then connected by wireless or wired way to promote the realization of bottom data upload and collection function.

(3) Information judgment and feedback. The operating system uses a mixed software architecture of B / s and C / s, and uses browse mode to implement status monitoring. This mode is not only clear and easy to operate, but also can provide guarantee for database security. In the aspect of system management, CS mode is used to manage database, which has strong interaction. The flow diagram of building energy system is shown in Fig. 7.

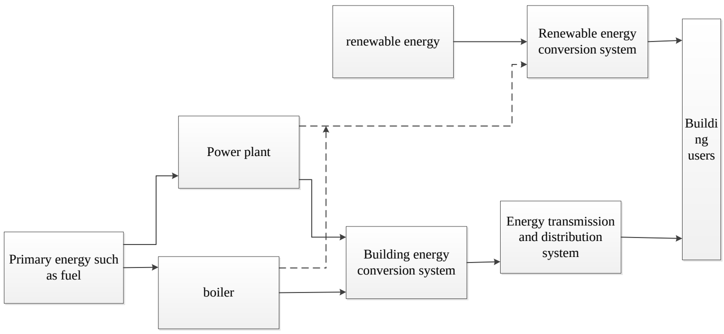

Figure. 7 Flow diagram of building energy system

Through the application of the above three aspects, for the management policy, data modification and query have faster response speed. For the data acquisition layer, because it collects the relevant data such as users, distribution network and boilers, and continues to transmit the breakpoints, it can guarantee the integrity of data and provide substantial basis for the analysis and decision-making of the upper layer. For the data aggregation layer, it mainly includes the data capacity of tens of thousands of points in the whole industrial database, which guarantees the safety and stability of data transmission, and also provides convenience for data query and storage.

3. Results and discussion

The impact of the thermal energy management system based on Internet of things on the heating heat utilization rate of users' buildings is shown in Fig. 8. From the data and column chart in the Fig. 8, it can be seen that through the control of the Internet of things heat management system, the heat utilization rate of heating buildings has been significantly improved compared with the previous one. Before the application of the system, the heat utilization rate of heating buildings is about 65%. After using the Internet of things thermal energy management system, the heat utilization rate of heating buildings is about 80%. It can be seen that the heat utilization rate of heating buildings has been improved by about 15%. The Internet of things thermal energy management system not only improves the utilization rate of heating equipment, saves energy, but also improves the residents' awareness of heating saving, and has made remarkable achievements.

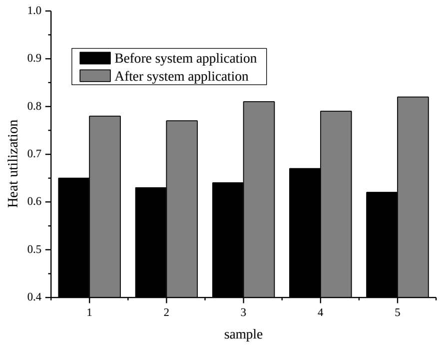

Figure. 8 Study on the influence of thermal energy management system on the utilization rate of heating energy in user building

The research on the control of heat management system for heating temperature is shown in Fig. 9. From the data and trend chart in the Fig. 9, it can be seen that the stability of heating water temperature has been greatly improved compared with that before the application of the Internet of things thermal energy management system. During the 24-hour detection time in this study, before using the system in this research, the heating water temperature has a very large fluctuation, and the fluctuation range is within 12°C. After adopting the Internet of things thermal energy management system in this study, the fluctuation of heating water temperature decreases greatly, and the fluctuation range is in the range of 4°C. It can be seen that the Internet of things thermal management system in this study plays a very important role in the control of heating water temperature. Through such a system, coal resources can be saved to the greatest extent, and residents' dissatisfaction and complaints can be reduced.

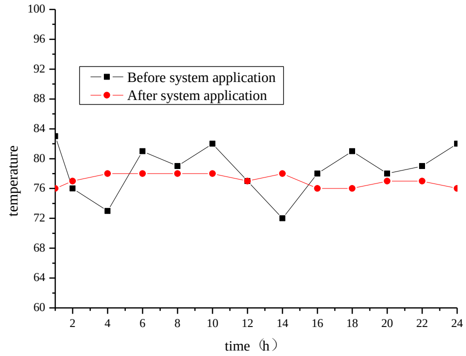

Figure. 9 Research on the control of heating temperature by thermal energy management system

The research on coal utilization control of the Internet of things thermal energy management system is shown in Fig. 10. From the data and trend chart in the Fig. 10, it can be seen that after the adoption of the Internet of things thermal energy management system in this study, the consumption of coal resources has declined significantly. In the six groups of experiments carried out in this study, before using the system, the coal consumption per hour is basically 63kg / h. After adopting the Internet of things thermal energy management system, the coal consumption per hour is basically 50kg / h, and the coal saving is about 15%. It can be seen that the effect of the heat energy management system based on the Internet of things is outstanding, which not only saves a lot of coal resources, but also reduces the environmental pollution caused by heating, so it should be vigorously supported and promoted.

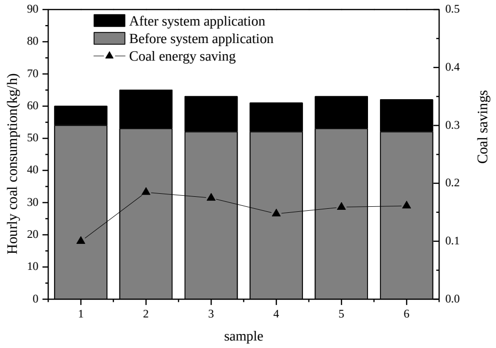

Figure. 10 Research on the control of the Internet of things thermal energy management system for coal utilization

4. Conclusion

In this study, through the heat management system of the Internet of things, the heat utilization rate of building heating, the stability of heating temperature, the change of heating energy consumption and the comprehensive effect of the heat management system are analyzed. The research results show that through the role of the Internet of things thermal energy management system, the heat utilization rate of heating buildings has increased from 65% to 80%, about 15%. The fluctuation of heating water temperature has been reduced from 12°C before the system is adopted to 4°C, which improves significantly. The coal consumption per hour of heating system is reduced from 63kg / h to 50kg / h, and the coal saving is about 15%. This not only saves resources but also reduces environmental pollution. There are also some deficiencies in the research process of this study, mainly reflected in the research of thermal energy management system and building heating, the conclusions are more out of investigation and simulation. For the actual situation and data, due to the limitations of objective factors, it cannot be accurately obtained, so there will be many interference factors. In this study, a lot of external factors are ignored, and the results are not convincing. However, this study provides a valuable reference for the follow-up study of thermal energy management system from a qualitative point of view.

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