Intelligent Regulation Method of University Heating Water Flow Based on Adaptive Control Algorithm

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Abstract. With the increasing requirements of energy saving and indoor environment, variable flow technology is widely used in heating system, and the adjustment of resistance is the throttle adjustment of valve. However, the economic loss of this adjustment method is too great. Therefore, a new intelligent adjustment method of university heating water flow is designed based on adaptive control algorithm. First, a single loop network is connected. Secondly, an intelligent adjustment system of university heating water flow is designed based on adaptive control algorithm. Experiments show that the designed intelligent adjustment of heating water flow is achieved.

Keywords: Adaptive control algorithm · Heating in colleges and universities · Water flow · Intelligent regulation

1 Introduction

In the traditional double-pipe heating pipe network system, regardless of the branch pipe network or the ring pipe network, the hydraulic conditions of the parallel branch lines in the pipe network system are mutually influenced, that is, if the hydraulic conditions of a branch line change, it will lead to the change of the hydraulic conditions of the parallel branch lines, thus changing the hydraulic conditions of the whole heating system [1]. In actual engineering, if the hydraulic condition of a branch changes greatly and the system itself cannot meet the requirements [2–4], in order to ensure the operating pressure of a branch line, a booster pump [5] should be installed on the branch line without increasing the head of the heat source circulating pump. However, this way will change the flow of the trunk line, and then change the hydraulic condition of the trunk line, which will lead to changes in the operating flow and pressure of other branches.

Because the water supply and backwater share the same pipe, the hot water in the pipe flows out of the heat source and flows through each branch trunk line in turn along the water flow direction, and finally flows back to the heat source [7]. In the process, the hot water in the ring trunk line flows into the branch trunk line and then flows back to the ring trunk line, so the circulating flow of each point of the ring trunk line is equal,

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and its value is equal to the flow of the heat source outlet pipe section [8]. It can be seen that the hot water flow of each branch trunk line is independent and unaffected. The hydraulic condition of the ring trunk line of the unidirectional ring heating system affects the hydraulic condition of the branch line [9], while the hydraulic condition of the branch line does not affect the hydraulic condition of the ring trunk line.

Because the traditional double-pipe heating system needs to lay two water supply and return pipes at the same time, the initial investment and operation cost of the pipe network are high, and the hydraulic condition of the system is complex [10], and the stability is poor. Reasonable design and planning of the heating pipe network system can ensure the high operating efficiency of the heating system and the heat medium transmission and distribution capacity under network expansion or accident conditions, which is of great benefit to reducing the initial investment and operating cost of the heating pipe network system and improving the heating quality of the heating network. One-way loop network has the greatest advantages of simple and stable hydraulic conditions and convenient adjustment of hydraulic conditions. However, this kind of system has been in existence for a short time. In order to ensure the heating quality of the system, meet the heat demand of users, make the heat energy production, transmission and distribution reasonable and economical, and reduce the operating cost of the heat supply network, it is necessary to study the operation regulation mode of the unidirectional ring network heating.

Intelligent regulation of university heating water needs to consider the increase of heating area, and solve the above problems such as large initial investment, high operating cost and complicated hydraulic conditions. It has become a trend to use multi-heat source combined heating. Compared with single heat source heating system, multi-heat source combined heating system has outstanding advantages, which disperses the supply position of heat sources, reduces the pipe diameter and flow rate of heating system, and increases the investment of pipe network and the energy consumption of system operation. The operation cost of heating system is very high, and its operation consumes huge power. Therefore, the research on heating regulation mode and operation regulation of multi-heat source combined heating system is of great significance to reduce the operation energy consumption of heating system.

2 Design of Intelligent Regulation Method of University Heating Water Flow Based on Adaptive Control Algorithm

2.1 Connect the Single Ring Network

One-way loop network system is composed of heat source, heat network and heat users, which is a heating system based on loop pipe network, while the core of double-pipe heating pipe network is heat source, which is different from each other. The unidirectional ring network system mainly includes unidirectional ring trunk line, ring trunk line boosting point, ring trunk line heating point and ring trunk line cooling point; The circulation schematic diagram of branch trunk water supply pipe, branch trunk return pipe, heating station and single ring network is shown in Fig. 1 below.

As can be seen from Fig. 1, the unidirectional ring trunk line: the hot water flows circularly along the unidirectional ring trunk line after flowing out from the heating point,

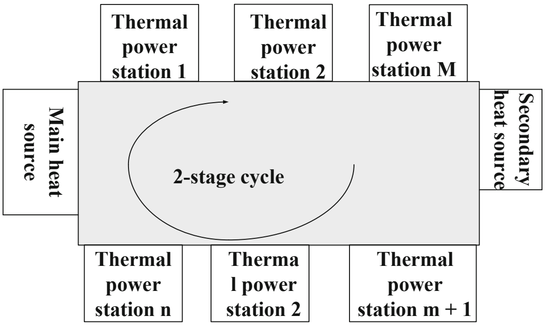

Fig. 1. Schematic diagram of single ring network connection

and some of the hot water flows out of the ring trunk line through the cooling point during the circulation process, and then flows back to the ring trunk line after cooling down, so that the temperature of the hot water in the ring trunk line gradually decreases along the flow direction, but the circulation flow of the ring trunk line is constant along the way, and the pressure of the pipe network gradually decreases along the circulation flow direction. Finally, the hot water in the one-way ring flows back to the heating point for heating, thus continuing to circulate.

Ring heating point of trunk line: In the one-way loop heating system, if the heat source heats the hot water in the loop, the heat source is the heating point of the one-way loop network. Cooling point of ring trunk line: When there is a branch trunk line connected to the ring trunk line, part of hot water flows into the branch trunk line from the ring trunk line to deliver heat to the heat users, and then flows back to the ring trunk line after the temperature drops. Ring-shaped trunk line boosting point: A circulating water pump is set on the ring-shaped trunk line to provide circulating power to eliminate the along-way resistance and local resistance caused by the hot water flowing along the one-way ring network, and then the device circulating water pump of the ring-shaped trunk line is the ring-shaped trunk line boosting point. One-way ring network system consists of three cycles-heat source cycle, heat network cycle and heat user cycle.

The operating temperature level of heat medium in the three-stage cycle is different, the heat source cycle temperature level is the highest, the loop trunk cycle temperature level is the second, and the heat user cycle temperature level is the lowest. Increasing the water supply temperature of heat source can increase the temperature difference between supply and return water of heat source circulation, thus reducing the power consumption of heat source circulation; The mixed temperature of the circulating water supply of heat source and the hot water of the ring trunk line decreases through the heating point of the ring trunk line, thus lowering the operating temperature of the ring trunk line and reducing the insulation investment of the ring trunk line network to a certain extent; As the heat is gradually transferred from the ring trunk line to the heat users along the flow direction of heat medium, the temperature of hot water on the ring trunk line gradually decreases, while the water supply temperature obtained by the heat users located in different branch trunk lines gradually decreases along the flow direction of hot water on the ring trunk line, and the temperature of hot water on the ring trunk line presents a stepwise distribution. Therefore, it can be seen from the form of unidirectional ring network system that the energy in unidirectional ring network system is in the form of cascade utilization.

The circulating water pump located at the heat source of the common double-pipe heating pipe network system provides the transmission power of the whole heating system. However, when the heating scale of the heating system is large, it is necessary to make the head of the circulating water pump large enough to meet the pressure requirements of the most unfavorable users at the end of the system, resulting in high operating pressure of the pipe network and heat users near the heat source. Excessive operating pressure of the system increases the investment cost of pipe network and equipment, and increases the damage probability of heating equipment. Moreover, the heat users close to the heat source need to reduce the operating pressure of the secondary network system by throttling and depressurizing, which leads to the waste of energy consumption and increases the operating cost of the system.

In the traditional double-pipe heating system, the change of hydraulic condition of any heat user will cause the change of hydraulic condition of the main line. Compared with the traditional double-pipe heating system [11], the trunk line of the unidirectional ring network system adopts the form of a single pipe, and the system has only one water supply pipe. The resistances of the ring trunk line and the branch trunk line of the heating system are powered by the pumps located on the ring trunk line and the branch trunk line respectively, and the required lift of the circulating pump on the ring trunk line is reduced, which reduces the pressure bearing capacity of the pipe network. This arrangement of power transmission equipment theoretically eliminates the throttling loss on the branch lines and reduces the operating cost. The hydraulic conditions of branch trunk lines in unidirectional ring network system do not affect the hydraulic conditions of trunk lines, and the hydraulic conditions of branch trunk lines do not affect each other.

In the traditional double-pipe heating system, because of the complex series-parallel control between pumps and the mutual influence of hydraulic conditions, it is not conducive to the application of distributed variable frequency pump system. However, in the unidirectional ring network system, the system operates in different levels, and each level of operation is relatively independent. The hydraulic condition of the secondary side of the branch trunk line does not affect the hydraulic condition of the ring trunk line. And the pressure loss of each branch line is overcome by the circulating pump on the branch line, which avoids the throttling loss and reduces the operation energy consumption compared with the double-pipe system. In the unidirectional loop network system, the pressure difference between the water supply and return branch lines from a branch node is small, and each heat user of the secondary network at the branch line side can select the appropriate distributed variable frequency pump according to the hydraulic calculation data. In the traditional double-pipe heating system, when the heat load in the area under its jurisdiction increases, the demand of load increase can only be met by increasing the circulating water volume of the pipe network. However, the increase of circulating water volume will lead to the increase of the hydraulic loss of the system, which will lead to the situation that the pressure difference for return pipe in the system becomes smaller or even negative.

The heat transfer capacity of single pipe system can be improved not only by increasing the circulating water flow, but also by raising the hot water temperature, so that the heat transfer and heat source configuration of the system are no longer limited by the circulating water. According to the distribution of heat load in the heating area, the pipe network and heat sources are scientifically arranged. When the heating load increases in the future, new heat sources can be installed at appropriate locations to provide the heating capacity of the high-heat network, thus improving the heat load carrying capacity of the heating system. Compared with the traditional double-pipe heating system, when new users are added, the supply and return water pressure of some branch end users does not meet the requirements and the heating effect becomes worse. Because the unidirectional ring network system is a cascade heating system, the hydraulic conditions of branch lines do not affect the hydraulic conditions of ring trunk lines. When new users are added to branch lines, the circulating water pump head of ring trunk lines remains unchanged, and the resistance of new users to branch lines is borne by the internal water pump of branch lines. For the increase of heating load of the system caused by new user branch lines, it is only necessary to increase the water supply temperature of the heat source or add new heat sources in the heating system to meet the demand of increasing heating load. The connection mode between heat network and heat users has different effects on the initial investment, hydraulic and thermal conditions, and operating costs of the heating system. Therefore, we should try our best to choose the appropriate heating connection mode. There are three traditional connection modes: direct connection, mixed water connection and indirect connection. The latter two connection modes are also suitable for one-way loop system. The schematic diagram of heating station connection at this time is shown in Fig. 2 below.

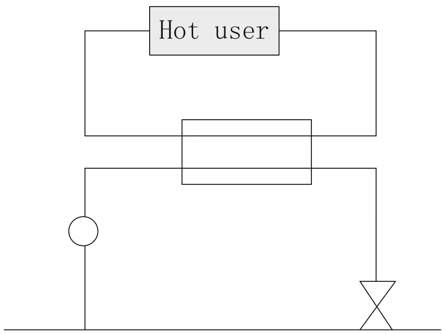

Fig. 2. Schematic diagram of thermal station connection

As can be seen from Fig. 2, the indirect connection form in the one-way loop network heating station is that the primary and secondary sides of the heating station are two independent circulation systems, and the calculation of the user heating heat load Q_i' of the heating station at this time is shown in the following (1).

$$Q_i' = q_f \bullet F \times 10^{-6} \tag{1}$$

In the formula (1), q_f represents the thermal index of heating buildings of heat users, and F represents the heating area of users of heating stations. For the primary and secondary sides of the thermal station, ignoring the heat loss along the heat network and the heat exchange efficiency of the heat exchanger, the heat balance equation for the primary side of the thermal station is shown in (2).

$$Q_i = cG_{i1} \cdot (\tau_i - \tau_{ih}) \tag{2}$$

In formula (2), G_{i1} represents the water supply flow of the branch line, τ_i represents the water supply temperature of the branch line on one side, and τ_{ih} represents the backwater temperature of the branch line. At this time, the thermal balance equation of the branch line will be shown in the following (3).

$$(G_c - G_{i1})c\tau_i + G_{i1}c\tau_{i1} = G_c c\tau_{i+1} \tag{3}$$

In formula (3), G_c represents the hot water circulating flow of the ring trunk line, and τ_{i+1} represents the water supply temperature at the cooling point. By integrating the above formulas, we can get the temperature of the cooling node of the ring trunk line and the primary side flow of the thermal station as shown in (4) and (5) below.

$$\tau_{i+1} = \tau_i - \frac{Q_i}{cG_c} \tag{4}$$

$$G_{i1} = \frac{Q_i}{c(\tau_i - \tau_{ih})} \tag{5}$$

When the mixed water pressurizing pump is installed in the heating station in the system, when the mixed water direct connection is adopted, compared with the direct connection without mixed water, the mixed water connection can increase the temperature difference between the supply and return water of the ring trunk line and the branch trunk line, reduce the flow in the ring network, reduce the pipe network diameter, reduce the initial investment cost and also reduce the operation power consumption. Compared with indirect connection, hybrid connection has stronger adaptability to the temperature of heat medium on the primary side of thermal power station.

However, when the mixed water direct connection mode is adopted, the hydraulic condition of the secondary side of the thermal power station will be affected by the primary side. When the traditional double-pipe heating system adopts mixed water connection, there are three forms of mixed water pump installed on the water supply pipe of the secondary network, return pipe and bypass pipe respectively. Because there is no return pipe in the unidirectional ring network system, the pressure head provided by the ring trunk line to the heating station is only the loss of hot water along the way between the connection point of the ring trunk line and the branch line for return pipe section. The pressure head is very small and negligible, so it cannot be used as the pressure head for hot water flow in the secondary side of the heating station. The mixed water pressurizing pump is needed to overcome the resistance loss in the secondary side of the heating station. However, when the water mixing pump is installed on the bypass pipe, it cannot overcome the resistance of the user side, so the water mixing connection of the circulating pump installed on the water mixing pipe is not suitable for the single-pipe water mixing direct connection system. As shown in the figure below, the water mixing connection of the water pump installed on the secondary water supply pipe is suitable for the middle and lower reaches of the heating system. In this area, the pressure of the pipe network is low, and the water supply of the water pump is pressurized, which not only meets the pressure requirements of the hydrostatic pressure line of the users on the secondary side, but also does not cause overpressure on the users' side. The mixed water connection of the water pump installed on the return pipe on the secondary side is suitable for the upper and middle reaches of the heating system. In this area, the pipe network pressure is high, and the backwater of the water pump is pressurized, so that the backwater on the secondary side can meet the pressure of the pipe network on the primary side. At this time, the circulating water flowmeter of the users on the secondary side of the thermal station is shown in the following formula (6). Among them, the economic ratio of hydraulic calculation of indoor mechanical circulating hot water heating system is set to 0.86.

$$G_{i2} = 0.86\frac{Q_i}{t_g - t_h} \tag{6}$$

In formula (6), t_g represents the water supply temperature of heat users and t_h represents the backwater temperature of heat users. At this time, assuming that G_{ih} represents the backwater quantity drawn from the backwater of the secondary side of the heat station, the mixing water of the heat station at this time is as shown in (7) and (8) below.

$$G_{i1} = \frac{0.86Q_i}{\tau_i - h} \tag{7}$$

$$u_i = \frac{G_{ih}}{G_{i1}} \tag{8}$$

From the above formula, we can know the relationship between water mixing ratio and temperature, and the relationship between water supply from the primary side of the thermal power station, water withdrawal from the secondary side and circulating water from the secondary side of the thermal power station.

Because the user system of the secondary side of the heating station is a traditional double-pipe heating system, the traditional double-pipe user system regulation mode is also suitable for the operation regulation of the secondary side of the heating station of the unidirectional ring network system, that is, the user system. When the user adopts quality control, the circulating water flow of the user system is a fixed value, and only the water supply temperature of the system can be adjusted. When the secondary network adopts quality control of changing flow by stages, the operating flow of the system is different in different operation stages. In each operation stage, the flow of the system is a fixed value. The water supply and return temperature formulas of quality control of changing flow by stages are shown in (9) and (10) below.

$$G_{i1} = \frac{G_{i2}}{G_{i1} + 1} \tag{9}$$

$$j = \frac{G_{i2} - 1}{G_{i1} + 1} \tag{10}$$

When the user system adopts the quality regulation of changing flow by stages, the larger the temperature difference between the supply and return water at the user side and the smaller the relative operation flow, the smaller the power of the water pump at the user side, the smaller the operation energy consumption of the system and the better the energy-saving effect. However, when the flow of the user system is too small, it will affect the heating effect of the user system. For the double-pipe user heating system, the user circulation flow is too small, which will lead to an increase in the proportion difference of gravity circulation effect among users at all levels, resulting in the vertical imbalance of the system. For a single-pipe user heating system, the circulation flow is too small, which leads to different degrees of change of heat transfer coefficient values of radiators of users in each floor, and also causes vertical misalignment of the user system.

2.2 Design an Intelligent Water Flow Regulation System Based on Adaptive Control Algorithm.

The adaptive process is a process of approaching the target continuously. The path it follows is expressed by mathematical model, which is called adaptive algorithm. Gradient-based algorithm is usually used, especially the least mean square error algorithm. Adaptive algorithm can be implemented by hardware or software. The former designs the circuit according to the mathematical model of the algorithm, while the latter compiles the mathematical model of the algorithm into a program and realizes it with a computer. There are many kinds of algorithms, and its selection is very important, which determines the performance, quality and feasibility of the processing system. In order to avoid vertical misalignment of user system, an intelligent water flow regulation system is designed based on adaptive control algorithm. The temperature of hot water on the ring trunk line of unidirectional ring network system gradually decreases with the direction of hot water flow, which is different from that of the ring trunk line.

The flow of branch trunk lines can be adjusted synchronously or asynchronously. The regulation of one-way loop network system includes hierarchical regulation of loop trunk line, primary side regulation of thermal station and secondary side regulation of thermal station. Therefore, when choosing the adjustment mode of unidirectional loop network system, the adjustment of primary and secondary sides of loop trunk line and thermal station must be considered at the same time. When the heating range of the heating system is relatively small, the single heat source and single loop ring pipe network system can meet the heating requirements of heat users. When the heating system adopts different regulation modes, the energy consumption of the system pumps is different. Because the study of heating regulation mode is of great significance to the economic and reliable operation of heating system, it is necessary to study the heating regulation mode of single heat source unidirectional ring network system as the basic model of multi-heat source unidirectional ring network system.

Under the condition that all the heating stations in the unidirectional loop network system are connected by mixed water, the regulation rules of the loop trunk line, branch trunk line and user side with different regulation modes are obtained, and the energy consumption of the system pumps combined by various regulation modes and the stability of the user system hydraulic conditions are analyzed, as well as the thermal accessibility of the heat users in the unidirectional loop network system with different regulation modes of the heat source water supply temperature.

When the heating stations in the unidirectional ring network system are connected by mixed water, in some cases (the user's geographical location is higher or the pressure level of the user's node is lower), the user-side circulating pump should not only overcome the system resistance but also pressurize the system. At this time, for the normal operation of the user-side, the head change of the user-side circulating pump should not be too large, thus limiting the change of the user-side operating flow. At this time, the user side can only use quality adjustment. Because each branch trunk line adopts quality control, and the temperature of the cooling point of the ring trunk line is equal to the water supply temperature of the primary side of the water mixing station, the temperature control of each cooling point of the ring trunk line also meets the quality control law, so when the ring trunk line keeps constant flow operation, the regulation law of the ring trunk line is also quality control, so it is necessary to design the design working condition parameters of the ring trunk line, as shown in Table 1 below.

Table 1. Working condition parameters

Cooling point	Temperature (°C)	Flow rate t/h	Water mixing ratio
1	130	54	3
2	124	58	2.7
3	118	63	2.4
4	112	69	2.1
5	106	77	1.8
6	100	86	1.5
7	94	98	1.2
8	88	113	0.9
9	82	134	0.6
10	76	165	0.3

It can be seen from Table 1 that the unidirectional ring network is also a hot water heating pipe network, and its heat medium parameters have little difference compared with the traditional double pipe system, so the diameter of the ring trunk line is selected according to the specific friction recommended by the design specification of heating pipe network.

On the premise that the secondary side of the heating station is subject to quality control, when the loop trunk line and branch trunk line adopt quality control at the same time, the temperature of heat source supply and return water and the temperature of each cooling point gradually decrease with the increase of outdoor temperature. The loop trunk line and the secondary side of the heating station both operate at a constant flow rate, and the water mixing ratio of each water mixing station remains unchanged with the outdoor temperature. However, the lower the water supply temperature at the cooling point along the direction of hot water circulating flow, the smaller the water mixing ratio of the water mixing station, and the larger the hot water flow from the primary side is required. When this regulation method is adopted, the system only needs to adjust the water supply temperature of the heat source of the unidirectional ring network system to meet the heat load demand of heat users with the change of outdoor temperature. This adjustment method has the advantages of small adjustment amount and simple operation. At the same time, the water pressure diagram of the ring trunk line has been kept at the design working condition, and the pressure at each cooling point remains unchanged, which does not affect the normal operation of the users on the secondary side, and the heating network runs stably. However, the circulating flow rates at all levels of the unidirectional ring network system are all constant, which makes the pump operation energy consumption of the system very high.

When the annular trunk line runs at a constant flow rate and the water supply temperature of the heat source remains unchanged, with the increase of outdoor temperature, the heat load of heat users decreases, the backwater temperature of the heat source increases, and the water supply temperature of the primary side of each cooling point also increases correspondingly, so the hot water flow from the annular trunk line into the water mixing station through the branch trunk line decreases, while the backwater flow of the secondary side pumped by the bypass pipe in the water mixing station increases, and the water mixing ratio of the water mixing pumps in each heat station increases with the increase of outdoor temperature. Under this regulation mode,

Under the operation mode of constant flow and constant water supply temperature of the ring trunk line, only the hot water flow supplied by the primary side of each mixing station and the return water flow of the secondary side pumped by the bypass pipe need to be adjusted, with few adjustment parameters. However, during the operation, the mixing ratio of each mixing station is constantly changing, and the above two parameters need to be constantly adjusted, which requires high operation requirements. In addition, when this regulation mode is adopted, the operation flow of the ring trunk line of the unidirectional ring network and the secondary side of the water mixing station are all designed flow, which leads to high operation energy consumption. Because the heat source water supply keeps the design temperature all the time, it is not conducive to the utilization of low-grade energy, and the heat source efficiency is low. The temperature of water supply at each cooling point of the ring trunk line increases with the increase of outdoor temperature, which requires higher pipeline insulation materials for the ring trunk line and larger initial investment of pipeline system. Although there are some disadvantages in the operation regulation mode of constant flow rate and constant water supply temperature of the ring trunk line for the unidirectional ring network heating system with single heat source, it has great applicability for the operation mode of the main heat source in the unidirectional ring network system with multiple heat sources, because the main heat source in the system runs at full load for a long time, and with the increase of outdoor temperature, the change law of water supply temperature of each cooling point within the heating range of the main heat source is the same as this.

2.3 Realize Intelligent Regulation of Heating Water Flow in Colleges and Universities

The temperature change of the supply and return water in the one-way loop network system with the quality control mode of changing the flow by stages is different from that of the double-pipe system. The increase of the supply water temperature in the two-pipe system is equal to the decrease of the return water temperature, while the temperature change of the heat source supply water in the one-way loop network system is larger, the change range of the return water temperature is smaller than that of the supply water temperature, and the supply and return water temperature of the heat source all show temperature increase. Along the circulating water flow direction of the ring trunk line, the increasing range of the primary water supply temperature of the heating station at each cooling point at the flow staging point gradually decreases.

On the premise that the secondary side of the heating station is of quality control, when the loop trunk line and branch trunk line simultaneously adopt the quality control of changing the flow by stages, the loop trunk line and the primary side of the heating station both operate at constant flow by stages, and the water mixing ratio of each water mixing station remains unchanged at each stage. In the low flow operation stage, the water mixing ratio of each heating station is greater than that of the design flow operation stage. In each operation stage, the system only needs to adjust the water supply temperature of heat source to meet the heat load demand of heat users with the change of outdoor temperature. When switching between different stages, it is necessary to adjust the water mixing ratio of each water mixing station. This combination of adjustment modes also has small adjustment amount and simple operation.

When the outdoor temperature rises, when the flow rate of the ring trunk line drops to 75% of the designed flow rate, the backwater temperature of the heat source decreases to expand the temperature difference between the supply and the backwater to ensure the heat supply; At the same time, the water supply temperature of each cooling point also decreases, and the cooling range of the water supply temperature of each cooling point is different, and the temperature of the cooling point decreases more along the direction of hot water circulating in the ring trunk line; On the contrary, the water supply flow of the primary side of each cooling point thermal station increases more along the hot water circulation direction of the ring trunk line.

During the operation of the system, it is only necessary to adjust the hot water flow in the primary side of each thermal station and the backwater flow in the secondary side of pumping, with few adjustment parameters. However, the mixing ratio of each mixing pump is constantly changing, so the above two parameters need to be constantly adjusted, and the operation requirements are high. The water supply temperature of the heat source in this regulation mode is always kept at the design temperature, which reduces the thermal efficiency of the heat source and wastes high-grade energy.

When equal temperature difference adjustment is adopted for the ring trunk line and branch trunk line, the temperature difference between the supply and return water of the heat source and the water supply temperature difference between the cooling points remain unchanged. With the increase of outdoor temperature, the flow rate of the primary side of the ring trunk line and branch line gradually decreases, and because of the constant flow rate of the secondary side of the heat station, the amount of backwater pumped by the heat station through the bypass pipe increases, and the water mixing ratio of the water mixing pump of each heat station gradually increases. During the operation stages of the heating system with different flow rates, the loop trunk line, branch trunk line and the three-stage pipe network on the secondary side of the heating station are all regulated by constant flow rate, and the water mixing ratio of each heating station keeps constant. When the system is switched from the high flow rate stage to the low flow rate stage, the temperature of the supply and return water of the heat source and the temperature of each cooling point increase, which is different from that of the ordinary double-pipe system, and the temperature increase degree of each cooling point decreases along the circulation direction.

When the secondary side of the thermal station is changed from the high-flow stage to the low-flow stage, the temperature difference between the supply and return water temperature of the heat source and the water temperature of each cooling water supply decreases by the same temperature difference, but at the same time, the flow rate of the primary side of the thermal station increases significantly along the direction of hot water circulation along the ring trunk line, especially at the last cooling point, and the water mixing ratio becomes negative, which shows that the water temperature of the cooling point at the end is lower than that of the secondary side of the thermal station. Under this combination mode, when the secondary side of the thermal station runs at low flow rate, the water supply temperature of the heat source decreases too much, which directly leads to the water supply temperature of the lower cooling point on the ring trunk line being lower than that of the users on the secondary side of the thermal station, resulting in poor heating effect of the end users.

3 Experiment

In order to test the conditional effect of the intelligent regulation method of heating water flow in colleges and universities designed in this paper, it is compared with the traditional intelligent regulation method of water flow. Ensure the environment of the control group and the experimental group is consistent. Methods Each experiment was repeated ten times. The experiment is as follows.

3.1 Experimental Preparation

The operation requirements of the adjustment mode combination when the primary side flow of the thermal station and the return water flow of the pumping secondary side continuously change are relatively high. The combination of variable flow regulation has a higher energy-saving rate. When the loop trunk line and branch trunk line are regulated by equal temperature difference, the combination of quality regulation by changing flow in stages at the user side has the highest energy-saving rate. The connection table of intelligent water supply regulation at this time is shown in Table 2 below. Among them, the energy saving rate exceeding 8% is regarded as a higher level, and the hydraulic condition of users is stable the stability of users' hydraulic state means that when other users' flow changes, it is a higher level to keep their own flow changes within 2%.

Table 2. Intelligent connection table of water supply

Operation requirement	1	2	3
Energy saving rate	Low	High	low
Insulation investment	1	1	26%
The hydraulic condition of users is stable	Low	High	low
Meet the water supply needs of end users	Yes	Yes	no
Avoid energy waste	Yes	Yes	yes

Table 3. Results of traditional intelligent regulation method of hot water flow

Operation requirement	1	2	3
Energy saving rate	Low	Low	Low
Insulation investment	67%	54%	23%
The hydraulic condition of users is stable	Low	Low	Low
Meet the water supply needs of end users	No	Yes	No
Avoid energy waste	No	No	No

It can be seen from Table 2 and Table 3 that the water flow adjusted by the automatic adjustment method designed in this paper is more stable, which proves that the adjustment effect of the designed method is better and has certain application value.

4 Discussion

Through the analysis of the hydraulic and thermal conditions of the unidirectional ring network, it can be seen that the hydraulic and thermal conditions of the unidirectional ring network system are more independent than those of the traditional double-pipe system. According to the analysis of thermal conditions, the temperature of the ring trunk line cooling point of the unidirectional ring network is calculated and determined, and the temperature characteristics of the unidirectional ring network system are obtained. It is concluded that the determination of the inlet temperature of heating point of trunk line of unidirectional ring network should meet the heating demand of end users.

For the single heat source unidirectional loop network system, under the mixed water connection or indirect connection mode, the operation regulation modes of the system are solved with different regulation modes combinations for the loop trunk line, branch trunk line and the secondary side of the thermal station, and the regulation rules of various regulation modes combinations are obtained. When the ring trunk line and branch trunk line are regulated by equal temperature difference, and the secondary side of the thermal station is regulated by changing the flow by stages, the combined system has the lowest energy consumption. When the same regulation mode combination is adopted, the power consumption of water pump in mixed water connection mode of the system is lower than that in indirect connection mode. The indirect connection system has more obvious energy-saving effect than the mixed water connection system by adopting the operation mode of constant water supply temperature of the ring trunk line, but this mode wastes high-grade energy. Moreover, the operation mode of constant water supply temperature and constant flow of the ring trunk line requires higher pipeline insulation materials, which increases the initial investment of the pipeline. When mixed water connection is used in the heating system, the equipment investment of the system is low, and the adaptability to the water supply temperature of the primary side of the heating station is strong. However, the operation regulation mode of the ring trunk line with variable flow will affect the normal operation of the user system, and the operating pressure of the ring trunk line should not be too high.

5 Conclusion

In this paper, the intelligent regulation method of university heating water flow is studied, and the unidirectional loop network system is introduced. By virtue of its superior hydraulic and thermal conditions compared with the traditional double pipe network system, the operation regulation modes such as trunk line, branch line and thermal station of heating water flow regulation loop network are improved. Experiments show that this method has the performance of more stable flow regulation, lower energy consumption and lower investment cost, and has certain application value.

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References

1. Gu, L., Zeng, D., Li, W., et al.: Intelligent VNF orchestration and flow scheduling via model-assisted deep reinforcement learning. IEEE J. Sel. Areas Commun. **38**(2), 279–291 (2020)
2. Liu, Y., Liu, X., Duan, B., et al.: Polymer-water interaction enabled intelligent moisture regulation in hydrogels. J. Phys. Chem. Lett. **12**(10), 2587–2592 (2021)
3. Yan, X., Gong, J., Wu, Q.: Pollution source intelligent location algorithm in water quality sensor networks. Neural Comput. Appl. **33**(1), 209–222 (2020). https://doi.org/10.1007/s00521-020-05000-8
4. Cerone, A.: Model mining: integrating data analytics, modelling and verification. J. Intell. Inf. Syst. **52**(3), 501–532 (2019)
5. Ma, Y., Fan, X., Cai, J., et al.: Application of sensor data information cognitive computing algorithm in adaptive control of wheeled robot. IEEE Sen. J. **22**(18), 17343–17350 (2021)
6. Yuan, D., Wang, Y.: Data driven model-free adaptive control method for quadrotor formation trajectory tracking based on RISE and ISMC algorithm. Sensors **21**(4), 1289 (2021)
7. Shukl, P., Singh, B.: Grid integration of three-phase single-stage PV system using adaptive Laguerre filter based control algorithm under nonideal distribution system. IEEE Trans. Ind. Appl. **55**(6), 6193–6202 (2019)
8. Ke, X., Zhang, D.: Fuzzy control algorithm for adaptive optical systems. Appl. Opt. **58**(36), 9967 (2019)

9. Landau, I.D., Melendez, R., Dugard, L., et al.: Robust and adaptive feedback noise attenuation in ducts. IEEE Trans. Control Syst. Technol. **27**(2), 872–879 (2019)
10. Mostafa, E., Li, F.U., Arafa, I.I., et al.: A solution of UAV localization problem using an interacting multiple nonlinear fuzzy adaptive H_∞ models filter algorithm. Chin. J. Aeronaut. **32**(04), 212–224 (2019)
11. Li, N., Gao, B., Fiona, F.: Design and simulation of bio-oxidation tank heating system in Alpine mining area. Comput. Simul. **38**(07), 214–218+260 (2021)
12. Liu, S., Liu, D., Muhammad, K., Ding, W.: Effective template update mechanism in visual tracking with background clutter. Neurocomputing **458**, 615–625 (2021)
13. Liu, S., et al.: Human memory update strategy: a multi-layer template update mechanism for remote visual monitoring. IEEE Trans. Multimedia **23**, 2188–2198 (2021)
14. Liu, S., Wang, S., Liu, X., et al.: Fuzzy detection aided real-time and robust visual tracking under complex environments. IEEE Trans. Fuzzy Syst. **29**(1), 90–102 (2021)