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(54) **PIPE NETWORK HEAT STORAGE SYSTEM BASED ON SERIES CONNECTION OF SUPPLY AND RETURN HEADER PIPES OF HEAT SUPPLY NETWORK, AND REGULATION AND CONTROL METHOD THEREFOR**

(57) The disclosure provides a pipe network heat storage system based on series connection of a supply main pipe and a return main pipe in a heating network and a control method thereof, which comprises a heat supply pipe network including a heating network initial station, heat station(s), a circulating water pump, a primary network water return pipe and a primary network water supply pipe. A heating network water bypass with an adjustment component for adjusting the flowrate and pressure of the heating network water is installed between the primary network water supply pipe and water return pipe. The heat storage and release can be realized by the heat supply pipe network. For the heating system of the cogeneration unit, the heat storage capacity of the heat supply pipe network can increase the peak regulation capacity of the cogeneration unit and save the huge investment cost of new energy storage devices.

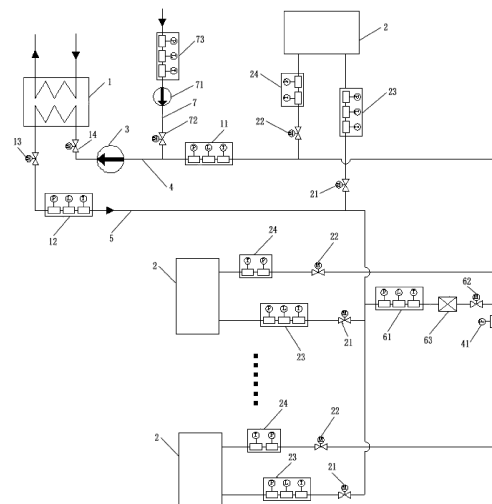


FIG. 1

Description

CROSS REFERENCE TO RELATED APPLICATIONS

5 **[0001]** This patent application claims the benefit and priority of Chinese Patent Application No. 202111629309.3 filed on December 28th, 2021 and Chinese Patent Application No. 202111626239.6 filed on December 28th, 2021, the disclosure of which is incorporated by reference herein in their entirety as part of the present application.

TECHNICAL FIELD

10 **[0002]** The present disclosure relates to the technical field of central heating, in particular to a pipe network heat storage system based on series connection of a supply main pipe and a return main pipe in a heating network and a control method thereof.

BACKGROUND

15 **[0003]** As an important way of efficient and clean utilization of energy in power and heat industries, cogeneration of heat and power has become an important method for the development of thermal power generation in the world, and has been included in key energy-saving projects and becomes a main way of clean heating in China. In recent years, the rapid development of new energy power generation has brought severe power peak regulation requirements to the thermal power generation. However, the operation way of conventional cogeneration units based on heat and power, in which the electricity is determined by the heat, has severely restricted the flexible adjustment of thermal power, resulting in a serious conflict between heat supply and power peak regulation.

20 **[0004]** At present, the conventional solution for the low efficiency of the cogeneration heating system is to increase thermal energy storage equipment(s). The excess heat can be stored through the heat storage technique when the load of the cogeneration unit is high, and the heat can be supplied to external device(s) through heat storage device(s) when the power peak regulation is difficult, thereby replenishing the insufficient heating capacity of the cogeneration unit caused by the reduced power generation load and improving the power peak regulation ability of the cogeneration unit. However, this greatly increases the construction investment cost for enterprises.

25 **[0005]** The existing patent "Balance Adjustment Method and Heating System for Heat Storage and Release in Heat and Hydraulic Network" (Application No.: CN202110294128.3) discloses that a heating pipe network can be used to store heat, and the huge heating pipe network is a natural heat storage equipment. If the heating pipe network is used for heat storage to increase the peak regulation capacity of the cogeneration unit, huge construction investment costs can be saved with a significant economic benefit. However, when the number of heat stations in the heating system is too large using the technology of the existing patent, it shall need to add a large number of heating network water bypasses, valves and other related facilities, which also increases the construction investment cost to a certain extent, and at the same time, the control becomes complicated which makes the precise heating be difficult.

SUMMARY

30 **[0006]** Embodiments of the present disclosure provide a pipe network heat storage system based on series connection of a supply main pipe and a return main pipe in a heating network and a control method thereof.

35 **[0007]** Detailed technical solutions are as follows:

40 A first aspect of the present disclosure provides a pipe network heat storage system based on series connection of a supply main pipe and a return main pipe in a heating network. The pipe network heat storage system comprises a heat supply pipe network including a heating network initial station, heat station(s), a circulating water pump, a primary network water return pipe and a primary network water supply pipe, in which the heating network initial station is communicated with a primary network of the heat station(s) through the primary network water return pipe and the primary network water supply pipe, the number of the heat station(s) is n which is not less than 1, the heating network water is driven by the circulating water pump to flow among the heating network initial station, the heat station(s), the primary network water return pipe and the primary network water supply pipe; wherein, a heating network water bypass is installed between the primary network water supply pipe and the primary network water return pipe, an adjustment component is arranged on the heating network water bypass for adjusting the flowrate and pressure of the heating network water in the heating network water bypass, the adjustment component comprises a first temperature-pressure-flowrate measuring instrument, a pressure relief device and a first regulating valve which are arranged on the heating network water bypass in sequence along the water flow direction, and a pressure measuring instrument is provided at an upstream position in the water flow direction of the primary network

water return pipe, in which the upstream position is at the connection position between the heating network water bypass and the primary network water return pipe;

a water outlet regulating valve for adjusting the water supply flowrate of the heating network water is arranged on a water outlet of the heating network initial station, and a water inlet regulating valve for adjusting the water return flowrate of the heating network water is arranged on a water inlet of the heating network initial station;

when the heat supply pipe network is storing heat, the heating network initial station is used to increase the heat supply and increase the water supply temperature and/or water supply flowrate of the heating network water; and when the heat supply pipe network is releasing heat, the heating network initial station is used to reduce the heat supply and reduce the water supply temperature and/or water supply flowrate of the heating network water;

the first regulating valve is used to be in a normally closed state to make the flowrate of the heating network water in the heating network water bypass be zero when the heat supply pipe network is not storing or not releasing heat, the first regulating valve can be adjustably open to make the flowrate of the heating network water in the heating network water bypass be gradually increased while storing heat, and the first regulating valve can be adjustably closed to make the flowrate of the heating network water in the heating network water bypass be gradually decreased while releasing heat; and,

the pressure relief device is used to reduce the pressure of the heating network water in the heating network water bypass to match with the pressure measured by the pressure measuring instrument, and then the heating network water can be returned to the primary network water return pipe.

[0008] In some embodiments, a second regulating valve and a second temperature-pressure-flowrate measuring instrument are arranged on a water inlet pipe connecting the heat station(s) with the primary network water supply pipe, and a third regulating valve and a temperature-pressure measuring instrument are arranged on a water outlet pipe connecting the heat station(s) with the primary network water return pipe;

when the heat supply pipe network is storing heat and the water supply temperature of the heating network water is increased by the heating network initial station, the second regulating valve and the third regulating valve are used to be adjustably closed in order to reduce the flowrate of the heating network water entering the heat station(s) and increase the flowrate of the heating network water entering the heating network water bypass; and, when the heat supply pipe network is releasing heat and the water supply temperature of the heating network water is decreased by the heating network initial station, the second regulating valve and the third regulating valve are used to be adjustably open in order to increase the flowrate of the heating network water entering the heat station(s) and reduce the flowrate of the heating network water entering the heating network water bypass.

[0009] In some embodiments, the pipe network heat storage system further comprises a water replenishing component including a primary network water replenishing pipe, a water replenishing pump, a fourth regulating valve and a third temperature-pressure-flowrate measuring instrument, in which the third temperature-pressure-flowrate measuring instrument, the water replenishing pump and the fourth regulating valve are arranged on the primary network water replenishing pipe in sequence along the water flow direction, and the primary network water replenishing pipe is connected to the primary network water return pipe;

a fourth temperature-pressure-flowrate measuring instrument is provided at an upstream position in the water flow direction of the primary network water return pipe, in which the upstream position is at the connection position between the primary network make-up water pipe and the primary network water return pipe; and, the fourth regulating valve is operated to be open when the pressure of the primary network water return pipe measured by the fourth temperature-pressure-flowrate measuring instrument is lower than the setting pressure, and the fourth regulating valve is operated to be closed when the pressure of the primary network water return pipe measured by fourth temperature-pressure-flowrate measuring instrument is not lower than the setting pressure; and, a fifth temperature-pressure-flowrate measuring instrument is provided at a water outlet of the heating network initial station.

[0010] In some embodiments, the heating network water bypass is arranged at the j^{th} heat station, in which $1 \leq j \leq n$, and the pressure measuring instrument is arranged on the primary network water return pipe connecting to the j^{th} heat station.

[0011] In some embodiments, the heating network water bypass is arranged at the j^{th} heat station, and number j represented in the j^{th} heat station can be calculated as follows:

the maximum heating network water flowrate G^f of the heat supply pipe network can be determined according to the design flowrate G^0 (unit: t/h) of the circulating water pump: $G^f = G^0$;

the minimum storage heat $Q_{\min}$ (unit: GJ) required by the heat supply pipe network can be determined according to the heat storage required by the cogeneration unit for power peak regulation;

the minimum heating network water flowrate $G_i^{station}$ (unit: t/h, $1 \leq i \leq n$) required by each heat station during the heating period can be determined according to the maximum heating load W_i (unit: GJ/h, $1 \leq i \leq n$) required by each heat station during the heating period and the maximum temperature difference between the heating network water supply temperature and water return temperature of the heat supply pipe network, and the water supply temperature

and the water return temperature can be respectively indicated as T^{01} (unit: °C) and T^{02} (unit: °C): $G_i^{station} = \frac{10^6 \times W_i}{C \cdot (T^{01} - T^{02})_{max}}$;

the maximum heating network water flowrate G^s of the heat supply pipe network used for heat storage in the heating period can determined according to the minimum heating network water flowrate $G_i^{station}$ required by each heat station during the heating period and the maximum heating network water flowrate G^r of the heat supply pipe network:

$$G^s = G^r - \sum_{i=1}^n G_i^{station};$$

the maximum value A_{max} of number j can be determined according to the design head H^0 (unit: m) of the circulating water pump and the resistance loss of different pipe sections used to connect the heat supply pipe network with each heat station during the heating period;

the minimum value B_{min} of number j can be determined according to the minimum heat storage required by the heat supply pipe network; and,

the final value of number j can be determined according to the following relationship:

when $B_{min} \geq A_{max}$, the final value of number j is A_{max} ; and,

when $B_{min} < A_{max}$, the final value of number j is A_{max} if the heat dissipation loss rate and water leakage loss rate of the heat power pipe network can be ignored, and the final value of number j is B_{min} if the heat dissipation loss rate and water leakage loss rate of the heat supply pipe network can not be ignored.

[0012] In some embodiments, the maximum value A_{max} of number j can be determined according to the design head H^0 (unit: m) of the circulating water pump and the resistance loss of different pipe sections used to connect the heat supply pipe network with each heat station during the heating period, and the maximum value A_{max} can be calculated as follows:

calculating the heating network water flowrate G_i^{pipe} in different pipe sections connecting each heat station by the following equations:

$$\begin{cases} x = 1, G_x^{pipe} = G^r \\ 1 < x \leq j, G_x^{pipe} = G^r - \sum_{y=1}^{x-1} G_y^{station} \\ j < x \leq n, G_x^{pipe} = G^r - G^s - \sum_{y=1}^{x-1} G_y^{station} \end{cases}$$

calculating the resistance loss R_x (unit: Palm) in different pipe sections connecting each heat station by the following equation:

$$R_x = 6.88 \times 10^{-3} \cdot \frac{K^{0.25} \cdot (G_x^{pipe})^2}{\rho \cdot D_x}$$

and calculating the total pressure drop of the heat supply pipe network during the heating period by the following equations:

$$\begin{cases}
 z = 1, P_z = P_1 = 0.00688 \times \frac{K^{0.25} \cdot (G^r)^2}{\rho \cdot D_1} \cdot (1 + \varphi) \cdot L_1 \\
 1 < z \leq j, P_z = P_1 + \sum_{t=2}^z 0.00688 \times \frac{K^{0.25} \cdot [G^r - \sum_{y=1}^{t-1} (G_y^{station})]^2}{\rho \cdot D_t} \cdot (1 + \varphi) \cdot L_t \\
 j < z \leq n, P_z = P_1 + P_j + \sum_{t=j+1}^z 0.00688 \times \frac{K^{0.25} \cdot [G^r - G^s - \sum_{y=1}^{t-1} (G_y^{station})]^2}{\rho \cdot D_t} \cdot (1 + \varphi) \cdot L_t
 \end{cases}$$

and, then the design head H^0 of the circulating water pump is compared with the total pressure drop of the heat supply pipe network during the heating period, and the maximum value $A_{\max}$ of number j can be determined according to the relationship: $10 \times H^0 \geq 0.002 \times P_z$;

in which: the design head H^0 of the circulating water pump is a known parameter; K (unit: m) is the equivalent absolute roughness of the heat supply pipe network; φ (unit: %) is the local resistance equivalent length percentage of the heat supply pipe network; L_i (unit: m, $1 \leq i \leq n$) is the length of each pipe section connecting each heat station to the heat supply pipe network; D_i (unit: m, $1 \leq i \leq n$) is the diameter of each pipe section connecting each heat station to the heat supply pipe network; and, ρ (unit: kg/m³) is the density of the heating network water.

[0013] In some embodiments, the minimum value $B_{\min}$ of number j can be determined according to the minimum heat storage required by the heat supply pipe network, and the minimum value $B_{\min}$ can be calculated as follows:

calculating the design heat storage of the heat supply pipe network by the following equation:

$$Q^e = 10^{-6} \times G^s \cdot C \cdot (T^{01} - T^{02})_{\max} \cdot \sum_{x=1}^j \frac{1.57 \times 10^{-3} \times L_x \cdot (D_x)^2 \cdot \rho}{G_x^{pipe}}$$

and, the minimum value $B_{\min}$ of number j can be determined according to the relationship $Q^e \geq Q_{\min}$; in which: ρ (unit: kg/m³) is the density of the heat supply network water; and, C (unit: J/(kg · °C)) is specific heat capacity of the heat supply network water.

[0014] A second aspect of the present disclosure provides a pipe network heat storage control method based on series connection of a supply main pipe and a return main pipe in a heating network. The control method uses any one of the aforementioned pipe network heat storage system and comprises the following steps:

when the heat supply pipe network is not storing or not releasing heat, the first regulating valve is used to be in a normally closed state to make the flowrate of the heating network water in the heating network water bypass be zero, the heating network water from the heating network initial station is transported to the heat station(s) through the primary network water supply pipe, and then the heating network water is returned to the heating network initial station through the primary network water return pipe in a continuous cycle;

when the heat supply pipe network is storing heat, the heat supply of the heating network initial station is increased and the water supply temperature and/or water supply flowrate of the heating network water is increased, the first regulating valve can be adjustably open to make the flowrate of the heating network water in the heating network water bypass be gradually increased; and, the pressure relief device is used to reduce the pressure of the heating network water in the heating network water bypass to match with the pressure measured by the pressure measuring instrument, and then the heating network water can be returned to the heating network initial station through the primary network water return pipe; and,

when the heat supply pipe network is releasing heat, the heat supply of the heating network initial station is decreased and the water supply temperature and/or water supply flowrate of the heating network water is decreased, the first regulating valve can be adjustably closed to make the flowrate of the heating network water in the heating network water bypass be gradually decreased.

[0015] In some embodiments, the second regulating valve and the second temperature-pressure-flowrate measuring instrument are arranged on a water inlet pipe connecting the heat station(s) with the primary network water supply pipe, and the third regulating valve and the temperature-pressure measuring instrument are arranged on a water outlet pipe

connecting the heat station(s) with the primary network water return pipe;

when the heat supply pipe network is storing heat, the heat supply of the heating network initial station is increased and the water supply temperature of the heating network water is increased, the second regulating valve and the third regulating valve are used to be adjustably closed in order to reduce the flowrate of the heating network water entering the heat station(s) and increase the flowrate of the heating network water entering the heating network water bypass; and,

when the heat supply pipe network is releasing heat, the heat supply of the heating network initial station is decreased and the water supply temperature of the heating network water is decreased, the second regulating valve and the third regulating valve are used to be adjustably open in order to increase the flowrate of the heating network water entering the heat station(s) and reduce the flowrate of the heating network water entering the heating network water bypass.

[0016] In some embodiments, the control method further comprises a water replenishing step:

the pipe network heat storage system comprises the water replenishing component including the primary network water replenishing pipe, the water replenishing pump, the fourth regulating valve and the third temperature-pressure-flowrate measuring instrument, in which the third temperature-pressure-flowrate measuring instrument, the water replenishing pump and the fourth regulating valve are arranged on the primary network water replenishing pipe in sequence along the water flow direction, the primary network water replenishing pipe is connected to the primary network water return pipe, and the fourth temperature-pressure-flowrate measuring instrument is provided at an upstream position in the water flow direction of the primary network water return pipe, in which the upstream position is at the connection position between the primary network water replenishing pipe and the primary network water return pipe; and

according to a pressure value measured by the fourth temperature-pressure-flowrate measuring instrument, the fourth regulating valve is operated to be open when the pressure of the primary network water return pipe is lower than the setting pressure, and the water replenishing pump replenishes water to the primary network water return pipe; and, the fourth regulating valve is operated to be closed when the pressure of the primary network water return pipe is not lower than the setting pressure, and the water replenishing pump stops replenishing water .

[0017] The present disclosure achieves the following beneficial effects:

the present disclosure provides a pipe network heat storage system and a control method thereof, which utilizes the heating network water bypass connecting the primary network water supply pipe with the primary network return water pipe to change the flowrate and temperature of heating network water through the heat station at an appropriate time, thereby realizing the function of storing heat by using the pipe network. For the heating system of the cogeneration unit, the heat storage capacity of the existing huge heating pipe network can be made full use to increase the peak regulation capacity of the cogeneration unit and can also save the huge investment cost of new energy storage devices. At the same time, in the heat storage process, through the heating network water bypass, part of the heating network water can be directly returned to the primary network water return pipe without passing through the heat station(s), which reduces the pressure loss of the heating system and effectively saves the power consumption of the circulating water pump; and, in the heat storage and release process, by adjusting the heating network water flowrate in the heating network water bypass, the heating network water flowrate required by each heat station can be ensured, which fully exerts the heat storage capacity of the existing heating pipe network and also effectively guarantees the heating requirement of each heat station.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The accompanying drawings described here are provided for further understanding of the present disclosure, and constitute a part of the present disclosure. The exemplary embodiments of the present disclosure and illustrations thereof are intended to explain the present disclosure, but do not constitute inappropriate limitations to the present disclosure. In the drawings:

FIG. 1 is a schematic diagram of a pipe network heat storage system provided in embodiments of the invention according to an embodiment of the present disclosure;

Reference numerals:

[0019] 1 - heating network initial station; 11- fourth temperature-pressure-flowrate measuring instrument; 12 - fifth temperature-pressure-flowrate measuring instrument; 13 - water outlet regulating valve; 14 - water inlet regulating valve;

2- heat station(s); 21 - second regulating valve; 22 - third regulating valve; 23 - second temperature-pressure-flowrate measuring instrument; 24 - temperature-pressure measuring instrument; 3 - circulating water pump; 4 - primary network water return pipe; 41 - pressure measuring instrument; 5 - primary network water supply pipe; 6 - heating network water bypass; 61 - first temperature-pressure-flowrate measuring instrument; 62 - first regulating valve; 63 - pressure relief device; 7 - primary network water replenishing pipe; 71 - water replenishing pump; 72 - fourth regulating valve; 73 - third temperature-pressure-flowrate measuring instrument.

DETAILED DESCRIPTION

[0020] To make the objectives, technical solutions, and advantages of the present disclosure clearer, the present disclosure is described below with reference to the accompanying drawings and embodiments. It should be understood that the embodiments described herein are merely used to explain the present disclosure, rather than to limit the present disclosure. All other embodiments obtained by those of ordinary skill in the art based on the embodiments of the present disclosure without creative efforts should fall within the protection scope of the present disclosure.

[0021] Apparently, the accompanying drawings in the following description show merely some embodiments of the present disclosure, and a person of ordinary skill in the art may apply the present disclosure to other similar scenarios according to these drawings without creative efforts. In addition, it can also be appreciated that, although it may take enduring and complex efforts to achieve such a development process, for those of ordinary skill in the art related to the present disclosure, some changes such as design, manufacturing or production made based on the technical content in the present disclosure are merely regular technical means, and should not be construed as insufficiency of the present disclosure.

[0022] The "embodiment" mentioned in the present disclosure means that a specific feature, structure, or characteristic described in combination with the embodiment may be included in at least one embodiment of the present disclosure. The phrase appearing in different parts of the specification does not necessarily refer to the same embodiment or an independent or alternative embodiment exclusive of other embodiments. It may be explicitly or implicitly appreciated by those of ordinary skill in the art that the embodiment described herein may be combined with other embodiments as long as no conflict occurs.

[0023] Unless otherwise defined, the technical or scientific terms used in the present disclosure are as they are usually understood by those of ordinary skill in the art to which the present disclosure pertains. The terms "one", "a", "the" and similar words are not meant to be limiting, and may represent a singular form or a plural form. The terms "include", "contain", "have" and any other variants in the present disclosure mean to cover the non-exclusive inclusion, for example, a process, method, system, product, or device that includes a series of steps or modules (units) is not necessarily limited to those steps or units which are clearly listed, but may include other steps or units which are not expressly listed or inherent to such a process, method, system, product, or device. The term "multiple" in the present disclosure means two or more. The term "and/or" describes associations between associated objects, and it indicates three types of relationships. For example, "A and/or B" may indicate that A exists alone, A and B coexist, or B exists alone. The character "/" generally indicates that the associated objects are in an "or" relationship.

[0024] The terms "center", "upper", "lower", "left", "right", "vertical", "horizontal", "inner", "outer" and so on in the present disclosure are intended to indicate orientation or positional relationship shown in the accompanying drawings, which is only for describing the present disclosure and simplifying the description, rather than indicating or implying the device or element with a specific orientation, a specific construction or a specific operation, and therefore should not be construed as limiting the present disclosure. The terms "first", "second", "third" and so on in the present disclosure are intended to distinguish between similar objects but do not necessarily indicate a specific order of the objects.

[0025] The terms "installed", "communicated", "interconnected", "coupled" and similar words in the present disclosure are not restricted to physical or mechanical connections, but may include electrical connections, whether direct or indirect. The terms should be understood in a broad sense, unless otherwise expressly specified and limited, for example, it may be a fixed connection or a detachable connection, or integral connection; can be mechanical connection, can also be electrical connection; can be directly connected, can also be indirectly connected through an intermediate medium, can be internal communication between two elements. For those of ordinary skill in the art, the specific meanings of the above terms in the present invention can be understood in specific situations.

[0026] Referring to FIG. 1, an embodiment of the present disclosure provides a pipe network heat storage system based on series connection of a supply main pipe and a return main pipe in a heating network. The pipe network heat storage system comprises a heat supply pipe network where the heating network water flows. The heat supply pipe network includes a heating network initial station 1, heat station(s) 2, a circulating water pump 3, a primary network water return pipe 4 and a primary network water supply pipe 5, in which the heating network initial station 1 is communicated with a primary network of the heat station(s) 2 through the primary network water return pipe 4 and the primary network water supply pipe 5. The number of the heat station(s) 2 is n which is not less than 1. The heating network water is driven by the circulating water pump 3 to flow among the heating network initial station 1, the heat station(s) 2, the

primary network water return pipe 4 and the primary network water supply pipe 5.

[0027] Specifically, the heating network initial station 1 is used to provide heat, and the circulating water pump 3 is used to drive the heating network water to flow in the heating network. The primary network water supply pipe 5 is connected with the heating network initial station 1 and a water inlet of the heat station(s) 2, and the high-pressure and high-temperature heating network water can be transported to the heat station(s) 2 through the primary network water supply pipe 5. The primary network return pipe 4 is connected with a water outlet of the heat station(s) 2 and the heating network initial station 1, and the cooled and depressurized heating network water can be transported back to the heating network initial station 1 through the primary network return pipe 4. The heating network water can be pressured and driven to enter the heating network initial station 1 by the circulating water pump 3, and then can be heated and transported back to the heat station(s) 2 for circulation.

[0028] For a cogeneration heating system, the huge heat supply pipe network is used as a natural heat storage equipment. While the heat storage capacity of heat supply pipe network is achieved by increasing the water supply temperature of the heating network initial station 1, since the total heat output by the heating network initial station 1 is increased by the increasing the water supply temperature, the heating network water output by the heating network initial station 1 can only pass through the heat station(s) 2 for heat exchange and then can be returned to the heating network initial station 1. After the excess heat supplied by the heating network initial station 1 enters the heat station(s) 2, most of the heat is absorbed by the heat station(s) 2 and then supplied to outside, instead of being stored in heat supply pipe network, which causes the excessive heat supply of the heat station(s) 2 resulting in energy waste.

[0029] Thus, in one preferred embodiment, a heating network water bypass 6 is installed between the primary network water supply pipe 5 and the primary network water return pipe 4. An adjustment component is arranged on the heating network water bypass 6 for adjusting the flowrate and pressure of the heating network water in the heating network water bypass 6. By setting the heating network water bypass 6, the excess heat output by the heating network initial station 1 is no longer transferred to the heat station(s) 2, instead to be transferred to the primary network water return pipe 4 through the heating network water bypass 6, so as to realize that the excess heat output by the heating network initial station 1 can be stored in the primary network water supply pipe 5 and the primary network return water pipe 4, which well exerts a heat storage capacity of heat supply pipe network.

[0030] Specifically, the adjustment component comprises a first temperature-pressure-flowrate measuring instrument 61, a pressure relief device 63 and a first regulating valve 62 which are arranged on the heating network water bypass 6 in sequence along the water flow direction. The first temperature-pressure-flowrate measuring instrument 61 is used to measure the temperature, pressure and flowrate of the heating network water flowing into the heating network water bypass 6, thus the heat of the heating network water passing through the heating network water bypass 6 can be calculated. The first regulating valve 62 is used to adjust the flowrate of the heating network water in the heating network water bypass 6. The first regulating valve 62 is used to be in a normally closed state to make the flowrate of the heating network water in the heating network water bypass 6 be zero when the heat supply pipe network is not storing or not releasing heat, the first regulating valve 62 can be adjustably open to make the flowrate of the heating network water in the heating network water bypass 6 be gradually increased while storing heat, and the first regulating valve 62 can be adjustably closed to make the flowrate of the heating network water in the heating network water bypass 6 be gradually decreased while releasing heat. The control method of an opening degree of the first regulating valve 62 is as follows: the heat passing through the heating network water bypass 6 is equal to a value which is a heat difference between the heat supplied by the heating network initial station 1 and the heat flowing into each heat station 2. The opening degree of the first regulating valve 62 can be adjusted according to the required heat passing through the heating network water bypass 6. The heat supplied by the heating network initial station 1 and the heat required by each heat station 2 are both known parameters. While storing heat, the opening degree of the first regulating valve 62 can be increased so as to increase the flowrate of the heating network water flowing through the heating network water bypass 6. When the flowrate of the heating network water in the heating network water bypass 6 is needed as a maximum set value, the first regulating valve 62 can be fully opened. While releasing heat, the opening degree of the first regulating valve 62 can be reduced. If the heat stored in heat supply pipe network is needed to be completely released, the opening degree of the first regulating valve 62 can be adjusted to a minimum opening degree, and the first regulating valve 62 can be completely closed, so that the flowrate of the heating network water in the heating network water bypass 6 can be reduced until to be zero. If there is no need to completely release the heat stored in heat supply pipe network, the opening degree of the first regulating valve 62 can be appropriately reduced so as to reduce the flowrate of the heating network water in the heating network water bypass 6 to a set value.

[0031] In one preferred embodiment, a pressure measuring instrument 41 is provided at an upstream position in the water flow direction of the primary network water return pipe 4, in which the upstream position is at the connection position between the heating network water bypass 6 and the primary network water return pipe 4. The pressure measuring instrument 41 is used to measure the pressure of the heating network water in the primary network water return pipe 4. The pressure relief device 63 is used to reduce the pressure of the heating network water in the heating network water bypass 6, thus the pressure of the high-temperature and high-pressure heating network water can be decreased to

match with the pressure measured by the pressure measuring instrument 41, so that the heating network water can be smoothly returned to the primary network water return pipe 4 and then can be returned to the heating network initial station 1. The pressure relief device 63 includes a throttle pressure reducing valve, an ejector pressure reducer and so on.

[0032] In any one of the aforementioned embodiments, a pipe network heat storage control method comprises the following steps:

when the heat supply pipe network is not storing or not releasing heat, the first regulating valve 62 is used to be in a normally closed state to make the flowrate of the heating network water in the heating network water bypass 6 be zero, the heating network water from the heating network initial station 1 is transported to the heat station(s) 2 through the primary network water supply pipe 5, and then the heating network water is returned to the heating network initial station 1 through the primary network water return pipe 4 in a continuous cycle;

when the heat supply pipe network is storing heat, the heat supply of the heating network initial station 1 is increased, which can be achieved by increasing the water supply temperature of the heating network water, increasing the water supply flowrate of the heating network water, or both; the first regulating valve 62 can be adjustably open to make the flowrate of the heating network water in the heating network water bypass 6 be gradually increased; and, specifically, if the heat supply of the heating network initial station 1 is increased only by increasing the water supply temperature of the heating network water, it is necessary to reduce the flowrate of the heating network water entering the heat station(s) 2 and increase the flowrate of the heating network water flowing through the heating network water bypass 6; if the heat supply of the heating network initial station 1 is increased only by increasing the water supply flowrate of the heating network water, it is unnecessary to change the flowrate of the heating network water entering the heat station(s) 2, and the increased water supply flowrate of the heating network water can be returned to the heating network initial station 1 through the heating network water bypass 6; and, if the water supply temperature and water supply flowrate of the heating network water are both increased, it is necessary to reduce the flowrate of the heating network water entering the heat station(s) 2 and increase the flowrate of the heating network water flowing through the heating network water bypass 6;

the heating network water flowing through the heating network water bypass 6 is the water with a high temperature and a high pressure; and, the pressure relief device 63 is used to reduce the pressure of the heating network water in the heating network water bypass 6 to match with the pressure measured by the pressure measuring instrument 41, and then the heating network water can be returned to the heating network initial station 1 through the primary network water return pipe 4; and,

when the heat supply pipe network is releasing heat, the heat supply of the heating network initial station 1 is decreased, which can be achieved by reducing the water supply temperature of the heating network water, reducing the water supply flowrate of the heating network, or both; the first regulating valve 62 can be adjustably closed to make the flowrate of the heating network water in the heating network water bypass 6 be gradually decreased; and, specifically, if the heat supply of the heating network initial station 1 is decreased only by reducing the water supply temperature of the heating network water, it is necessary to increase the flowrate of the heating network water entering the heat station(s) 2 and reduce the flowrate of the heating network water flowing through the heating network water bypass 6, and the opening degree of the first regulation valve 62 can be gradually decreased; if the heat supply of the heating network initial station 1 is decreased only by decreasing the water supply flowrate of the heating network water, it is unnecessary to change the flowrate of the heating network water entering the heat station(s) 2, the flowrate of the heating network water flowing through the heating network water bypass 6 can be gradually decreased, and the opening degree of the first regulating valve 62 can be gradually decreased; and, if the water supply temperature and water supply flowrate of the heating network water are both decreased, it is necessary to increase the flowrate of the heating network water entering the heat station(s) 2 and reduce the flowrate of the heating network water flowing through the heating network water bypass 6, and the opening degree of the first regulating valve 62 can be gradually reduced.

[0033] Heat storage in heat supply pipe network means that when the cogeneration unit needs to reduce its output capacity in the power grid peak regulation process, the output capacity can be reduced by increasing the heating extraction steam flowrate of the cogeneration unit. The excess heat generated by the increased extraction steam flowrate of the cogeneration unit is stored by the pipe network heating system. Due to the increased extraction steam flowrate of the cogeneration unit, the heat supply of the heating network initial station 1 can be increased. If the heating network water bypass 6 is not provided, the excess heat will be transported to outside from the heat station(s) 2, resulting in waste.

[0034] As an example, the heat supply of the heating network initial station 1 is increased only by increasing the water supply temperature of the heating network water. In this embodiment, when heat storage is required in the pipe network heating system, the first regulating valve 62 is controlled to be adjustably open, thus part of the heating network water in the primary network water supply pipe 5 does not flow into the heat station(s) 2 and can be directly returned to the

primary network water return pipe 4 through the heating network water bypass 6, and the other part of the heating network water continues to flow through the heat station(s) 2. The water flowrate of the heating network water flowing through the heating network water bypass 6 can be determined by the heat value difference between the total heat supply of the heating network initial station 1 (heat = flowrate $\times$ temperature difference $\times$ specific heat capacity as shown in below related equation) and the heat required by each heat station 2. In this case, the heat supply increased in the heating network initial station 1 can be stored among the primary network water return pipe 4, the heating network water bypass 6 and the primary network water supply pipe 5, and the heating network water corresponding to the increased heat supply can flow between the primary network water return pipe 4 and the primary network water supply pipe 5 to avoid waste. At the same time, as the temperature of the heating network water is increased, the heat supply of the heat station(s) 2 remains unchanged.

[0035] After passing through the heat station(s) 2, the temperature and pressure of the heating network water in the primary network return pipe 4 are both relatively low. If the high pressure heating network water in the heating network water bypass 6 directly flows into the primary network water return pipe 4, it tends to cause uneven pressure, thereby affecting water return effect and increasing the burden of the circulating water pump 3. Therefore, in this embodiment, the pressure relief device 63 is provided on the heating network water bypass 6, and the pressure relief device 63 is used to reduce the pressure of the high pressure heating network water in the heating network water bypass 6, thus the pressure can be decreased to match with the pressure of the heating network water in an upstream position of the primary network water return pipe 4, in which the upstream position is at the connection position between the primary network water return pipe 4 and the heating network water bypass 6, so that the water in the heating network water bypass 6 can normally flow into the primary network water return pipe 4 and then can be returned to the heating network initial station 1.

[0036] Heat release in heat supply pipe network means that when the cogeneration unit needs to increase its output capacity in the power grid peak regulation process, the output capacity can be increased by reducing the heating extraction steam flowrate of the cogeneration unit. Insufficient heat load caused by the reduced extraction steam flowrate of the cogeneration unit needs to be satisfied by the release of the stored heat in the pipe network heating system. As an example, the heat supply of the heating network initial station 1 is decreased only by reducing the water supply temperature of the heating network water. When the heat supply is decreased in the heating network initial station 1, the temperature of the heating network water is decreased, and the first regulating valve 62 is controlled to be adjustably closed, thus the flowrate of the heating network water flowing into the heating network water bypass 6 is decreased and the flowrate of the heating network water entering the heat station(s) 2 is increased, thus ensuring the heating load balance of the heat station(s) 2. In this case, it is necessary to combine the peak regulation demand of the cogeneration unit and the heat storage of heat supply pipe network to determine if the heat release process can be finished or not. If the cogeneration unit continues to have a peak regulation demand to increase the output capacity of the unit, the heat release process of the heat supply pipe network can be finished until all the heat stored in heat supply pipe network is released. While the total heat supply of the heating network initial station 1 is equal to the total heat required by the heat station(s) 2, the first regulating valve 62 is completely closed. If there is still some heat stored in the pipe network heating system and there is a peak regulation demand to reduce the output capacity of the cogeneration unit, it is necessary to finish the heat release process of the heat supply pipe network and start the heat storage process, and at this time, the opening degree of the first regulating valve 62 can be increased and a new heat storage process can be started. It is worth noting that no matter whether the heat stored in the heat pipe network is completely released, according to the peak regulation demand, the heat release process shall be finished immediately and the heat storage process shall be started. That is, at the end of the heat release process, the heat supply pipe network can still have a remained heat store and can also completely release all the stored heat, according to the specific peak regulation demand.

[0037] The above-mentioned embodiments describe three adjustment methods for changing the heat supply of the heating network initial station 1. In one example, the flowrate of the heating network water in the heat station(s) 2 needs to be adjusted when adopting the adjustment method for changing the water supply temperature of the heating network water in the heating network initial station 1. Therefore, a second regulating valve 21 and a second temperature-pressure-flowrate measuring instrument 23 are provided on a water inlet pipe connecting the heat station(s) 2 and the primary network water supply pipe 5, and a third regulating valve 22 and a temperature-pressure measuring instrument 24 are provided on a water outlet pipe connecting the heat station(s) 2 and the primary network water return pipe 4. The second regulating valve 21 and the third regulating valve 22 are used to adjust the flowrate of the heating network water in the heat station(s) 2 and assist in adjusting the flowrate of the heating network water flowing through the heating network water bypass 6 at the same time. The second temperature-pressure-flowrate measuring instrument 23 is used to measure the temperature, pressure and flowrate of the heating network water entering the heat station(s) 2, and the temperature-pressure measuring instrument 24 is used to measure the temperature and pressure of the heating network water from the heat station(s) 2. According to the total heat supply of the heating network initial station 1 and the heat required by each heat station 2, the flowrate of the heating network water flowing into the heat station(s) 2 can be controlled by adjusting the opening degrees of the second regulating valve 21 and the third regulating valve 22 of each heat station

2. The second regulating valve 21 and the third regulating valve 22 both use a directly regulated way so that the heating load balance of the heat station(s) 2 can be easier to be regulated. The number of the second regulating valve 21, the second temperature-pressure-flowrate measuring instrument 23, the third regulating valve 22 and the temperature-pressure measuring instrument 24 matches with the number of the heat station(s) 2 respectively. If the number of the heat station 2 is n, each number of the second regulating valve 21, the second temperature-pressure-flowrate measuring instrument 23, the third regulating valve 22 and the temperature-pressure measuring instrument 24 is also n, in which n is not less than 1.

[0038] Specifically, the second regulating valve 21 and the third regulating valve 22 are used to be adjustably closed when storing heat, so that the flowrate of the heating network water entering the heat station(s) 2 is decreased, and the flowrate of the heating network water flowing through the heating network water bypass 6 is increased. The second regulating valve 21 and the third regulating valve 22 are used to be adjustably open when releasing heat, so that the flowrate of the heating network water entering the heat station(s) 2 is increased, and the flowrate of the heating network water flowing through the heating network water bypass 6 is decreased. The second temperature-pressure-flowrate measuring instrument 23 and the temperature-pressure measuring instrument 24 are respectively provided on the water inlet pipe and the water outlet pipe of the heat station(s) 2. According to the total heat supply of the heating network initial station 1 (specifically reflected in the temperature and flowrate of the heating network water flowing into and out of the heating network initial station 1) and the heat required by each heat station 2 (specifically reflected in the temperature and flowrate of the heating network water flowing into and out of the heat station(s) 2), the opening degrees of the second regulating valve 21 and the third regulating valve 22 can be adjusted to ensure the heating load balance in the heat station(s) 2.

[0039] A specific control method comprises the following steps:

when the heat supply pipe network is storing heat, the heat supply of the heating network initial station 1 is increased and the temperature of the heating network water is increased, the second regulating valve 21 and the third regulating valve 22 are used to be adjustably closed in order to reduce the flowrate of the heating network water entering each heat station 2 and increase the flowrate of the heating network water entering the heating network water bypass 6; and when the heat supply pipe network is releasing heat, the heat supply of the heating network initial station 1 is decreased and the temperature of the heating network water is decreased, the second regulating valve 21 and the third regulating valve 22 are used to be adjustably open in order to increase the flowrate of the heating network water entering each heat station(s) 2 and reduce the flowrate of the heating network water entering the heating network water bypass 6 until it is zero.

[0040] In order to facilitate the regulation of the pipe network heat storage system, in one preferred embodiment, a water outlet regulating valve 13 for adjusting the water supply flowrate of the heating network water is arranged on a water outlet of the heating network initial station 1, and a water inlet regulating valve 14 for adjusting the water return flowrate of the heating network water is arranged on a water inlet of the heating network initial station 1. The circulating water pump 3 is arranged at a position where the primary network water return pipe 4 is close to the water inlet of the heating network initial station 1. A fifth temperature-pressure-flowrate measuring instrument 12 is provided at a water outlet of the heating network initial station 1 for measuring the temperature, pressure and flowrate of the heating network water from the heating network initial station 1. A fourth temperature-pressure-flowrate measuring instrument 11 is provided at a water inlet of the heating network initial station 1 for measuring the temperature, pressure and flowrate of the heating network water entering the heating network initial station 1.

[0041] All regulating valves in the aforementioned embodiments are electric regulating valves, and all measuring instruments in the aforementioned embodiments are instruments in the internet of things, which can perform wireless remote transmission of measurement data.

[0042] It is worth noting that the adjustably open and adjustably closed state of each regulating valve in the embodiments means that the opening degree of each regulating valve is adjusted between fully open and fully closed state. Specifically, the opening degrees of the second regulating valve 21 and the third regulating valve 22 can be adjusted according to the heat required by the heat station(s) 2, so as to control the heat transferring into each heat station 2. The heat of the heating network water bypass 6 is equal to a value which is the heat difference between the heat supply of the heating network initial first station 1 and the heat required by each heating station 2. According to the heat required by the heating network water bypass 6, the opening degree of the first regulating valve 62 can be adjusted, in which the first regulating valve 62 can be fully opened, partially opened or fully closed.

[0043] In one preferred embodiment, the pipe network heat storage system further comprises a water replenishing component including a primary network water replenishing pipe 7, a water replenishing water pump 71, a fourth regulating valve 72 and a third temperature-pressure-flowrate measuring instrument 73, in which the third temperature-pressure-flowrate measuring instrument 73, the water replenishing pump 71 and the fourth regulating valve 72 are arranged on the primary network make-up water pipe 7 in sequence along the water flow direction. The primary network make-up

water pipe 7 is connected to the primary network water return pipe 4. The fourth temperature-pressure-flowrate measuring instrument 11 is provided at an upstream position in the water flow direction of the primary network water return pipe 4, in which the upstream position is at the connection position between the primary network make-up water pipe 7 and the primary network water return pipe 4. After the parameter of the heating network water being measured by the fourth temperature-pressure-flowrate measuring instrument 11, the heating network water flows through the connection position of the primary network water return pipe 4 and a primary network make-up water pipe 7. The fourth regulating valve 72 is operated to be open when the water pressure in the primary network water return pipe 4 measured by the fourth temperature-pressure-flowrate measuring instrument 11 is lower than a set pressure, and the fourth regulating valve 72 is operated to be closed when the water pressure in the primary network water return pipe 4 measured by fourth temperature-pressure-flowrate measuring instrument 11 is not lower than the set pressure.

[0044] A specific water replenishing step comprises:

according to a pressure value measured by the fourth temperature-pressure-flowrate measuring instrument 11, the fourth regulating valve 72 is operated to be open when the water pressure in the primary network water return pipe 4 is lower than the set pressure, and the water replenishing pump 71 replenishes water to the primary network water return pipe 4; and, the fourth regulating valve 72 is operated to be closed when the water pressure in the primary network water return pipe 4 is not lower than the set pressure, and the water replenishing pump 71 stops replenishing water.

[0045] In one preferred embodiment, the heating network water bypass 6 is arranged at the j^{th} heat station 2, in which $1 \leq j \leq n$, and the pressure measuring instrument 41 is arranged on the primary network water return pipe 4 connecting to the j^{th} heat station 2. In order to improve the heat storage effect of the pipe network, the location of the heating network water bypass 6 can be optimized. Number j represented in the j^{th} heat station can be calculated as follows:

firstly, the maximum heating network water flowrate G^r of the heat supply pipe network can be determined according to the design flowrate of the circulating water pump 3, and the design flowrate G^0 (unit: t/h) is a known parameter, thereby the maximum heating network water flow is defined as $G^r = G^0$; then the minimum storage heat required by the heat supply pipe network can be determined according to the heat storage required by the cogeneration unit in the power peak regulation process, and the minimum storage heat $Q_{\min}$ (unit: GJ) is a known parameter;

secondly, the minimum heating network water flowrate G_i^{station} (unit: t/h, $1 \leq i \leq n$) required by each heat station 2 during the high cold period can be determined according to the maximum heating load W_i (unit: GJ/h, $1 \leq i \leq n$) required by each heat station 2 during the high cold period and the maximum temperature difference between the heating network water supply temperature and water return temperature of the heat supply pipe network, and the water supply temperature and the water return temperature can be respectively indicated as T^{01} (unit: °C) and T^{02} (unit: °C) which are both known preset parameters; the actual temperature measured by the first temperature-pressure-flowrate measuring instrument 61 and the second temperature-pressure-flowrate measuring instrument 23 can be

adjusted to the preset parameters accordingly; and, thus the minimum heating network water flowrate G_i^{station} is

$$G_i^{\text{station}} = \frac{10^6 \times W_i}{C \cdot (T^{01} - T^{02})_{\max}};$$

defined as

thirdly, the maximum heating network water flowrate G^s of the heat supply pipe network used for heat storage in

the heating period can be determined according to the minimum heating network water flowrate G_i^{station} required by each heat station 2 in the heating period and the maximum heating network water flowrate G^r of the heat supply

$$\text{pipe network: } G^s = G^r - \sum_{i=1}^n G_i^{\text{station}};$$

fourthly, the maximum value $A_{\max}$ of number j can be determined according to the design head H^0 (unit: m) of the circulating water pump 3 and the resistance loss of different pipe sections used to connect the heat supply pipe network with each heat station 2 during the heating period, in which H^0 is the design head of the circulating water pump, K (unit: m) is the equivalent absolute roughness of the heat supply pipe network, φ (unit: %) is the local resistance equivalent length percentage of the heat supply pipe network, L_i (unit: m, $1 \leq i \leq n$) is the length of each pipe section connecting each heat station to the heat supply pipe network, and D_i (unit: m, $1 \leq i \leq n$) is the diameter of each pipe section connecting each heat station 2 to the heat supply pipe network; and, H^0 , K , φ , L_i and D_i are all known parameters;

the minimum value $B_{\min}$ of number j can be determined according to the minimum heat storage required by the heat supply pipe network; and,

the final value of number j can be determined according to the following relationship:

when $B_{\min} \geq A_{\max}$, the final value of number j is $A_{\max}$; and,

when $B_{\min} < A_{\max}$, the final value of number j is $A_{\max}$ if the heat dissipation loss rate and water leakage loss rate of the heat power pipe network can be ignored, and the final value of number j is $B_{\min}$ if the heat dissipation loss rate and water leakage loss rate of the heat supply pipe network can not be ignored. The heat dissipation loss rate can be calculated according to the heating network water parameters measured by each measuring instrument, and the water leakage loss rate can be determined according to the water replenishment amount of the water replenishing component. When the heat dissipation loss rate and water leakage loss rate of heat supply pipe network are both less than the advanced level values in the industry, the heat dissipation loss rate and water leakage loss rate of heat supply pipe network can be ignored. For example, when the advanced level values in the industry refer to standard CJJ/T185-2012, the water leakage loss rate should not be greater than 0.3%, and the heat dissipation loss rate should not be greater than 0.1 °C /Km according to the temperature drop along the route.

[0046] In one preferred embodiment, the maximum value $A_{\max}$ of number j can be determined according to the design head H^0 (unit: m) of the circulating water pump 3 and the resistance loss of different pipe sections used to connect the heat supply pipe network with each heat station 2 during the heating period, and the maximum value $A_{\max}$ can be calculated as follows:

calculating the heating network water flowrate G_i^{pipe} in different pipe sections connecting each heat station 2 by the following equations:

$$\begin{cases} x = 1, G_x^{\text{pipe}} = G^r \\ 1 < x \leq j, G_x^{\text{pipe}} = G^r - \sum_{y=1}^{x-1} G_y^{\text{station}} \\ j < x \leq n, G_x^{\text{pipe}} = G^r - G^s - \sum_{y=1}^{x-1} G_y^{\text{station}} \end{cases}$$

calculating the resistance loss R_x (unit: Palm) in different pipe sections connecting each heat station 2 by the following equation:

$$R_x = 6.88 \times 10^{-3} \cdot \frac{K^{0.25} \cdot (G_x^{\text{pipe}})^2}{\rho \cdot D_x}$$

calculating the total pressure drop of the heat supply pipe network during the heating period by the following equation:

$$\begin{cases} z = 1, P_z = P_1 = 0.00688 \times \frac{K^{0.25} \cdot (G^r)^2}{\rho \cdot D_1} \cdot (1 + \varphi) \cdot L_1 \\ 1 < z \leq j, P_z = P_1 + \sum_{t=2}^z 0.00688 \times \frac{K^{0.25} \cdot [G^r - \sum_{y=1}^{t-1} (G_y^{\text{station}})]^2}{\rho \cdot D_t} \cdot (1 + \varphi) \cdot L_t \\ j < z \leq n, P_z = P_1 + P_j + \sum_{t=j+1}^z 0.00688 \times \frac{K^{0.25} \cdot [G^r - G^s - \sum_{y=1}^{t-1} (G_y^{\text{station}})]^2}{\rho \cdot D_t} \cdot (1 + \varphi) \cdot L_t \end{cases}$$

and, then comparing the design head H^0 of the circulating water pump 3 with the total pressure drop of the heat supply pipe network during the heating period, and determining the maximum value $A_{\max}$ of number j according to the relationship: $10 \times H^0 \geq 0.002 \times P_z$; in which the design head H^0 of the circulating water pump 3 is a known parameter, K (unit: m) is the equivalent

absolute roughness of the heat supply pipe network, φ (unit: %) is the local resistance equivalent length percentage of the heat supply pipe network, L_i (unit: m, $1 \leq i \leq n$) is the length of each pipe section connecting each heat station 2 to the heat supply pipe network, D_i (unit: m, $1 \leq i \leq n$) is the diameter of each pipe section connecting each heat station 2 to the heat supply pipe network and ρ (unit: kg/m³) is the density of the heating network water.

[0047] In one preferred embodiment, the minimum value $B_{\min}$ of number j can be determined according to the minimum heat storage required by the heat supply pipe network, and the minimum value $B_{\min}$ can be calculated as follows:

calculating the design heat storage of the heat supply pipe network by the following equation:

$$Q^e = 10^{-6} \times G^s \cdot C \cdot (T^{01} - T^{02})_{\max} \cdot \sum_{x=1}^j \frac{1.57 \times 10^{-3} \times L_x \cdot (D_x)^2 \cdot \rho}{G_x^{\text{pipe}}}$$

and, determining the minimum value $B_{\min}$ of number j according to the relationship: $Q^e \geq Q_{\min}$, in which ρ (unit: kg/m³) is the density of the heat supply network water and C (unit: J/(kg·°C)) is specific heat capacity of the heat supply network water.

[0048] Based on the above calculation method, the value of number j can be determined, and the position of the heating network water bypass 6 can be determined, so as to meet the use requirements of the pipe network heat storage.

[0049] Those skilled in the art should understand that, the technical features of the above embodiments can be arbitrarily combined. In an effort to provide a concise description, not all possible combinations of all the technical features of the embodiments are described. However, these combinations of technical features should be construed as disclosed in the description as long as no contradiction occurs.

[0050] The above embodiments are merely illustrative of several implementation manners of the present disclosure, and the description thereof is more specific and detailed, but is not to be construed as a limitation to the patentable scope of the present disclosure. It should be pointed out that several variations and improvements can be made by those of ordinary skill in the art without departing from the conception of the present disclosure, but such variations and improvements should fall within the protection scope of the present disclosure. Therefore, the protection scope of the present disclosure should be subject to the protection scope defined by the claims.

Claims

1. A pipe network heat storage system based on series connection of a supply main pipe and a return main pipe in a heating network, **characterized in that** the pipe network heat storage system comprises a heat supply pipe network including a heating network initial station (1), heat station(s) (2), a circulating water pump (3), a primary network water return pipe (4) and a primary network water supply pipe (5), in which the heating network initial station (1) is communicated with a primary network of the heat station(s) (2) through the primary network water return pipe (4) and the primary network water supply pipe (5), the number of the heat station(s) (2) is n which is not less than 1, the heating network water is driven by the circulating water pump (3) to flow among the heating network initial station (1), the heat station(s) (2), the primary network water return pipe (4) and the primary network water supply pipe (5); wherein,

a heating network water bypass (6) is installed between the primary network water supply pipe (5) and the primary network water return pipe (4), an adjustment component is arranged on the heating network water bypass (6) for adjusting the flowrate and pressure of the heating network water in the heating network water bypass (6), the adjustment component comprises a first temperature-pressure-flowrate measuring instrument (61), a pressure relief device (63) and a first regulating valve (62) which are arranged on the heating network water bypass (6) in sequence along the water flow direction, and a pressure measuring instrument (41) is provided at an upstream position in the water flow direction of the primary network water return pipe (4), in which the upstream position is at the connection position between the heating network water bypass (6) and the primary network water return pipe (4);

a water outlet regulating valve (13) for adjusting the water supply flowrate of the heating network water is arranged on a water outlet of the heating network initial station (1), and a water inlet regulating valve (14) for adjusting a water return flowrate of the heating network water is arranged on a water inlet of the heating network initial station (1);

when the heat supply pipe network is storing heat, the heating network initial station (1) is used to increase the heat supply and increase the water supply temperature and/or water supply flowrate of the heating network water; and when the heat supply pipe network is releasing heat, the heating network initial station (1) is used to reduce the heat supply and reduce the water supply temperature and/or water supply flowrate of the heating network water;

the first regulating valve (62) is used to be in a normally closed state to make the flowrate of the heating network water in the heating network water bypass (6) be zero when the heat supply pipe network is not storing or not releasing heat, the first regulating valve (62) can be adjustably open to make the flowrate of the heating network water in the heating network water bypass (6) be gradually increased while storing heat, and the first regulating valve (62) can be adjustably closed to make the flowrate of the heating network water in the heating network water bypass (6) be gradually decreased while releasing heat; and, the pressure relief device (63) is used to reduce the pressure of the heating network water in the heating network water bypass (6) to match with the pressure measured by the pressure measuring instrument (41), and then the heating network water can be returned to the primary network water return pipe (4).

2. The pipe network heat storage system according to claim 1, wherein

a second regulating valve (21) and a second temperature-pressure-flowrate measuring instrument (23) are arranged on a water inlet pipe connecting the heat station(s) (2) with the primary network water supply pipe (5), and a third regulating valve (22) and a temperature-pressure measuring instrument (24) are arranged on a water outlet pipe connecting the heat station(s) (2) with the primary network water return pipe (4); and,

when the heat supply pipe network is storing heat and the water supply temperature of the heating network water in the heating network initial station (1) is increased, the second regulating valve (21) and the third regulating valve (22) are used to be adjustably closed in order to reduce the flowrate of the heating network water entering the heat station(s) (2) and increase the flowrate of the heating network water entering the heating network water bypass (6); and, when the heat supply pipe network is releasing heat and the water supply temperature of the heating network water in the heating network initial station (1) is decreased, the second regulating valve (21) and the third regulating valve (22) are used to be adjustably open in order to increase the flowrate of the heating network water entering the heat station(s) (2) and reduce the flowrate of the heating network water entering the heating network water bypass (6).

3. The pipe network heat storage system according to claim 1, wherein the pipe network heat storage system further comprises a water replenishing component including a primary network water replenishing pipe (7), a water replenishing pump (71), a fourth regulating valve (72) and a third temperature-pressure-flowrate measuring instrument (73), in which the third temperature-pressure-flowrate measuring instrument (73), the water replenishing pump (71) and the fourth regulating valve (72) are arranged on the primary network water replenishing pipe (7) in sequence along the water flow direction, and the primary network water replenishing pipe (7) is connected to the primary network water return pipe (4);

a fourth temperature-pressure-flowrate measuring instrument (11) is provided at an upstream position in the water flow direction of the primary network water return pipe (4), in which the upstream position is at the connection position between the primary network water replenishing pipe (7) and the primary network water return pipe (4); and, the fourth regulating valve (72) is operated to be open when the pressure of the primary network water return pipe (4) measured by the fourth temperature-pressure-flowrate measuring instrument (11) is lower than a set pressure, and the fourth regulating valve (72) is operated to be closed when the pressure of the primary network water return pipe (4) measured by the fourth temperature-pressure-flowrate measuring instrument (11) is not lower than the set pressure; and, a fifth temperature-pressure-flowrate measuring instrument (12) is provided at a water outlet of the heating network initial station (1).

4. The pipe network heat storage system according to claim 1, wherein the heating network water bypass (6) is arranged at the j^{th} heat station (2), in which $1 \leq j \leq n$, and the pressure measuring instrument (41) is arranged on the primary network water return pipe (4) connecting to the j^{th} heat station (2).

5. The pipe network heat storage system according to claim 4, wherein the heating network water bypass (6) is arranged at the j^{th} heat station (2), and number j represented in the j^{th} heat station (2) can be calculated as follows:

the maximum heating network water flowrate G^r of the heat supply pipe network can be determined according

to the design flowrate G^0 (unit: t/h) of the circulating water pump (3): $G^r = G^0$;
the minimum storage heat $Q_{\min}$ (unit: GJ) required by the heat supply pipe network can be determined according to the heat storage required by the cogeneration unit for power peak regulation;

the minimum heating network water flowrate G_i^{station} (unit: t/h, $1 \leq i \leq n$) required by each heat station (2) during the heating period can be determined according to the maximum heating load W_i (unit: GJ/h, $1 \leq i \leq n$) required by each heat station (2) during the heating period and the maximum temperature difference between the heating network water supply temperature and water return temperature of the heat supply pipe network, and the water supply temperature and the water return temperature can be respectively indicated as T^{01} (unit: °C) and T^{02}

$$G_i^{\text{station}} = \frac{10^6 \times W_i}{C \cdot (T^{01} - T^{02})_{\max}};$$

(unit: °C):

the maximum heating network water flowrate G^s of the heat supply pipe network used for heat storage in the heating period can be determined according to the minimum heating network water flowrate G_i^{STATION} required by each heat station (2) in the heating period and the maximum heating network water flowrate G^r of the heat

$$G^s = G^r - \sum_{i=1}^n G_i^{\text{station}};$$

supply pipe network: the maximum value $A_{\max}$ of number j can be determined according to the design head H^0 (unit: m) of the circulating water pump (3) and the resistance loss of different pipe sections used to connect the heat supply pipe network with each heat station (2) during the heating period;

the minimum value $B_{\min}$ of number j can be determined according to the minimum heat storage required by the heat supply pipe network; and,

the final value of number j can be determined according to the following relationship:

when $B_{\min} \geq A_{\max}$, the final value of number j is $A_{\max}$; and,
when $B_{\min} < A_{\max}$, the final value of number j is $A_{\max}$ if the heat dissipation loss rate and water leakage loss rate of the heat power pipe network can be ignored, and the final value of number j is $B_{\min}$ if the heat dissipation loss rate and water leakage loss rate of the heat supply pipe network can not be ignored.

6. The pipe network heat storage system according to claim 5, wherein the maximum value $A_{\max}$ of number j can be determined according to the design head H^0 (unit: m) of the circulating water pump (3) and the resistance loss of different pipe sections used to connect the heat supply pipe network with each heat station (2) during the heating period, and the maximum value $A_{\max}$ can be calculated as follows:

calculating the heating network water flowrate G_i^{pipe} in different pipe sections connecting each heat station (2) by the following equations:

$$\begin{cases} x = 1, G_x^{\text{pipe}} = G^r \\ 1 < x \leq j, G_x^{\text{pipe}} = G^r - \sum_{y=1}^{x-1} G_y^{\text{station}} \\ j < x \leq n, G_x^{\text{pipe}} = G^r - G^s - \sum_{y=1}^{x-1} G_y^{\text{station}} \end{cases}$$

calculating the resistance loss R_x (unit: Palm) in different pipe sections connecting each heat station (2) by the following equation:

$$R_x = 6.88 \times 10^{-3} \cdot \frac{K^{0.25} \cdot (G_x^{\text{pipe}})^2}{\rho \cdot D_x}$$

calculating the total pressure drop of the heat supply pipe network during the heating period by the following equations:

$$\begin{cases}
 z = 1, P_z = P_1 = 0.00688 \times \frac{K^{0.25} \cdot (G^r)^2}{\rho \cdot D_1} \cdot (1 + \varphi) \cdot L_1 \\
 1 < z \leq j, P_z = P_1 + \sum_{t=2}^z 0.00688 \times \frac{K^{0.25} \cdot [G^r - \sum_{y=1}^{t-1} (G_y^{station})]^2}{\rho \cdot D_t} \cdot (1 + \varphi) \cdot L_t \\
 j < z \leq n, P_z = P_1 + P_j + \sum_{t=j+1}^z 0.00688 \times \frac{K^{0.25} \cdot [G^r - G^s - \sum_{y=1}^{t-1} (G_y^{station})]^2}{\rho \cdot D_t} \cdot (1 + \varphi) \cdot L_t
 \end{cases}$$

and, then comparing the design head H^0 of the circulating water pump (3) with the total pressure drop of the heat supply pipe network during the heating period, and determining the maximum value $A_{\max}$ of number j according to the relationship $10 \times H^0 \geq 0.002 \times P_z$;

in which: the design head H^0 of the circulating water pump (3) is a known parameter; K (unit: m) is the equivalent absolute roughness of the heat supply pipe network; φ (unit: %) is the local resistance equivalent length percentage of the heat supply pipe network; L_i (unit: m, $1 \leq i \leq n$) is the length of each pipe section connecting each heat station (2) to the heat supply pipe network; D_i (unit: m, $1 \leq i \leq n$) is the diameter of each pipe section connecting each heat station (2) to the heat supply pipe network; and, ρ (unit: kg/m^3) is the density of the heating network water.

7. The pipe network heat storage system according to claim 5, wherein the minimum value $B_{\min}$ of number j can be determined according to the minimum heat storage required by the heat supply pipe network, and the minimum value $B_{\min}$ can be calculated as follows:

calculating the design heat storage of the heat supply pipe network by the following equation:

$$Q^e = 10^{-6} \times G^s \cdot C \cdot (T^{01} - T^{02})_{\max} \cdot \sum_{x=1}^j \frac{1.57 \times 10^{-3} \times L_x \cdot (D_x)^2 \cdot \rho}{G_x^{pipe}}$$

and, determining the minimum value $B_{\min}$ of number j according to the relationship: $Q^e \geq Q_{\min}$; in which: ρ (unit: kg/m^3) is the density of the heat supply network water; and, C (unit: $\text{J}/(\text{kg} \cdot ^\circ\text{C})$) is specific heat capacity of the heat supply network water.

8. A pipe network heat storage control method based on series connection of a supply main pipe and a return main pipe in a heating network, **characterized in that** the control method uses the pipe network heat storage system as described in any one of claim 1 to claim 7 and comprises the following steps:

when the heat supply pipe network is not storing or not releasing heat, the first regulating valve (62) is used to be in a normally closed state to make the flowrate of the heating network water in the heating network water bypass (6) be zero, the heating network water from the heating network initial station (1) is transported to the heat station(s) (2) through the primary network water supply pipe (5), and then the heating network water is returned to the heating network initial station (1) through the primary network water return pipe (4) in a continuous cycle;

when the heat supply pipe network is storing heat, the heat supply of the heating network initial station (1) is increased and the water supply temperature and/or water supply flowrate of the heating network water is increased, the first regulating valve (62) can be adjustably open to make the flowrate of the heating network water in the heating network water bypass (6) be gradually increased; and, the pressure relief device (63) is used to reduce the pressure of the heating network water in the heating network water bypass (6) to match with the pressure measured by the pressure measuring instrument (41), and then the heating network water can be returned to the heating network initial station (1) through the primary network water return pipe (4); and,

when the heat supply pipe network is releasing heat, the heat supply of the heating network initial station (1) is decreased and the water supply temperature and/or water supply flowrate of the heating network water is decreased, the first regulating valve (62) can be adjustably closed to make the flowrate of the heating network water in the heating network water bypass (6) be gradually decreased.

9. The pipe network heat storage control method according to claim 8, wherein the second regulating valve (21) and the second temperature-pressure-flowrate measuring instrument (23) are arranged on a water inlet pipe connecting the heat station(s) (2) with the primary network water supply pipe (5), and the third regulating valve (22) and the temperature-pressure measuring instrument (41) (24) are arranged on a water outlet pipe connecting the heat station(s) (2) with the primary network water return pipe (4);

when the heat supply pipe network is storing heat, the heat supply of the heating network initial station (1) is increased and the water supply temperature of the heating network water is increased, the second regulating valve (21) and the third regulating valve (22) are used to be adjustably closed in order to reduce the flowrate of the heating network water entering the heat station(s) (2) and increase the flowrate of the heating network water entering the heating network water bypass (6); and,

when the heat supply pipe network is releasing heat, the heat supply of the heating network initial station (1) is decreased and the water supply temperature of the heating network water is decreased, the second regulating valve (21) and the third regulating valve (22) are used to be adjustably open in order to increase the flowrate of the heating network water entering the heat station(s) (2) and reduce the flowrate of the heating network water entering the heating network water bypass (6).

10. The pipe network heat storage control method according to claim 8, wherein the control method further comprises a water replenishing step:

the pipe network heat storage system comprises the water replenishing component including the primary network water replenishing pipe (7), the water replenishing pump (71), the fourth regulating valve (72) and the third temperature-pressure-flowrate measuring instrument (73), in which the third temperature-pressure-flowrate measuring instrument (73), the water replenishing pump (71) and the fourth regulating valve (72) are arranged on the primary network water replenishing pipe (7) in sequence along the water flow direction, the primary network water replenishing pipe (7) is connected to the primary network water return pipe (4), and the fourth temperature-pressure-flowrate measuring instrument (11) is provided at an upstream position in the water flow direction of the primary network water return pipe (4), in which the upstream position is at the connection position between the primary network water replenishing pipe (7) and the primary network water return pipe (4); and, according to a pressure value measured by the fourth temperature-pressure-flowrate measuring instrument (11), the fourth regulating valve (72) is operated to be open when the pressure of the primary network water return pipe (4) is lower than the set pressure, and the water replenishing pump (71) replenishes water to the primary network water return pipe (4); and, the fourth regulating valve (72) is operated to be closed when the pressure of the primary network water return pipe (4) is not lower than the set pressure, and the water replenishing pump (71) stops replenishing water.

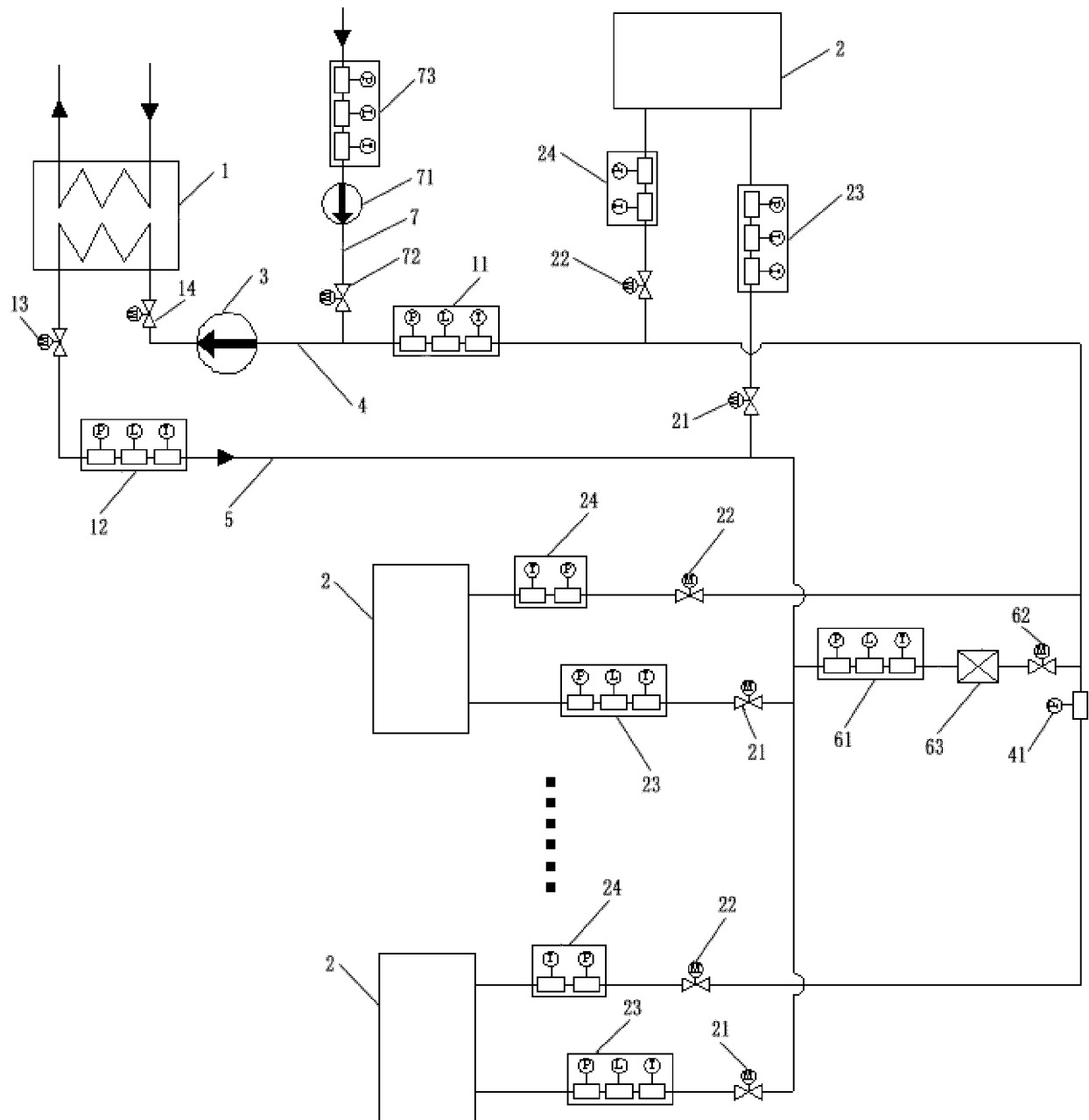


FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/143346

A. CLASSIFICATION OF SUBJECT MATTER F24D 19/10(2006.01)i; F24D 11/00(2022.01)i According to International Patent Classification (IPC) or to both national classification and IPC																		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) F24D19:F24D11 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched																		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) CNTXT: WPABSC; WPABS; CJFD; Patentics: 华电, 热力站, 热力网, 热力管网, 供热站, 供热网, 供热管网, 蓄热, 调峰, 移峰填谷, 旁通, 旁路, 水, 压力, 减压, 降压, 水压, 一次, 热水, 泵, heat, network, supply, regenerative, regenerator?, bypass, bypath, shunt, pressure, water, pump																		
C. DOCUMENTS CONSIDERED TO BE RELEVANT																		
<table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>CN 111396982 A (HUADIAN ELECTRIC POWER RESEARCH INSTITUTE CO., LTD.) 10 July 2020 (2020-07-10) description, paragraphs 56-100, and figure</td> <td>1-10</td> </tr> <tr> <td>A</td> <td>CN 113108356 A (HUADIAN ELECTRIC POWER RESEARCH INSTITUTE CO., LTD.) 13 July 2021 (2021-07-13) description, paragraphs 44-77, and figure 1</td> <td>1-10</td> </tr> <tr> <td>A</td> <td>CN 207487723 U (HANGZHOU CHAUMET TECHNOLOGY CO., LTD.) 12 June 2018 (2018-06-12) entire document</td> <td>1-10</td> </tr> <tr> <td>A</td> <td>CN 106123086 A (NORTH CHINA ELECTRIC POWER UNIVERSITY) 16 November 2016 (2016-11-16) entire document</td> <td>1-10</td> </tr> <tr> <td>A</td> <td>CN 207893829 U (DANDONG POWER PLANT OF HUANENG POWER INTERNATIONAL, INC. et al.) 21 September 2018 (2018-09-21) entire document</td> <td>1-10</td> </tr> </tbody> </table>	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	A	CN 111396982 A (HUADIAN ELECTRIC POWER RESEARCH INSTITUTE CO., LTD.) 10 July 2020 (2020-07-10) description, paragraphs 56-100, and figure	1-10	A	CN 113108356 A (HUADIAN ELECTRIC POWER RESEARCH INSTITUTE CO., LTD.) 13 July 2021 (2021-07-13) description, paragraphs 44-77, and figure 1	1-10	A	CN 207487723 U (HANGZHOU CHAUMET TECHNOLOGY CO., LTD.) 12 June 2018 (2018-06-12) entire document	1-10	A	CN 106123086 A (NORTH CHINA ELECTRIC POWER UNIVERSITY) 16 November 2016 (2016-11-16) entire document	1-10	A	CN 207893829 U (DANDONG POWER PLANT OF HUANENG POWER INTERNATIONAL, INC. et al.) 21 September 2018 (2018-09-21) entire document	1-10
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A	CN 207893829 U (DANDONG POWER PLANT OF HUANENG POWER INTERNATIONAL, INC. et al.) 21 September 2018 (2018-09-21) entire document	1-10																
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2021/143346

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C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2020326077 A1 (UNIVERSITY OF MARIBOR) 15 October 2020 (2020-10-15) entire document	1-10

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Information on patent family members

International application No.
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Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 111396982 A	10 July 2020	CN 111396982 B	13 April 2021
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		EP 3452758 A1	13 March 2019
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REFERENCES CITED IN THE DESCRIPTION

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