

Description

Title of Invention

GROUND THERMAL ENERGY SYSTEM, CONTROL DEVICE, CONTROL
METHOD, AND PROGRAM

5

Technical Field

[0001]

The present disclosure relates to a ground thermal energy system, a control device, a control method, and a program.

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This application claims priority based on Japanese Patent Application No. 2021-78634 filed on May 6, 2021, contents of which are incorporated herein by reference.

Background Art

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[0002]

In recent years, a ground thermal energy system that utilizes groundwater as a hot energy source or a cold energy source has been proposed.

[0003]

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For example, Patent Document 1 proposes a groundwater heat exchange device in which a pump pipe and a return pipe are respectively inserted into two wells, groundwater in one well is pumped up by a pump through the pump pipe, and the groundwater is subjected to heat utilization and then poured into the other well through the return pipe of the other well.

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Citation List

Patent Literature

[0004]

Patent Document 1: JP 2011-21804 A

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Summary of Invention

Technical Problem

[0005]

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In the groundwater heat exchange device disclosed in Patent Document 1, to keep the temperature of water poured into a water injection well constant, it is necessary to adjust a water injection flow rate in accordance with factors such as load and outside air temperature.

However, in the configuration disclosed in Patent Document 1, the water injection flow rate is adjusted only by the pump. Thus, it is desirable to further facilitate adjustment of the water injection flow rate.

[0006]

5 The present disclosure has been made to solve the above-described problem, and an object of the present disclosure is to provide a ground thermal energy system, a control device, a control method, and a program capable of facilitating flow rate adjustment.

10 Solution to Problem

[0007]

To solve the above problem, a ground thermal energy system according to the present disclosure includes a well; piping including an end portion on a side extending toward the well; and a heat exchanger provided to the piping, wherein the piping includes, at the end portion, a pump pipe connected to a pump configured to pump groundwater in the well, and a plurality of water injection pipes each provided with a flow control valve.

[0008]

A control device according to the present disclosure includes a pump operation control unit configured to operate a pump provided in a pump pipe provided in one well of a pair of wells to pump up groundwater from the pump pipe; and a valve opening control section configured to adjust a degree of opening of a flow control valve provided in each of a plurality of water injection pipes such that the groundwater pumped up from the pump pipe passes through a heat exchanger and is made to flow into the other of the pair of wells at a predetermined flow rate through the plurality of water injection pipes provided in the other of the pair of wells.

[0009]

A control method according to the present disclosure includes operating a pump provided in a pump pipe provided in one well of a pair of wells to pump up groundwater from the pump pipe; and adjusting a degree of opening of a flow control valve provided in each of a plurality of water injection pipes such that the groundwater pumped up from the pump pipe passes through a heat exchanger and is made to flow into the other of the pair of wells at a predetermined flow rate through the plurality of water injection pipes provided in the other of the pair of wells.

[0010]

A program according to the present disclosure causes a computer to execute a method of operating a pump provided in a pump pipe provided in one well of a pair of wells to pump up groundwater from the pump pipe; and adjusting a degree of opening of a flow control valve provided in each of a plurality of water injection pipes such that the groundwater pumped up from the pump pipe passes through a heat exchanger and is made to flow into the other of the pair of wells at a predetermined flow rate through the plurality of water injection pipes provided in the other of the pair of wells.

Advantageous Effects of Invention

[0011]

According to the ground thermal energy system, the control device, the control method, and the program of the present disclosure, it is possible to easily adjust the flow rate.

Brief Description of Drawings

[0012]

FIG. 1 is a diagram illustrating a schematic configuration of a ground thermal energy system according to an embodiment of the present disclosure.

FIG. 2 is a system diagram of the ground thermal energy system according to the embodiment of the present disclosure.

FIG. 3 is a block diagram of a control device according to the embodiment of the present disclosure.

FIG. 4 is a flowchart illustrating a procedure of a control method according to the embodiment of the present disclosure.

FIG. 5 is a diagram illustrating an example of a hardware configuration of a computer included in the control device according to the embodiment of the present disclosure.

Description of Embodiments

[0013]

Hereinafter, an embodiment of the present disclosure will be described with reference to the drawings. In all the drawings, the same or corresponding components are denoted by the same reference signs, and common descriptions will be omitted.

[0014]

Embodiments

An embodiment of a ground thermal energy system according to the present disclosure will be described with reference to FIGS. 1 to 4.

Configuration of Ground Thermal Energy System

5 As illustrated in FIGS. 1 and 2, a ground thermal energy system 1 primarily includes a well 2, piping 3, a heat exchanger 4, and a flow control system 7.

For example, the ground thermal energy system 1 may include a pair of the wells 2.

10 [0015]

Configuration of Well

As illustrated in FIG. 1, the pair of wells 2 extend into an aquifer LY from a ground OG.

For example, the pair of wells 2 includes a first well 2A and a second well 2B.

15 The ground thermal energy system 1 pumps up groundwater from one of the first well 2A and the second well 2B, performs heat exchange in the heat exchanger 4, and then makes the groundwater after the heat exchange flow into the other of the first well 2A and the second well 2B. That is, the ground
20 thermal energy system 1 has two operation modes of a case where the groundwater is pumped up from the first well 2A and made to flow into the second well 2B and a case where the groundwater is pumped up from the second well 2B and made to flow into the first well 2A.

In the following description, one of the first well 2A and the second well 2B from which the groundwater is pumped up is referred to as a pump well 21,
25 and one of the first well 2A and the second well 2B receiving the inflow of the groundwater is referred to as a water injection well 22. That is, each of the first well 2A and the second well 2B may function as the pump well 21 or the water injection well 22.

30 However, the following description focuses on a case where the first well 2A is the pump well 21, the second well 2B is the water injection well 22, and heat exchange is performed by the heat exchanger 4 to simplify the description.

[0016]

35 Each of the wells 2 includes a casing 2a embedded in an excavated hole HOL excavated toward the underground from the ground OG to the aquifer LY.

The casing 2a has a tubular shape extending in the up-down direction.

[0017]

Each of the wells 2 has an opening 2c at an upper portion.

For example, the opening 2c may be an opening at the upper portion of the casing 2a.

[0018]

5 The casing 2a has, for example, a strainer 2b formed of a plurality of slits.

The strainer 2b allows the well 2 to take groundwater in the aquifer LY into the casing 2a and to return the groundwater from the casing 2a to the aquifer LY.

10 For example, a well cover (not illustrated) for closing the opening may be provided at the opening in the upper portion of the casing 2a.

[0019]

Configuration of Piping

15 As illustrated in FIGS. 1 and 2, the piping 3 has end portions on sides extending toward the well 2.

The piping 3 includes a pump pipe 71 and a plurality of water injection pipes 75 at the end portions thereof.

20 For example, the piping 3 may include the pump pipe 71 and the plurality of water injection pipes 75 at end portions on the side extending toward each well 2 of the pair of wells 2.

25 For example, in the present embodiment, the piping 3 includes the pump pipe 71 and the plurality of water injection pipes 75 at end portions of the sides of the pair of wells 2. That is, the piping 3 includes the pump pipe 71 and the plurality of water injection pipes 75 at an end portion 3a on the first well 2A side and an end portion 3b on the second well 2B side, respectively.

The pump pipe 71 and the plurality of water injection pipes 75 are provided branching from the end portions 3a and 3b of the piping 3.

[0020]

The pump pipe 71 extends from the ground OG into the well 2.

30 Both ends of the pump pipe 71 may be immersed in the groundwater in the well 2.

In a case where the well 2 on the side where the pump pipe 71 is provided functions as the pump well 21, the pump pipe 71 pumps up the groundwater from the well 2 (pump well 21).

35 [0021]

The pump pipe 71 includes a pump 72.

The pump 72 pumps water from the well 2 to the piping 3.

For example, in a case where the well 2 functions as the pump well 21, the pump 72 pumps water from the well 2 to the piping 3.

For example, the pump 72 may pump up the groundwater in the well 2 into the piping 3.

5 For example, the pump 72 may be provided in the pump pipe 71 and be immersed in the groundwater in each well 2.

For example, an output of the pump 72 may be changed by inverter control.

[0022]

10 A check valve 73 is provided in the pump pipe 71.

The check valve 73 is provided closer to the heat exchanger 4 than the pump 72 in the pump pipe 71.

The check valve 73 is provided closer to the pump 72 than connecting portions between the pump pipe 71 and the end portions 3a and 3b of the piping
15 3.

The check valve 73 suppresses backflow of some of the inflow groundwater to the pump 72 when water is made to flow from the piping 3 through the water injection pipe 75 in the well 2 on the side where the check valve 73 is provided.

20 [0023]

The plurality of water injection pipes 75 extend from the ground OG into the wells 2 at the end portions 3a and 3b of the piping 3 on the side of the wells 2 (the first well 2A and the second well 2B).

Both ends of each water injection pipe 75 may be immersed in the
25 groundwater in the well 2.

In the present embodiment, for example, two water injection pipes 75 are provided.

Three or more water injection pipes 75 may be provided.

In a case where the well 2 provided with the plurality of water injection
30 pipes 75 functions as the water injection well 22, the plurality of water injection pipes 75 make the groundwater flow into the well 2 (water injection well 22).

[0024]

The plurality of water injection pipes 75 may have different pipe
35 diameters.

In the present embodiment, the plurality of water injection pipes 75 include a small-diameter water injection pipe 75A and a large-diameter water injection pipe 75B.

The small-diameter water injection pipe 75A has a pipe diameter smaller than a pipe diameter of the large-diameter water injection pipe 75B.

The large-diameter water injection pipe 75B has a pipe diameter larger than a pipe diameter of the small-diameter water injection pipe 75A.

5 Each of the small-diameter water injection pipe 75A and the large-diameter water injection pipe 75B may have a pipe diameter smaller than a pipe diameter of the pump pipe 71.

The small-diameter water injection pipe 75A and the large-diameter water injection pipe 75B may be configured such that the sum of the flow path cross-sectional area of the small-diameter water injection pipe 75A and the
10 flow path cross-sectional area of the large-diameter water injection pipe 75B is greater than or equal to the flow path cross-sectional area of the pump pipe 71.
[0025]

Each of the plurality of water injection pipes 75 includes a flow control
15 valve 77.

The small-diameter water injection pipe 75A includes a small-diameter flow control valve 77A as the flow control valve 77.

The large-diameter water injection pipe 75B includes a large-diameter flow control valve 77B as the flow control valve 77.

20 The small-diameter flow control valve 77A has a bore smaller than a bore of the large-diameter flow control valve 77B.

The small-diameter flow control valve 77A has a bore corresponding to a pipe diameter of the small-diameter water injection pipe 75A.

The large-diameter flow control valve 77B has a bore corresponding to a
25 pipe diameter of the large-diameter water injection pipe 75B.
[0026]

The flow control valve 77 controls the flow rate of the groundwater flowing through the water injection pipe 75.

In a case where the well 2 functions as the water injection well 22, the
30 flow control valve 77 controls the flow rate of the groundwater flowing through the water injection pipe 75 provided in the water injection well 22.

The flow control valve 77 can control the flow rate of the groundwater in the water injection pipe 75 provided with the flow control valve 77 by adjusting a degree of opening of the flow control valve 77.

35 The flow control valve 77 may be configured to stop the operation of the pump 72 after the flow control valve 77 is fully closed when the operation of the ground thermal energy system 1 is stopped. Thus, the ground thermal

energy system 1 can stop the operation while maintaining the groundwater in the piping 3 in a pressurized state.

[0027]

5 The plurality of flow control valves 77 provided in the plurality of water injection pipes 75 can independently perform valve opening degree adjustment.

The flow control valve 77 of some (one) of the water injection pipes 75 among the plurality of water injection pipes 75 may be closed, and water may be made to flow into the well 2 on the water inflow side only from the other water injection pipe 75.

10 [0028]

As illustrated in FIG. 2, the piping 3 includes check valves 35a to 35d between the heat exchanger 4 and the pair of wells 2.

15 The check valves 35a to 35d control the flow of the groundwater in the piping 3 so that the groundwater flows in the same direction with respect to the heat exchanger 4 regardless of whether the groundwater is pumped up from the first well 2A or pumped up from the second well 2B.

[0029]

20 For example, when the groundwater is pumped up from the first well 2A, the groundwater in the piping 3 is made to flow into the second well 2B from the first well 2A via the check valve 35a, the heat exchanger 4, and the check valve 35b in this order. At this time, since pressure in the piping 3 on the upstream side (the first well 2A side) of the heat exchanger 4 is greater than pressure on the downstream side, the water does not flow to the check valve 35c and the check valve 35d.

25 Similarly, when the groundwater is pumped up from the second well 2B, the groundwater in the piping 3 is made to flow into the first well 2A from the second well 2B via the check valve 35c, the heat exchanger 4, and the check valve 35d in this order. Also at this time, since pressure in the piping 3 on the upstream side (the second well 2B side) of the heat exchanger 4 is greater than
30 pressure on the downstream side, the water does not flow to the check valve 35a and the check valve 35b.

[0030]

Configuration of Heat Exchanger

35 The heat exchanger 4 performs heat exchange between the groundwater in the piping 3 and a medium on a side of a load facility 100.

For example, the heat exchanger 4 performs heat exchange between the groundwater pumped up from the well 2 and flowing in the piping 3 and the medium on the load facility 100 side. The groundwater after heat exchange

flows from the heat exchanger 4 through the piping 3 and is made to flow into the well 2.

For example, the heat exchanger 4 may be provided partway along the piping 3 on the ground OG.

5 [0031]

When the water that has passed through the heat exchanger 4 is hot water, the ground thermal energy system 1 performs hot water heat storage by making the hot water flow into the well 2.

10 When the water that has passed through the heat exchanger 4 is cold water, the ground thermal energy system 1 performs cold water heat storage by making the cold water flow into the well 2.

As used herein, the “hot water” refers to water at a temperature greater than the initial ground temperature of the groundwater in the aquifer, and the “cold water” refers to water at a temperature lower than the initial ground
15 temperature of the groundwater in the aquifer.

For example, the initial groundwater temperature of the aquifer is 18°C.

[0032]

Configuration of Flow Control System

20 The flow control system 7 includes a pump controller 74, the flow control valve 77, and a control device 80. The flow control system 7 adjusts the inflow temperature in the water injection well 22 by adjusting the flow rate of the groundwater made to flow into the water injection well 22.

[0033]

The pump controller 74 controls the operation of the pump 72.

25 For example, the pump controller 74 may be provided in association with the pump 72 of each well 2.

For example, the pump controller 74 includes an inverter circuit (not illustrated) and performs inverter control of the pump 72.

30 The pump controller 74 adjusts a rotational speed of the pump 72 by varying the operating frequency of the inverter control performed by the inverter circuit under control of the control device 80 to be described below.

By varying the operating frequency of the inverter control performed by the inverter circuit, the pump controller 74 adjusts the rotational speed of the pump 72 to adjust the flow rate of the groundwater made to flow into the water
35 injection well 22 from the piping 3 through the heat exchanger 4.

Hereinafter, the operating frequency of the inverter control of the pump 72 is also referred to as an “operating frequency of the pump 72”.

[0034]

Configuration of Control Device

The control device 80 controls the flow rate of the groundwater made to flow into the water injection well 22.

5 The control device 80 controls the operating frequency of the pump 72 and the degree of opening of the flow control valve 77 so that the inflow temperature of the groundwater made to flow into the water injection well 22 is constant.

10 The control device 80 adjusts the flow rate of the groundwater made to flow into the water injection well 22 by adjusting only the operating frequency of the pump 72 in a region where the operating frequency of the pump 72 is greater than or equal to a predetermined minimum frequency.

For example, the control device 80 may be controllably connected to each pump controller 74.

[0035]

15 For example, the control device 80 may be controllably connected to each of the flow control valves 77.

For example, when the operating frequency of the pump 72 decreases to the minimum frequency, the control device 80 adjusts the degree of opening of the flow control valve 77 to adjust the flow rate of the groundwater made to
20 flow into the water injection well 22.

When the operating frequency of the pump 72 decreases to the minimum frequency, the control device 80 reduces the flow rate of the groundwater made to flow into the water injection well 22 by throttling (reducing) the degree of opening of the flow control valve 77.

25 For example, the control device 80 may maintain the operating frequency of the pump 72 at the minimum frequency in a state where the operating frequency of the pump 72 is decreased to the minimum frequency and the flow rate of the groundwater made to flow into the water injection well 22 is adjusted by adjusting the degree of opening of the flow control valve 77.

30 [0036]

For example, the control device 80 may open only the flow control valve 77 provided in the small-diameter water injection pipe 75A of the two water injection pipes 75 when the flow rate of the groundwater toward the well 2 on the water inflow side is smaller than a predetermined flow rate setting reference
35 value in a state where the operating frequency of the pump 72 is decreased to the minimum frequency.

[0037]

As illustrated in FIG. 3, the control device 80 includes a pump operation control unit 81 and a valve opening control section 82.

[0038]

5 The pump operation control unit 81 adjusts the rotational speed of the pump 72 by varying the operating frequency of the inverter control performed by the inverter circuit of the pump controller 74.

10 The pump operation control unit 81 adjusts the operating frequency of the pump 72 for pumping the groundwater from the pump well 21 in accordance with the temperature of the groundwater made to flow into the water injection well 22.

The pump operation control unit 81 adjusts the flow rate of the groundwater made to flow from the piping 3 into the water injection well 22 by varying the operating frequency of the pump 72 based on a map or the like stored in advance.

15 For example, when a cooling operation is performed on the load facility 100 side and the hot water heat storage is performed in the water injection well 22, the pump operation control unit 81 controls the operating frequency of the pump 72 on the basis of a difference between the actual inflow temperature of the groundwater made to flow from the piping 3 into the water injection well 22 and the preset temperature.

20 For example, when a heating operation is performed on the load facility 100 side and the cold water heat storage is performed in the water injection well 22, the pump operation control unit 81 controls the operating frequency of the pump 72 on the basis of a difference between the actual inflow temperature of the groundwater made to flow from the piping 3 into the water injection well 22 and the preset temperature.

The pump operation control unit 81 controls the pump controller 74 to adjust the operating frequency (output) of the pump 72 in accordance with the required inflow temperature based on a map or the like stored in advance.

30 The pump operation control unit 81 stores, for example, a lower limit value of the operating frequency at which the pump 72 can be stably operated as the minimum frequency. The pump operation control unit 81 controls the pump controller 74 to adjust the operation of the pump 72 in a frequency domain greater than or equal to a preset minimum frequency.

35 [0039]

The valve opening control section 82 adjusts the flow rate of the groundwater in the piping 3 by opening and closing the flow control valve 77.

The valve opening control section 82 adjusts the flow rate of the groundwater in the piping 3 by adjusting the degree of opening of the flow control valve 77.

5 The valve opening control section 82 adjusts the degree of opening of the flow control valve 77 when the operating frequency of the pump 72 decreases to the minimum frequency.

When the operating frequency of the pump 72 reaches the minimum frequency, the valve opening control section 82 adjusts the degree of opening of the flow control valve 77 in accordance with the temperature of the groundwater made into the water injection well 22.
[0040]

15 In the present embodiment, the valve opening control section 82 opens only the small-diameter flow control valve 77A provided in the small-diameter water injection pipe 75A of the two water injection pipes 75 to make water flow into the well 2 on the water inflow side only from the small-diameter water injection pipe 75A when the flow rate of the groundwater toward the well 2 on the water inflow side is smaller than a predetermined flow rate setting reference value in a state where the operating frequency of the pump 72 is decreased to the minimum frequency.

20 In the present embodiment, the valve opening control section 82 may adjust the degree of opening of only the small-diameter water injection pipe 75A when the flow rate of the groundwater toward the well 2 on the water inflow side is smaller than a predetermined flow rate setting reference value in a state where the operating frequency of the pump 72 is decreased to the minimum frequency.
25

In the present embodiment, the valve opening control section 82 may open both the small-diameter flow control valve 77A provided in the small-diameter water injection pipe 75A and the large-diameter flow control valve 77B provided in the large-diameter water injection pipe 75B to make water
30 flow into the well 2 on the water inflow side through both the small-diameter water injection pipe 75A and the large-diameter water injection pipe 75B when the flow rate of the groundwater toward the well 2 on the water inflow side is greater than a predetermined flow rate setting reference value in a state where the operating frequency of the pump 72 is reduced to the minimum frequency.

35 In the present embodiment, the valve opening control section 82 may adjust the degree of opening of only the large-diameter flow control valve 77B provided in the large-diameter water injection pipe 75B when the flow rate of the groundwater toward the well 2 on the water inflow side is greater than a

predetermined flow rate setting reference value in a state where the operating frequency of the pump 72 is reduced to the minimum frequency.

[0041]

5 An operation of the control device 80 of the present embodiment will be described.

The operation of the control device 80 corresponds to an embodiment of a control method.

The control device 80 performs each step illustrated in FIG. 4.

[0042]

10 First, when the load facility 100 is operated in a cooling mode or a heating mode, the pump operation control unit 81 operates the pump 72 to pump up the groundwater from the pump pipe 71 of the pump well 21 of the pair of wells 2 (ST01: step of operating the pump). Thus, the groundwater pumped up from the pump well 21 is sent to the heat exchanger 4 through the
15 piping 3. In the heat exchanger 4, the groundwater in the piping 3 is heat-exchanged with the medium on the load facility 100 side. The groundwater passed through the heat exchanger 4 is made to flow into the other water injection well 22 from the water injection pipe 75. At this time, on the water injection well 22 side, the ground thermal energy system 1 makes water flow
20 through all of the plurality of water injection pipes 75 (the small-diameter water injection pipe 75A and the large-diameter water injection pipe 75B).

In the initial stage of activation of the pump 72, the valve opening control section 82 may open only the small-diameter flow control valve 77A to make water flow into the water injection well 22 only from the small-diameter
25 water injection pipe 75A. Thereafter, the valve opening control section 82 may open the small-diameter flow control valve 77A to increase the water injection flow rate through the small-diameter water injection pipe 75A as the operating frequency of the pump 72 increases. The valve opening control section 82 may further open the large-diameter flow control valve 77B in a state where the
30 operating frequency of the pump 72 is increased to some extent, and may make water flow into the water injection well 22 through the small-diameter water injection pipe 75A and the large-diameter water injection pipe 75B. Thereafter, the valve opening control section 82 may further open the large-diameter flow control valve 77B to increase the water injection flow rate through the large-
35 diameter water injection pipe 75B as the operating frequency of the pump 72 increases.

[0043]

When the load facility 100 is operated in the cooling mode or the heating mode, the pump operation control unit 81 adjusts the inverter-controlled operating frequency of the pump 72 for feeding the groundwater from the pump well 21 to the water injection well 22 in accordance with the preset temperature of the groundwater made to flow into the water injection well 22 via the heat exchanger 4 (ST02: step of adjusting the operating frequency of the pump). Thus, the water injection flow rate from the pump well 21 to the water injection well 22 by the pump 72 is adjusted.

[0044]

Following the execution of ST02, the pump operation control unit 81 determines whether the inverter-controlled operating frequency of the pump 72 has decreased to the minimum frequency (ST03: step of determining whether the operating frequency of the pump has decreased to the minimum frequency).

[0045]

As a result of the determination in ST03, if the inverter-controlled operating frequency of the pump 72 has not decreased to the minimum frequency, the process returns to ST02, and the pump operation control unit 81 continues adjusting the water injection flow rate from the pump well 21 to the water injection well 22 by the pump 72.

As a result of the determination in ST03, in a case where the inverter-controlled operating frequency of the pump 72 has decreased to the minimum frequency, the valve opening control section 82 adjusts the degree of opening of the large-diameter flow control valve 77B in a closing direction in accordance with the preset temperature of the groundwater made to flow into the water injection well 22 (ST04: step of adjusting the degree of opening of the large-diameter flow control valve). The valve opening control section 82 adjusts the degree of opening of the large-diameter flow control valve 77B to adjust the water injection flow rate into the water injection well 22. At this time, the pump operation control unit 81 maintains the operating frequency of the inverter control of the pump 72 at the minimum frequency. That is, by closing the large-diameter flow control valve 77B in a state where the inverter-controlled operating frequency of the pump 72 is the minimum frequency, the control device 80 further decreases the flow rate of the groundwater made to flow into the water injection well 22.

[0046]

Following the execution of ST04, the valve opening control section 82 determines whether the degree of opening of the large-diameter flow control

valve 77B is fully closed (ST05: step of determining whether the degree of opening of the large-diameter flow control valve is fully closed).

If the result of the determination in ST05 indicates that the degree of opening of the large-diameter flow control valve 77B is not fully closed, the process returns to ST04, and the valve opening control section 82 continues the process.

If the result of the determination of the ST05 indicates that the degree of opening of the large-diameter flow control valve 77B is fully closed, the flow rate of the groundwater made to flow into the well 2 is smaller than the flow rate setting reference value, so that the inflow toward the water injection well 22 is performed only through the small-diameter water injection pipe 75A. In this case, the valve opening control section 82 adjusts the degree of opening of the small-diameter flow control valve 77A in the closing direction in accordance with the preset temperature of the groundwater made to flow into the water injection well 22 (ST06: step of adjusting the degree of opening of the small-diameter flow control valve). The valve opening control section 82 adjusts the degree of opening of the small-diameter flow control valve 77A to adjust the water injection flow rate into the water injection well 22. Also at this time, the pump operation control unit 81 maintains the inverter-controlled operating frequency of the pump 72 at the minimum frequency. In other words, in a state where the inverter-controlled operating frequency of the pump 72 is the minimum frequency, the valve opening control section 82 closes the small-diameter flow control valve 77A while making water flow into the water injection well 22 only through the small-diameter water injection pipe 75A. Thus, the control device 80 can further reduce the flow rate of the groundwater made to flow into the water injection well 22.

[0047]

When the operation of the ground thermal energy system 1 is stopped, the pump operation control unit 81 stops the operation of the pump 72 after the valve opening control section 82 fully closes the small-diameter flow control valve 77A and the large-diameter flow control valve 77B. Thus, the ground thermal energy system 1 can stop the operation while maintaining the groundwater in the piping 3 in a pressurized state. By maintaining the groundwater in the piping 3 in a pressurized state (positive pressure), entry of foreign substances and oxygen into the piping 3 from the outside can be suppressed, and corrosion and the like of the piping 3 can be suppressed.

[0048]

Actions and Effects

According to the present embodiment, the ground thermal energy system 1 can send the groundwater pumped up from the well 2 by the pump 72 to the heat exchanger 4 through the pump pipe 71 and the piping 3. On the other hand, in the ground thermal energy system 1, when the groundwater passed through the heat exchanger 4 is made to flow into the well 2 through the piping 3 and the water injection pipe 75, the flow rate of the groundwater made to flow into the well 2 can be adjusted by adjusting the degree of opening of the flow control valve 77 provided in the water injection pipe 75. At this time, a plurality of the water injection pipes 75 are provided. Each of the plurality of water injection pipes 75 includes the flow control valve 77. Therefore, by adjusting the degree of opening of the flow control valve 77 in each of the plurality of water injection pipes 75, the ground thermal energy system 1 can more precisely adjust the flow rate of the groundwater made to flow into the well 2. For example, the ground thermal energy system 1 can also adjust the flow rate of the groundwater made to flow into the well 2 by opening the flow control valves 77 of some of the plurality of water injection pipes 75 and closing the flow control valves 77 of the other water injection pipes 75. Therefore, the ground thermal energy system 1 can easily adjust the flow rate.

Further, since the pump 72 is provided in the pump pipe 71 and the flow control valve 77 is provided in the water injection pipe 75, when trouble occurs in pumping or water inflow due to some issue, the user can easily identify the cause of the issue, i.e., whether the issue occurred in the pump pipe 71 or in the water injection pipe 75. In addition, since the user can replace the pump 72 alone and the flow control valve 77 alone, maintenance can be performed easily and at low cost.

[0049]

In addition, according to an example of the present embodiment, the piping 3 includes the pump pipe 71 and the plurality of water injection pipes 75 at the end portions on the side extending toward each well 2 of the pair of wells 2.

Since the plurality of water injection pipes 75 are provided in each of the end portions 3a and 3b on the sides extending toward each of the wells 2, the ground thermal energy system 1 can easily adjust the flow rate of the groundwater made to flow into each of the wells 2.

[0050]

In addition, according to an example of the present embodiment, when the operation of the ground thermal energy system 1 is stopped, the ground thermal energy system 1 can stop the operation while maintaining the

groundwater in the piping 3 in a pressurized state by stopping the operation of the pump 72 after fully closing the flow control valve 77. Since the ground thermal energy system 1 can maintain the groundwater in the piping 3 in a pressurized state (positive pressure), entry of foreign substances or oxygen into the piping 3 from the outside and corrosion or the like of the piping 3 can be suppressed.

[0051]

In addition, according to an example of the present embodiment, the ground thermal energy system 1 further includes the valve opening control section 82 that adjusts the degree of opening of the flow control valve 77 in accordance with the water injection flow rate toward the well 2.

Thus, the ground thermal energy system 1 can easily adjust the inflow temperature by adjusting the degree of opening of the flow control valve 77 by the valve opening control section 82 in accordance with the water injection flow rate toward the well 2.

[0052]

In addition, according to an example of the present embodiment, when the flow rate of the groundwater made to flow into the well 2 is smaller than the flow rate setting reference value, the valve opening control section 82 opens only the flow control valve 77 provided in some of the plurality of water injection pipes 75.

Since the plurality of water injection pipes 75 are provided, the pipe diameter of each water injection pipe 75 and the bore of the flow control valve 77 provided in each water injection pipe 75 can be reduced. Therefore, when the flow rate of the groundwater made to flow into the well 2 is small, the ground thermal energy system 1 can more precisely adjust the flow rate of the groundwater in the small flow rate region by opening only the flow control valves 77 of some of the water injection pipes 75 among the plurality of water injection pipes 75.

[0053]

In addition, according to an example of the present embodiment, the plurality of water injection pipes 75 have different pipe diameters.

Thus, for example, when the flow rate of the groundwater made to flow into the well 2 is small, the ground thermal energy system 1 can adjust the flow rate of the groundwater made to flow into the well 2 by only the small-diameter flow control valve 77A of the small-diameter water injection pipe 75A. Thus, the ground thermal energy system 1 can more precisely adjust the flow rate of the groundwater in the small flow rate region.

[0054]

Further, according to an example of the present embodiment, the control device 80 includes the pump operation control unit 81 and the valve opening control section 82.

5 Thus, by the control device 80 operating the pump 72 by the pump operation control unit 81, the groundwater can be pumped up from the pump pipe 71 provided in one well 2 of the pair of wells 2. The groundwater pumped up from the pump pipe 71 is made to flow into the other well 2 from the plurality of water injection pipes 75 through the heat exchanger 4. By adjusting
10 the degree of opening of the flow control valve 77 provided in each of the plurality of water injection pipes 75 by the valve opening control section 82, the control device 80 can easily adjust the flow rate of the groundwater made to flow into the other well 2.

[0055]

15 Modification Example

In the above-described embodiment, a program for realizing various functions of the control device 80 is recorded in a computer-readable recording medium, and the program recorded in the recording medium is read and executed by a computer system such as a microcomputer to perform various
20 processes. Here, the steps of the various processes of the CPU of the computer system are stored in a computer-readable recording medium in the form of a program, and the various steps are performed by the computer reading and executing the program. The computer readable recording medium refers to a magnetic disk, a magneto-optical disk, a CD-ROM, a DVD-ROM, a
25 semiconductor memory, or the like. Also, this computer program may be distributed to the computer on a communication circuit, and the computer that receives this distribution may execute the program.

[0056]

In the above-described embodiment, an example of a hardware
30 configuration of a computer 190 that executes a program for realizing various functions of the control device 80 will be described.

[0057]

As illustrated in FIG. 5, the computer 190 included in the control device 80 includes a processor 195, a memory 196, a storage/reproduction device 197,
35 an input/output interface (hereinafter, referred to as “IO I/F”) 198, and a communication interface (hereinafter, referred to as “communication I/F”) 199.

[0058]

For example, the processor 195 may be a CPU.

For example, the memory 196 may be a medium such as a random-access memory (hereinafter, referred to as a “RAM”) that temporarily stores data or the like used in a program executed by the control device 80.

For example, the storage/reproduction device 197 may be a device for
5 storing data or the like in an external medium such as a CD-ROM, a DVD, or a flash memory, or reproducing data or the like in an external medium.

For example, the IO I/F 198 may be an interface for inputting/outputting information and the like between the control device 80 and another device.

For example, the communication I/F 199 may be an interface that
10 performs communication between the control device 80 and another device via a communication line such as the Internet or a dedicated communication line.
[0059]

Other Embodiments

While certain embodiments of the present disclosure have been
15 described, this embodiment has been presented by way of example only, and is not intended to limit the scope of the present disclosure. This embodiment can be implemented in various other forms, and various omissions, substitutions, and changes can be made without departing from the gist of the present disclosure. Embodiments and modification examples thereof are included in the
20 scope and spirit of the present disclosure, and are also included in the scope of the present disclosure and equivalents thereof.

[0060]

Notes

The ground thermal energy system 1, the control device 80, the control
25 method, and the program described in the embodiment are understood as follows, for example.

[0061]

(1) A ground thermal energy system 1 according to a first aspect
includes a well 2, piping 3 including an end portion on a side extending toward
30 the well 2, and a heat exchanger 4 provided to the piping 3, wherein the piping 3 includes, at the end portion, a pump pipe 71 connected to a pump 72 configured to pump groundwater in the well 2, and a plurality of water injection pipes 75 each including a flow control valve 77.

[0062]

35 The ground thermal energy system 1 can send the groundwater pumped up from the well 2 by the pump 72 to the heat exchanger 4 through the pump pipe 71 and the piping 3. On the other hand, in the ground thermal energy system 1, when the groundwater passed through the heat exchanger 4 is made

to flow into the well 2 through the piping 3 and the water injection pipe 75, the flow rate of the groundwater made to flow into the well 2 can be adjusted by adjusting the degree of opening of the flow control valve 77 provided in the water injection pipe 75. At this time, a plurality of the water injection pipes 75 are provided. Each of the plurality of water injection pipes 75 includes the flow control valve 77. Therefore, by adjusting the degree of opening of the flow control valve 77 in each of the plurality of water injection pipes 75, the ground thermal energy system 1 can more precisely adjust the flow rate of the groundwater made to flow into the well 2. For example, the ground thermal energy system 1 can also adjust the flow rate of the groundwater made to flow into the well 2 by opening the flow control valves 77 of some of the plurality of water injection pipes 75 and closing the flow control valves 77 of the other water injection pipes 75. Therefore, the ground thermal energy system 1 can easily adjust the flow rate.

[0063]

(2) The ground thermal energy system 1 according to a second aspect is the ground thermal energy system 1 according to (1), wherein a pair of the wells 2 may be provided, and the piping 3 may include the water pump pipe 71 and a plurality of the water injection pipes 75 at end portions 3a and 3b on a side extending toward each of the pair of wells 2.

[0064]

Since the plurality of water injection pipes 75 are provided in the ends 3a and 3b of the piping 3 on the side extending toward each of the pair of wells 2, the ground thermal energy system 1 can easily adjust the flow rate of the groundwater made to flow into each of the pair of wells 2.

[0065]

(3) The ground thermal energy system 1 according to a third aspect may be the ground thermal energy system 1 according to (1) or (2), wherein the flow control valve 77 may be capable of maintaining the pressure in the piping 3 in a pressurized state.

[0066]

Thus, when the operation of the ground thermal energy system 1 is stopped, the ground thermal energy system 1 can stop the operation while maintaining the groundwater in the piping 3 in a pressurized state by stopping the operation of the pump 72 after fully closing the flow control valve 77. Since the ground thermal energy system 1 can maintain the groundwater in the piping 3 in a pressurized state (positive pressure), entry of foreign substances

or oxygen into the piping 3 from the outside and corrosion or the like of the piping 3 can be suppressed.

[0067]

5 (4) The ground thermal energy system 1 according to a fourth aspect may be the ground thermal energy system 1 according to any one of (1) to (3), further including a valve opening control section 82 that adjusts a degree of opening of the flow control valve 77 in accordance with a water injection flow rate toward the well 2.

[0068]

10 Thus, the ground thermal energy system 1 can easily adjust the inflow temperature by adjusting the degree of opening of the flow control valve 77 by the valve opening control section 82 in accordance with the water injection flow rate toward the well 2.

[0069]

15 (5) The ground thermal energy system 1 according to a fifth aspect is the ground thermal energy system 1 according to any one of (1) to (4), wherein the valve opening control section 82 may open only the flow control valve 77 provided in some of the plurality of water injection pipes 75 when the flow rate of the groundwater made to flow into the well 2 is smaller than a flow rate
20 setting reference value.

[0070]

Since the plurality of water injection pipes 75 are provided, the pipe diameter of each water injection pipe 75 and the bore of the flow control valve 77 provided in each water injection pipe 75 can be reduced. Therefore, when
25 the flow rate of the groundwater made to flow into the well 2 is small, the ground thermal energy system 1 can more precisely adjust the flow rate of the groundwater in the small flow rate region by opening only the flow control valves 77 of some of the water injection pipes 75 among the plurality of water injection pipes 75.

30 [0071]

(6) The ground thermal energy system 1 according to a sixth aspect is the ground thermal energy system 1 according to any one of (1) to (5), wherein the plurality of water injection pipes 75 may have pipe diameters different from each other.

35 [0072]

Thus, for example, when the flow rate of the groundwater made to flow into the well 2 is small, the ground thermal energy system 1 can adjust the flow rate of the groundwater made to flow into the well 2 only by the flow control

valve 77 of the water injection pipe 75 having a small diameter. Thus, the ground thermal energy system 1 can more precisely adjust the flow rate of the groundwater in the small flow rate region.

[0073]

- 5 (7) A control device 80 according to a seventh aspect includes a pump operation control unit 81 that operates a pump 72 provided in a pump pipe 71 provided in one well 2 of a pair of wells 2 to pump up groundwater from the pump pipe 71, and a valve opening control section 82 that adjusts a degree of opening of a flow control valve 77 provided in each of a plurality of water
10 injection pipes 75 such that the groundwater pumped up from the pump pipe 71 passes through a heat exchanger 4 and is made to flow into the other of the pair of wells 2 at a predetermined flow rate through the plurality of water injection pipes 75 provided in the other of the pair of wells 2.

[0074]

- 15 Thus, by the control device 80 operating the pump 72 by the pump operation control unit 81, the groundwater can be pumped up from the pump pipe 71 provided in one well 2 of the pair of wells 2. The groundwater pumped up from the pump pipe 71 is made to flow into the other well 2 from the plurality of water injection pipes 75 through the heat exchanger 4. By adjusting
20 the degree of opening of the flow control valve 77 provided in each of the plurality of water injection pipes 75 by the valve opening control section 82, the control device 80 can easily adjust the flow rate of the groundwater made to flow into the other well 2.

[0075]

- 25 (8) A control method according to an eighth aspect includes operating a pump 72 provided in a pump pipe 71 provided in one well 2 of a pair of wells 2 to pump up groundwater from the pump pipe 71, and adjusting a degree of opening of a flow control valve 77 provided in each of a plurality of water injection pipes 75 such that the groundwater pumped up from the pump pipe 71
30 passes through a heat exchanger 4 and is made to flow into the other of the pair of wells 2 at a predetermined flow rate through the plurality of water injection pipes 75 provided in the other of the pair of wells 2.

[0076]

- 35 Thus, by the control method operating the pump 72, the groundwater can be pumped up from the pump pipe 71 provided in one well 2 of the pair of wells 2. The groundwater pumped up from the pump pipe 71 is made to flow into the other well 2 from the plurality of water injection pipes 75 through the heat exchanger 4. By adjusting the degree of opening of the flow control valve

77 provided in each of the plurality of water injection pipes 75, the control method can easily adjust the flow rate of the groundwater made to flow into the other well 2.

[0077]

- 5 (9) A program according to a ninth aspect causes a computer 190 to execute a method of operating a pump 72 provided in a pump pipe 71 provided in one well 2 of a pair of wells 2 to pump up groundwater from the pump pipe 71, and adjusting a degree of opening of a flow control valve 77 provided in each of a plurality of water injection pipes 75 such that the groundwater
- 10 pumped up from the pump pipe 71 passes through a heat exchanger 4 and is made to flow into the other of the pair of wells 2 at a predetermined flow rate through the plurality of water injection pipes 75 provided in the other of the pair of wells 2.

[0078]

- 15 Thus, by the computer 190 operating the pump 72, the groundwater can be pumped up from the pump pipe 71 provided in one well 2 of the pair of wells 2. The groundwater pumped up from the pump pipe 71 is made to flow into the other well 2 from the plurality of water injection pipes 75 through the heat exchanger 4. By adjusting the degree of opening of the flow control valve
- 20 77 provided in each of the plurality of water injection pipes 75, the flow rate of the groundwater made to flow into the other well 2 can be easily adjusted.

Reference Signs List

[0079]

- 25 1 Ground thermal energy system
2 Well
2A First well
2B Second well
2a Casing
30 2b Strainer
2c Opening
3 Piping
3a End portion
3b End portion
35 4 Heat exchanger
7 Flow control system
21 Pump well
22 Water injection well

- 35a to 35d Check valve
- 71 Pump pipe
- 72 Pump
- 73 Check valve
- 5 74 Pump controller
- 75 Water injection pipe
- 75A Small-diameter water injection pipe
- 75B Large-diameter water injection pipe
- 77 Flow control valve
- 10 77A Small-diameter flow control valve
- 77B Large-diameter flow control valve
- 80 Control device
- 81 Pump operation control unit
- 82 Valve opening control section
- 15 100 Load facility
- 190 Computer
- 195 Processor
- 196 Memory
- 197 Storage/reproduction device
- 20 198 IO I/F
- 199 Communication I/F
- HOL Excavated hole
- LY Aquifer
- OG Ground
- 25 ST01 Step of operating the pump
- ST02 Step of adjusting the operating frequency of the pump
- ST03 Step of determining whether the operating frequency of the pump has decreased to the minimum frequency
- ST04 Step of adjusting the degree of opening of the large-diameter flow control
- 30 valve
- ST05 Step of determining whether the degree of opening of the large-diameter flow control valve is fully closed
- ST06 Step of adjusting the degree of opening of the small-diameter flow control valve

Claims

[Claim 1]

A ground thermal energy system comprising:
a well;
piping including an end portion on a side extending toward the well; and
a heat exchanger provided to the piping, wherein
the piping includes, at the end portion, a pump pipe connected to a pump configured to pump groundwater in the well, and a plurality of water injection pipes each including a flow control valve.

[Claim 2]

The ground thermal energy system according to claim 1, wherein
the well comprises a pair of wells,
the piping includes, at the end portion on a side extending toward each of the pair of wells, the pump pipe and the plurality of water injection pipes.

[Claim 3]

The ground thermal energy system according to claim 1 or 2, wherein
the flow control valve is capable of maintaining a pressure in the piping in a pressurized state.

[Claim 4]

The ground thermal energy system according to any one of claims 1 to 3, further comprising a valve opening control section configured to adjust a degree of opening of the flow control valve in accordance with a water injection flow rate toward the well.

[Claim 5]

The ground thermal energy system according to claim 4, wherein
the valve opening control section opens only the flow control valve provided in some of the plurality of water injection pipes when a flow rate of the groundwater made to flow into the well is smaller than a flow rate setting reference value.

[Claim 6]

The ground thermal energy system according to any one of claims 1 to 5, wherein

pipe diameters of the plurality of water injection pipes are different from each other.

[Claim 7]

A control device comprising:

a pump operation control unit configured to operate a pump provided in a pump pipe provided in one well of a pair of wells to pump up groundwater from the pump pipe; and

a valve opening control section configured to adjust a degree of opening of a flow control valve provided in each of a plurality of water injection pipes such that the groundwater pumped up from the pump pipe passes through a heat exchanger and is made to flow into the other of the pair of wells at a predetermined flow rate through the plurality of water injection pipes provided in the other of the pair of wells.

[Claim 8]

A control method comprising:

operating a pump provided in a pump pipe provided in one well of a pair of wells to pump up groundwater from the pump pipe; and

adjusting a degree of opening of a flow control valve provided in each of a plurality of water injection pipes such that the groundwater pumped up from the pump pipe passes through a heat exchanger and is made to flow into the other of the pair of wells at a predetermined flow rate through the plurality of water injection pipes provided in the other of the pair of wells.

[Claim 9]

A program for causing a computer to execute a method of:

operating a pump provided in a pump pipe provided in one well of a pair of wells to pump up groundwater from the pump pipe; and

adjusting a degree of opening of a flow control valve provided in each of a plurality of water injection pipes such that the groundwater pumped up from the pump pipe passes through a heat exchanger and is made to flow into the other of the pair of wells at a predetermined flow rate through the plurality of water injection pipes provided in the other of the pair of wells.