

Analysis of the Core Ideas for the Application of Energy-saving Heating Technology in Centralized Heating Systems

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Abstract:

The main heating method used in northern China is centralized heating, but traditional heating systems generally have problems such as low heat source efficiency, severe heat loss in the heating network, and hydraulic imbalance, resulting in high energy consumption. Therefore, the energy consumption issue of centralized heating systems should be highly valued, and new energy-saving heating technologies should be scientifically applied to systematically transform and upgrade from the heat source, conduction path to the user end, in order to comprehensively improve system energy efficiency, reduce heat loss, and avoid energy waste, thus providing strong support for the special upgrade of heating systems.

Keywords:

Energy-saving Technology for Heating, Central Heating System, Technical Application

1. Introduction

With the proposal of China's "dual carbon" target, the heating system should also continuously improve its energy efficiency, reduce energy consumption, and reduce carbon emissions. However, in the actual operation of centralized heating systems, there is a problem of high energy consumption from the heat source to the user end. For example, traditional coal-fired boilers and other equipment are still used on the heat source side, which not only have low operating efficiency but also cause significant pollution to the environment. At the same time, there are also problems such as hydraulic imbalance and high heat loss in the operation of the heating network, which to varying degrees increase the energy consumption of the centralized heating system. To solve these problems, we should start from multiple dimensions such as heat sources, pipeline networks, and users, and build a full chain energy-saving system through the scientific application of heating energy-saving technology, in order to effectively improve energy conservation and emission reduction effects.

2. Analysis of Energy Consumption Issues in Traditional Central Heating Systems

2.1. Low efficiency on the heat source side

Due to factors such as economic conditions and technological level, some existing heating systems in China still use traditional equipment such as coal-fired boilers as heat source generation devices. They have not only been operating continuously for a long time, but also suffer from serious equipment aging and relatively low heating efficiency. These factors result in a low recovery rate of flue gas waste heat, high equipment maintenance costs, and the generation of a large amount of exhaust gas, causing serious pollution to the environment and affecting the ecological environment of surrounding areas as well as the physical and mental health of residents. At the same time, the boiler management mode is also relatively backward, unable to finely control energy.

2.2. Significant losses in the pipeline network

Due to the long-term continuous operation of the centralized heating network, the equipment in the network is prone to corrosion, which not only increases the heat loss of the heating system, but also seriously affects the overall performance of the heating system. At the same time, many heating pipelines suffer from problems such as water leakage and dripping due to long-term disrepair, further increasing heat loss and energy consumption.

2.3. Terminal control issues

Due to the widespread hydraulic imbalance in the centralized heating network and the lack of household control devices in the system, the room temperature of nearby users often exceeds the heating standard temperature, resulting in serious waste of heat energy. However, at the same time, the room temperature of remote users is significantly lower than the heating temperature standard.

3. Application Path Analysis of Heating Energy saving Technology in Central Heating System

3.1. Application of energy-saving heating technology on the heat source side

3.1.1. Optimize the heat generation system

Boiler is a commonly used heat generating equipment in centralized heating systems. It mainly generates heat by burning fuel and heats water or other media, and then transports the heat medium to the user end through pipeline guidance. Therefore, in order to improve the energy-saving effect of centralized heating systems, we should start with upgrading and renovating the boilers on the heat source side. Firstly, it is necessary to fully understand the main factors that contribute to boiler energy consumption. Through analysis, it was found that if the insulation effect of the water or heat medium storage container in the boiler system is poor, heat loss will occur before pressurized transportation, resulting in energy waste. Therefore, the storage container should be optimized and better insulation equipment and materials should be used. At the same time, there are significant differences in the thermal conversion rate of different fuels in boiler systems. Compared with traditional open flame coal

combustion and new water gas fuel, the thermal conversion rate is significantly lower. Therefore, new fuels with better energy-saving effects should be actively adopted. In addition, maintenance and upkeep of the boiler system should be strengthened, residual fly ash in the boiler should be promptly removed, and daily maintenance of equipment should be strengthened to avoid problems such as water and liquid leakage, thereby improving energy efficiency from the source of heat generation. On this basis, artificial intelligence technology should also be organically integrated into the boiler system to establish a heat generation and control system with a high level of intelligence. The AI control system can monitor and collect key parameters such as flue gas oxygen content and furnace temperature during the boiler combustion process in real time, and can dynamically optimize and adjust them through random forest algorithm to obtain the optimal air-fuel ratio, thereby effectively improving the coal-fired efficiency of the boiler and reducing nitrogen oxide emissions. In AI control systems, digital twin technology should also be combined to set up fault diagnosis modules to achieve early warning of abnormal working conditions such as air leakage and coking, thereby avoiding shutdown maintenance and reducing energy waste.

3.1.2. Actively apply energy recovery equipment

When using boilers as the heat source equipment for centralized heating systems, energy combustion not only heats the heat medium, but also dissipates a lot of heat or is discharged in the form of exhaust gas, resulting in significant heat loss. This is also an important link in the formation of energy consumption in centralized heating systems. Therefore, energy recovery equipment should be actively applied to concentrate and recycle this part of heat, thereby improving energy efficiency. For example, smoke heat recovery devices can be installed in centralized heating systems. This new energy-saving device can effectively collect the waste heat and water vapor from the exhaust outlet and reuse them. The heat medium and water are generally stored in liquid form in the heat recovery device, and then the hot water can be directly mixed with the water or heat medium in the boiler for continued use, thereby improving the overall energy conversion rate of the heat source and reducing energy consumption without affecting temperature requirements. At the same time, the recycling device can also be used to collect the high-temperature wastewater generated during the pressurization process and the heat medium inside the boiler, and recycle the heat for secondary use, in order to improve the energy-saving effect of the centralized heating system. In addition, we should actively build an intelligent energy recovery system. In the system, the 5G communication module and Internet of Things sensing equipment can be deployed to dynamically monitor the recovery of flue gas waste heat, and the recovery power can be adjusted in real time in combination with edge computing technology to effectively control the flue gas temperature and improve the annual recovery of heat. In the future, further exploration should be conducted on the deep integration of reinforcement learning control strategies with heat pump systems, so that they can automatically switch between recovery/energy storage modes according to the load requirements of the pipeline network.

3.1.3. Establish a climate adaptive control system

The purpose of centralized heating is to regulate the indoor thermal environment of buildings, so its system energy consumption is closely related to building heating measures, and natural climate is also an important influencing factor. The centralized heating system should be able to dynamically adjust its operating power according to

natural climate change. Therefore, the constant power operation mode of the existing centralized heating system should be optimized and improved to avoid energy waste caused by heating capacity exceeding user demand. In order to enable the heating system to adjust heating according to external climate changes, IoT sensing devices should be actively used to dynamically monitor the outdoor ambient temperature of buildings, compare the collected external ambient temperature data with the actual needs of users, and then compensate for the difference through centralized heating. That is to say, when the external ambient temperature is low, the heat is increased by adjusting the temperature of centralized heating, and when the ambient temperature is high, the heating is reduced. At present, although it is possible to adjust the heating effect on the user end, there are still shortcomings in the accuracy of adjustment and control. Therefore, it is necessary to further strengthen the integration with artificial intelligence technology and algorithms. For example, an intelligent heat load regulation system can be constructed using LSTM time series prediction models to predict changes in heating demand in advance. In the system, it can also be integrated with meteorological forecast data to provide reliable basis for establishing a “temperature energy consumption” response surface, thereby effectively reducing energy losses caused by excessive heating in climate sensitive areas.

3.2. Application of energy-saving heating technology in heat transfer pathways

3.2.1 Optimize the pressurization control system

In order to meet the heating needs of high-rise buildings and long-distance heating, it is necessary to transport heat medium through pressurization in centralized heating systems. However, a large amount of heat is often consumed during the pressurization process, which is also an important link in the energy consumption of the system. Moreover, pressurization can lead to an increase in the transfer time of the heat medium, thereby increasing heat loss. Therefore, in order to improve the energy-saving effect of centralized heating systems, it is necessary to introduce energy-saving technologies during the pressurization process and optimize and improve the pressurization control system. When applying pressure, the current method of applying pressure and then releasing pressure should be changed, and a new mode of dynamically adjusting the pressure position and pressure value according to the actual heating demand should be adopted [3]. At the same time, necessary insulation measures should be taken for pressurized areas and pressurized equipment to reduce the heat loss of the heat medium during the pressurization process. To reduce heat loss when supplying heat to high-rise buildings, measures such as installing water storage tanks in high-rise buildings can be taken to lower energy consumption. Hot water tanks can generally be installed on the top floor of high-rise buildings. When they participate in the water circulation of the building's heating system, they can reduce the need for pressurization, thereby effectively reducing the overall energy consumption of the centralized heating system. In addition, an intelligent pressurization control system should be actively constructed. Variable frequency pressurization technology should be adopted in the system and deeply integrated with genetic algorithms and pressure sensing networks to reduce ineffective pressurization energy consumption. During system construction, intelligent devices such as MEMS micro pressure sensor arrays can be deployed at key nodes of the pipeline network to form a digital image of the pressure field, thereby improving the control capability of hydraulic balance.

3.2.2. Strengthen the insulation monitoring of heating pipelines

Due to the characteristics of centralized heating systems, the pipeline from the heat source to the user end is often relatively long, which leads to a large amount of heat loss during the heating process and increases the overall energy consumption of the system. Although the current heating network uses underground piping to utilize natural soil insulation, which can reduce some heat loss, the vertical heat medium channels inside residential areas and buildings are still the key link in heat loss. Especially in high-rise buildings, due to some heating pipelines being exposed outdoors, the problem of heat loss in their heating systems is more prominent. Meanwhile, circulating water is still a commonly used form of heating, but during the flow of the heat medium, as the contact area between it and the external low-temperature environment increases, more heat is lost. Therefore, in order to solve this problem, necessary insulation measures should be taken for the heating pipeline, and the pipeline layout structure should be continuously optimized to further improve the insulation effect and achieve the goal of energy conservation and consumption reduction. When laying heating pipelines, the heat medium transmission pipeline should generally adopt a fishbone type dispersed layout, and the length of the pipeline exposed to the external environment should be minimized as much as possible to reduce heat exchange between it and low-temperature environments. When setting up vertical transportation pipelines inside buildings, insulation layers should be installed for indoor pipelines, and insulation materials with good insulation performance should be selected reasonably to minimize heat loss as much as possible. For underground pipelines, insulation layers should also be installed or other insulation measures should be taken when necessary to comprehensively improve the insulation performance of heating pipelines and create favorable conditions for achieving energy-saving and consumption reducing goals in centralized heating systems. In addition, in the construction of centralized heating systems, it is also necessary to actively build an intelligent pipeline insulation monitoring system. The intelligent insulation system can apply DTS fiber optic temperature measurement technology and adopt a distributed layout to achieve real-time detection of heat loss per meter of pipeline. The monitoring error can be controlled at around 0.5 °C, which plays an important role in reducing heat loss in the pipeline network. At the same time, the system can also be combined with Building Information Modeling (BIM) technology to accurately predict and identify weak insulation points through three-dimensional heat conduction simulation, providing reliable reference for carrying out preventive maintenance work.

2.3. Application of energy-saving heating technology on the user side

2.3.1. Optimize the heating fee model

The energy waste on the user side is also an important factor affecting the overall energy consumption of centralized heating systems. Due to the limitations of current technology and economic conditions in accurately defining the boundaries of centralized heating and precise regulation of heating, it is difficult to achieve comprehensive implementation in the short term. Therefore, most of China's centralized heating systems adopt a one-time charging method based on heating cycles. Although this charging method is relatively simple and convenient, it objectively affects the overall energy consumption of the centralized heating system and is not conducive to achieving energy-saving and emission reduction goals. The

amount of heat consumed by the user end is a key factor affecting the energy consumption of centralized heating systems. Currently, there is a phenomenon in some areas where the temperature of centralized heating exceeds the average demand of the population, and even the indoor environment temperature reaches 25 °C or above, which requires users to improve indoor comfort by opening windows for ventilation and other means, resulting in a large amount of heat being wasted. But under the existing fixed fee model, it is difficult to make necessary adjustments to this. Therefore, we should actively explore new models of charging based on heat, and install heat control devices at the entrance to give users greater choice and the ability to use heat reasonably according to their actual needs. This will reduce heat consumption and loss while maintaining a stable indoor thermal environment and comfortable experience, in order to achieve the goal of reducing energy consumption. However, this model is still in the pilot stage and there are still some shortcomings. It is necessary to increase technological research and development efforts in terms of the convenience and precision of heat regulation on the user side.

In this context, in order to effectively alleviate this problem, blockchain technology should be actively introduced to build a digital heat metering system with a high level of intelligence. The heat metering system based on smart contracts can store heat consumption data on the blockchain by setting up TEE trusted execution environment chips in household heat meters, and can provide support for minute level fee settlement. Its settlement accuracy can be controlled within 0.01 yuan, and users can easily complete transactions using digital wallets, thus having high application value. At present, the system has achieved good results in pilot areas.

3.3.2. Building an intelligent terminal interaction system

In traditional centralized heating systems, mechanical valves generally need to be manually adjusted, which is difficult to operate and many residents are unaware of the adjustment position of the heating system. This makes it difficult for users to truly achieve autonomous adjustment of household heat, resulting in ineffective implementation of energy-saving and consumption reducing measures on the user side. Therefore, it is necessary to strengthen the construction of intelligent terminal interaction systems and provide convenience for user operations through intelligent adjustment methods. In the deployment process of the intelligent terminal interaction system, mature data obtained from previous experiments can be used as preset adjustment parameters, and real-time monitoring of household water temperature can also be achieved by deploying IoT sensors at the user's water inlet. At the same time, it should be connected to the operation panel in the form of an electromagnetic valve to display real-time monitoring data of the current heating temperature, and users can conveniently adjust the temperature directly through the panel. In the AIoT temperature control panel, multiple functions such as behavior learning and voice interaction can be highly integrated, and heating curves can be automatically drawn according to the different daily routines of family members. The digital twin user portrait technology can also be combined with VR virtual reality technology to visually present the thermal energy flow trajectory on the interface, allowing users to form a clear understanding of the control effect. Therefore, this visual and convenient temperature control method can to some extent encourage users to actively adjust the temperature according to their needs, not only reducing their own heating expenses, but also promoting the overall energy-saving effect of the centralized heating system.

4. Conclusions

The application of energy-saving heating technology can effectively improve the energy efficiency of centralized heating systems and reduce their operational energy consumption. At the same time, in the construction and renovation of centralized heating systems, it is necessary to strengthen the deep integration with new predictive and control technologies such as digital twins, so that the heating system can achieve cross energy coordination with the power system, thereby further improving energy efficiency.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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