

Description

Title of Invention

GEOTHERMAL HEAT UTILIZATION SYSTEM, CONTROL DEVICE,
CONTROL METHOD, AND PROGRAM

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Technical Field

[0001]

The present disclosure relates to a geothermal heat utilization system, a control device, a control method, and a program.

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This application claims priority based on Japanese Patent Application No. 2021-078700 filed in Japan on May 6, 2021, the contents of which are incorporated herein.

Background Art

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[0002]

In recent years, geothermal heat utilization systems that utilize groundwater as a heat source or a cold source have been proposed.

[0003]

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For example, Patent Document 1 proposes a geothermal heat utilization system including a pumping well and a water injection well, in which groundwater is pumped up from the pumping well by a pump and heat exchange is performed with a load side by a heat exchanger. Such a geothermal heat utilization system stores heat by injecting groundwater having passed through a heat exchanger into a water injection well.

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Citation List

Patent Literature

[0004]

Patent Document 1: JP 2018-173256 A

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Summary of Invention

Technical Problem

[0005]

In the geothermal heat utilization system disclosed in Patent Document 1, in order to keep constant a water injection temperature of water injected into the water injection well, a flow rate of water injection at the time of low load needs to be reduced.

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However, when inverter control is performed in the pump disclosed in Patent Document 1, it may be difficult to control the water injection temperature at the time of low load at which the flow rate of water injection is smaller than the flow rate of water injection at the minimum frequency of the inverter control.

[0006]

The present disclosure has been made to solve the problem described above, and an object of the present disclosure is to provide a geothermal heat utilization system, a control device, a control method, and a program that can easily control a water injection temperature at the time of low load.

Solution to Problem

[0007]

In order to solve the above-described problem, a geothermal heat utilization system according to the present disclosure includes: a pumping well; a water injection well; piping extending from the pumping well to the water injection well; a pump configured to feed groundwater from the pumping well to the water injection well via the piping; a heat exchanger provided at the piping; a control valve provided at the piping and configured to adjust a flow rate of the groundwater in the piping; and a control device configured to, when an operation frequency of inverter control of the pump reaches a minimum frequency, adjust a flow rate of the groundwater injected into the water injection well by controlling the control valve to reduce the flow rate in the piping.

[0008]

A control device according to the present disclosure includes: a pump operation control unit configured to adjust an operation frequency of inverter control of a pump according to a temperature of groundwater pumped up from a pumping well, passed through a heat exchanger, and injected into a water injection well, the pump being configured to feed the groundwater from the pumping well to the water injection well; and a control valve opening/closing control unit configured to adjust, when the operation frequency reaches a minimum frequency, an opening degree of a control valve according to a temperature of the groundwater injected into the water injection well, the control valve being provided at piping configured to feed the groundwater to the water injection well.

[0009]

A control method according to the present disclosure includes: adjusting an operation frequency of inverter control of a pump according to a temperature of groundwater pumped up from a pumping well, passed through a heat exchanger, and injected into a water injection well, the pump being configured to feed the groundwater from the pumping well to the water injection well; and adjusting, when the operation frequency reaches a minimum frequency, an opening degree of a control valve according to a temperature of the groundwater injected into the water injection well, the control valve being provided at piping configured to feed the groundwater to the water injection well.

[0010]

A program according to the present disclosure causes a computer to perform a method, the method including: adjusting an operation frequency of inverter control of a pump according to a temperature of groundwater pumped up from a pumping well, passed through a heat exchanger, and injected into a water injection well, the pump being configured to feed the groundwater from the pumping well to the water injection well; and adjusting, when the operation frequency reaches a minimum frequency, an opening degree of a control valve according to a temperature of the groundwater injected into the water injection well, the control valve being provided at piping configured to feed the groundwater to the water injection well.

Advantageous Effects of Invention

[0011]

According to the geothermal heat utilization system, the control device, the control method, and the program of the present disclosure, water injection temperature can be easily controlled at the time of low load.

Brief Description of Drawings

[0012]

FIG. 1 is a diagram illustrating a schematic configuration of a geothermal heat utilization system according to an embodiment of the present disclosure.

FIG. 2 is a diagram illustrating a schematic configuration of the geothermal heat utilization system and a load facility side according to the embodiment of the present disclosure.

FIG. 3 is a system diagram of the geothermal heat utilization system according to the embodiment of the present disclosure.

FIG. 4 is a diagram illustrating flows of groundwater and a medium when a cooling mode operation is performed on the load facility side in the geothermal heat utilization system according to the embodiment of the present disclosure.

FIG. 5 is a diagram illustrating the flows of the groundwater and the medium when a heating mode operation is performed on the load facility side in the geothermal heat utilization system according to the embodiment of the present disclosure.

FIG. 6 is a block diagram of a control device according to the
10 embodiment of the present disclosure.

FIG. 7 is a diagram illustrating the flows of the groundwater and the medium when a cooling tower mode operation is performed on the load facility side in the geothermal heat utilization system according to the embodiment of the present disclosure.

FIG. 8 is a diagram illustrating the flows of the groundwater and the medium when a refrigerator mode operation is performed on the load facility side in the geothermal heat utilization system according to the embodiment of the present disclosure.

FIG. 9 is a flowchart illustrating a procedure of a control method
20 according to the embodiment of the present disclosure.

FIG. 10 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.

25 Description of Embodiments

[0013]

Hereinafter, embodiments according to 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 the
30 common description will be omitted.

[0014]

Embodiment

An embodiment of a geothermal heat utilization system according to the present disclosure will be described with reference to FIGS. 1 to 9.

Configuration of Geothermal Heat Utilization System

As illustrated in FIGS. 1 to 3, a geothermal heat utilization system 1 mainly includes a plurality of wells 2, piping 3, a heat exchanger 4, a temperature adjustment system 7 (see FIG. 3), and a pump 31.

[0015]

5 Configuration of Wells

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

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

10 In the geothermal heat utilization system 1, groundwater is pumped up from one of the first well 2A and the second well 2B, heat exchange is performed by the heat exchanger 4, and then the groundwater after the heat exchange is injected into the other of the first well 2A and the second well 2B. In other words, the geothermal heat utilization system 1 has two operation
15 modes: for pumping up groundwater from the first well 2A and injecting the groundwater into the second well 2B; and for pumping up groundwater from the second well 2B and injecting the groundwater into the first well 2A.

In the following description, of the first well 2A and the second well 2B, the one from which groundwater is pumped up is referred to as a pumping well
20 21; and of the first well 2A and the second well 2B, the one into which the groundwater is injected is referred to as a water injection well 22. That is, each of the first well 2A and the second well 2B may serve as the pumping well 21 or may serve as the water injection well 22.

However, in the following description, in order to simplify the
25 description, a case where the first well 2A serves as the pumping well 21, the second well 2B serves as the water injection well 22, and heat exchange is performed by the heat exchanger 4 will be mainly described.

[0016]

Each of the wells 2 is provided with a casing 2a buried in a borehole
30 HOL bored toward underground from the ground OG to the aquifer LY.

The casing 2a has a tubular shape extending in a vertical direction.

[0017]

Each of the wells 2 includes an opening 2c at an upper part thereof.

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

[0018]

The casing 2a includes, for example, a strainer 2b including a plurality of slits.

The strainer 2b enables 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.

For example, as illustrated in FIG. 3, the opening at the upper part of the casing 2a may be provided with a well lid 6 that closes the opening.

[0019]

Configuration of Piping and Pump

As illustrated in FIGS. 1 and 3, the piping 3 extends into the wells 2.

For example, both ends of the piping 3 may be immersed in the respective groundwater of the pumping well 21 and the water injection well 22 so as to connect the pumping well 21 and the water injection well 22.

For example, one end of the piping 3 may be provided in the pumping well 21 and the other end of the piping 3 may be provided in the water injection well 22 so that the groundwater pumped up by the pump 31 can flow from the pumping well 21 toward the water injection well 22.

[0020]

The piping 3 is provided with the pump 31.

The pump 31 pumps up water from the well 2 into the piping 3.

For example, when the well 2 serves as the pumping well 21, the pump 31 pumps up water from the well 2 to the piping 3.

For example, the pump 31 may pump up the groundwater in the well 2 into the piping 3.

For example, the pump 31 may be provided at both ends of the piping 3 and immersed in the groundwater in each of the wells 2.

For example, the output of the pump 31 may be changed by inverter control.

[0021]

The piping 3 is provided with water injection valves 32.

The water injection valves 32 are provided at both end portions of the piping 3, respectively.

The water injection valves 32 may be disposed between the pumps 31 at both ends of the piping 3 and the heat exchanger 4.

For example, the water injection valve 32 may be immersed in the groundwater in each of the wells 2.

The water injection valve 32 injects the groundwater in the piping 3.

For example, when the well 2 serves as the water injection well 22, the water injection valve 32 injects the groundwater in the piping 3 into the well 2 (the water injection well 22).

When the pressure in the piping 3 becomes larger than a set pressure, the water injection valve 32 is opened and the groundwater in the piping 3 is injected into the water injection well 22.

[0022]

5 As illustrated in FIG. 3, the piping 3 includes check valves 35a to 35d between the heat exchanger 4 and the pumping well 21 and between the heat exchanger 4 and the water injection well 22.

The check valves 35a to 35d control the flow of the groundwater in the piping 3 such that the groundwater flows in the same direction with respect to
10 the heat exchanger 4 regardless of whether the groundwater is pumped up from the pumping well 21 or the groundwater is pumped up from the water injection well 22.

[0023]

For example, when the groundwater is pumped up from the first well
15 2A, the groundwater in the piping 3 is injected from the first well 2A to the second well 2B through the check valve 35a, the heat exchanger 4, and the check valve 35b in this order. At this time, the pressure in the piping 3 is higher on an upstream side (the first well 2A side) than on a downstream side of the heat exchanger 4, and thus water does not flow through neither the check valve
20 35c nor the check valve 35d.

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

[0024]

Configuration of Heat Exchanger

30 The heat exchanger 4 exchanges heat between the groundwater in the piping 3 and a medium on a load facility 100 side.

For example, the heat exchanger 4 performs heat exchange between the groundwater pumped up from the well 2 and flowing through the piping 3 and a medium on the load facility 100 side. The groundwater after the heat exchange
35 flows from the heat exchanger 4 through the piping 3 and is injected into the well 2.

For example, the heat exchanger 4 may be provided at the middle of the piping 3 on the ground OG.

[0025]

When the water having passed through the heat exchanger 4 is hot water, the geothermal heat utilization system 1 performs hot water heat storage by injecting the hot water into the well 2.

- 5 When the water having passed through the heat exchanger 4 is cold water, the geothermal heat utilization system 1 performs cold water heat storage by injecting the cold water into the well 2.

Here, “hot water” refers to water having a temperature higher than an initial underground temperature of groundwater in an aquifer, and “cold water”
10 refers to water having a temperature lower than the initial underground temperature of the groundwater in the aquifer.

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

[0026]

- 15 Configuration of Load Facility

As illustrated in FIG. 2, the load facility 100 uses the medium that has exchanged heat with the groundwater in the piping 3 in the heat exchanger 4.

The load facility 100 is, for example, an air conditioning system including a heat source device 110 and an air conditioner 120.

- 20 For example, the heat source device 110 may be a heat pump including a condenser, an evaporator, and a compressor.

The air conditioner 120 performs air conditioning of a space in which the air conditioner 120 is installed by exchanging heat with the medium supplied from the heat source device 110.

- 25 For example, the operation mode of the load facility 100 as an air conditioning system can be switched between a cooling mode and a heating mode.

- The load facility 100 includes a piping system 101 for forming a flow of a medium according to each operation mode between the heat exchanger 4, the
30 heat source device 110, and the air conditioner 120. The piping system 101 is provided with an opening/closing valve or the like (not illustrated) as appropriate so that the medium is circulated through a predetermined route between the heat exchanger 4, the heat source device 110, and the air conditioner 120 according to each operation mode of the air conditioning
35 system.

[0027]

In the present embodiment, the load facility 100 may further include a cooling tower 130 and a second heat exchanger 140.

[0028]

The cooling tower 130 cools cooling water by vaporization heat generated when the cooling water is vaporized by being brought into contact with the atmosphere. The cooling tower 130 circulates the cooling water
5 between the cooling tower 130 and the second heat exchanger 140.

The second heat exchanger 140 performs heat exchange between a medium in the piping system 101 on the air conditioning system side and the cooling water on the cooling tower 130 side.

The second heat exchanger 140 cools the medium in the piping system
10 101 on the air conditioning system side by performing heat exchange with the cooling water cooled in the cooling tower 130.

The configuration and the application of the load facility 100 are not limited to those described above and can be changed as appropriate.

[0029]

As illustrated in FIG. 4, when cooling operation is performed on the
15 load facility 100 side and hot water heat storage is performed in the water injection well 22, the second well 2B serves as the pumping well 21 and the first well 2A serves as the water injection well 22. Groundwater is pumped up by the pump 31 of the second well 2B serving as the pumping well 21 and fed
20 into the heat exchanger 4. In the heat exchanger 4, heat exchange is performed between the groundwater in the piping 3 and the medium flowing through the piping system 101 on the load facility 100 side. On the load facility 100 side, the medium cooled by the heat exchange in the heat exchanger 4 is fed into the heat source device 110, and heat exchange is performed in the heat source
25 device 110. As a result, the air conditioner 120 connected to the heat source device 110 can perform indoor cooling. On the other hand, the medium heated by the heat exchange in the heat source device 110 is fed into the heat exchanger 4 again and circulated. In the heat exchanger 4, heat exchange is performed between the heated medium and the groundwater flowing through
30 the piping 3, whereby the groundwater is heated. The geothermal heat utilization system 1 performs hot water heat storage by injecting the heated groundwater into the water injection well 22 through the piping 3.

[0030]

As illustrated in FIG. 5, when heating operation is performed on the load
35 facility 100 side and cold water heat storage is performed in the water injection well 22, the first well 2A serves as the pumping well 21 and the second well 2B serves as the water injection well 22. Groundwater is pumped up by the pump 31 of the first well 2A serving as the pumping well 21 and fed into the heat

exchanger 4. In the heat exchanger 4, heat exchange is performed between the groundwater in the piping 3 and the medium flowing through the piping system 101 on the load facility 100 side. On the load facility 100 side, the medium heated by the heat exchange in the heat exchanger 4 is fed into the heat source device 110, and heat exchange is performed in the heat source device 110. As a result, the air conditioner 120 connected to the heat source device 110 can perform indoor heating. On the other hand, the medium cooled by the heat exchange in the heat source device 110 is fed into the heat exchanger 4 again and circulated. In the heat exchanger 4, heat exchange is performed between the cooled medium and the groundwater flowing through the piping 3, whereby the groundwater is cooled. The geothermal heat utilization system 1 performs cold water heat storage by injecting the cooled groundwater into the water injection well 22 through the piping 3.

[0031]

15 Configuration of Temperature Adjustment System

As illustrated in FIG. 3, the temperature adjustment system 7 includes a pump controller 71, a control valve 72, and a control device 80. The temperature adjustment system 7 adjusts a water injection temperature of the water injection well 22 by adjusting the flow rate of the groundwater injected into the water injection well 22.

[0032]

The pump controller 71 controls the operation of the pump 31.

For example, the pump controller 71 may be provided in association with the pump 31 of each of the wells 2.

25 For example, the pump controller 71 includes an inverter circuit (not illustrated) and performs inverter control of the pump 31.

The pump controller 71 adjusts a rotation speed of the pump 31 by changing an operation frequency of inverter control by the inverter circuit under the control of the control device 80 to be described below.

30 The pump controller 71 adjusts the rotation speed of the pump 31 by changing the operation frequency of the inverter control by the inverter circuit, and adjusts a flow rate of the groundwater passed through the heat exchanger 4 and injected into the water injection well 22 from the piping 3.

Hereinafter, an operation frequency of inverter control of the pump 31 is also referred to as the “operation frequency of the pump 31”.

[0033]

The control valve 72 is provided at the piping 3.

For example, the control valve 72 may be provided between each of the wells 2 and the heat exchanger 4.

For example, in the present embodiment, the control valve 72 may be provided on the side of the water injection well 22 of the heat exchanger 4.

5 The control valve 72 can adjust the flow rate of the groundwater in the piping 3.

The control valve 72 adjusts the flow rate of the groundwater in the piping 3 by opening and closing a flow path in the piping 3.

10 The control valve 72 adjusts the opening degree thereof to control the flow rate of the groundwater in the piping 3.

The control valve 72 adjusts the flow rate of the groundwater in the piping 3 under the control of the control device 80.

The control valve 72 adjusts the opening degree thereof when the operation frequency of the pump 31 is decreased to a minimum frequency.

15 For example, the minimum frequency depends on the type of pump and may vary by pump manufacturer.

[0034]

Configuration of Control Device

20 The control device 80 adjusts the flow rate of the groundwater injected into the water injection well 22.

The control device 80 adjusts the operation frequency of the pump 31 and the opening degree of the control valve 72 such that the water injection temperature of the groundwater injected into the water injection well 22 is kept constant.

25 In a region where the operation frequency of the pump 31 is equal to or higher than the minimum frequency, the control device 80 adjusts the flow rate of the groundwater injected into the water injection well 22 by adjusting only the operation frequency of the pump 31.

30 For example, the control device 80 may be controllably connected to each of the pump controllers 71.

For example, the control device 80 may be controllably connected to each of the control valves 72.

35 For example, when the operation frequency of the pump 31 is decreased to the minimum frequency, the control device 80 adjusts the flow rate of the groundwater injected into the water injection well 22 by adjusting the opening degree of the control valve 72.

When the operation frequency of the pump 31 is decreased to the minimum frequency, the control device 80 reduces the flow rate of the

groundwater injected into the water injection well 22 by narrowing (reducing) the opening degree of the control valve 72.

For example, in a state where the operation frequency of the pump 31 is decreased to the minimum frequency and the control device 80 adjusts the flow rate of the groundwater injected into the water injection well 22 by adjusting the opening degree of the control valve 72, the control device 80 may keep the operation frequency of the pump 31 at the minimum frequency.

When the opening degree of the control valve 72 is narrowed to a minimum opening degree set in advance, the control device 80 adjusts the flow rate of the groundwater injected from the piping 3 into the water injection well 22 by causing the heat exchanger 4 to exchange heat with the medium on the load facility 100 side cooled by the cooling tower 130.

[0035]

As illustrated in FIG. 6, the control device 80 includes a pump operation control unit 81, a control valve opening/closing control unit 82, and a load side flow path control unit 83.

[0036]

The pump operation control unit 81 adjusts the rotation speed of the pump 31 by changing the operation frequency of the inverter control by the inverter circuit of the pump controller 71.

The pump operation control unit 81 adjusts the operation frequency of the pump 31 that pumps up groundwater from the pumping well 21 according to the temperature of the groundwater injected into the water injection well 22.

The pump operation control unit 81 adjusts the flow rate of the groundwater injected from the piping 3 into the water injection well 22 by changing the operation frequency of the pump 31 based on a map or the like stored in advance.

For example, when cooling operation is performed on the load facility 100 side and hot water heat storage is performed in the water injection well 22, the pump operation control unit 81 controls the operation frequency of the pump 31 based on a difference between an actual water injection temperature of the groundwater injected from the piping 3 into the water injection well 22 and a set temperature.

For example, when heating operation is performed on the load facility 100 side and cold water heat storage is performed in the water injection well 22, the pump operation control unit 81 controls the operation frequency of the pump 31 based on the difference between the actual water injection temperature

of the groundwater injected from the piping 3 into the water injection well 22 and the set temperature.

5 The pump operation control unit 81 controls the pump controller 71 to adjust the operation frequency (output) of the pump 31 in accordance with a required water injection temperature based on a map or the like stored in advance.

10 The pump operation control unit 81 stores, for example, a lower limit value of the operation frequency at which the pump 31 can stably operate as the minimum frequency. The pump operation control unit 81 controls the pump controller 71 to adjust the operation of the pump 31 in a frequency region equal to or higher than the minimum frequency set in advance.

[0037]

The control valve opening/closing control unit 82 adjusts the flow rate of the groundwater in the piping 3 by opening and closing the control valve 72.

15 The control valve opening/closing control unit 82 adjusts the flow rate of the groundwater in the piping 3 by adjusting the opening degree of the control valve 72.

20 The control valve opening/closing control unit 82 adjusts the opening degree of the control valve 72 when the operation frequency of the pump 31 is decreased to the minimum frequency.

When the operation frequency of the pump 31 reaches the minimum frequency, the control valve opening/closing control unit 82 adjusts the opening degree of the control valve 72 according to the temperature of the groundwater injected into the water injection well 22.

25 [0038]

The load side flow path control unit 83 controls the flow of the medium in the load facility 100 by switching a valve or the like provided at the piping system 101 on the load facility 100 side.

30 The load side flow path control unit 83 controls the flow of the medium in the piping system 101 according to each operation mode such as a cooling mode and a heating mode.

35 When the opening degree of the control valve 72 reaches a minimum set opening degree set in advance and the water injection temperature does not reach the set temperature, the load side flow path control unit 83 switches the operation mode on the load facility 100 side to a cooling tower mode to be described below.

When the opening degree of the control valve 72 reaches the minimum set opening degree set in advance in a state where the operation frequency of

the pump 31 is decreased to the minimum frequency, the load side flow path control unit 83 switches the operation mode on the load facility 100 side to the cooling tower mode.

5 In the cooling tower mode, the groundwater that has exchanged heat with the medium cooled by the cooling water of the cooling tower 130 in the heat exchanger 4 is injected into the water injection well 22.

Further, the load side flow path control unit 83 may switch the operation mode on the load facility 100 side to a refrigerator mode to be described below. [0039]

10 As illustrated in FIG. 7, the cooling tower mode may be used to cool groundwater and perform cold water heat storage.

In the cooling tower mode, the load facility 100 feeds, to the second heat exchanger 140, the cooling water cooled by vaporization heat generated when the cooling water is vaporized by being brought into contact with the atmosphere in the cooling tower 130. In the second heat exchanger 140, heat exchange is performed between the cooling water and the medium in the piping system 101. That is, in the second heat exchanger 140, the medium in the piping system 101 is cooled by the cooling water cooled in the cooling tower 130. The cooled medium is fed to the heat exchanger 4 to exchange heat with the groundwater in the piping 3. As a result, the groundwater in the piping 3 is cooled and injected into the water injection well 22, whereby cold water heat storage is performed.

[0040]

25 In addition, as illustrated in FIG. 8, the refrigerator mode may be used to cool groundwater and perform cold water heat storage.

In the refrigerator mode, the load facility 100 uses the cooling tower 130 and the heat source device 110 as a refrigeration unit. In this case, the pump 31 of the first well 2A serving as the pumping well 21 pumps up groundwater and feeds the groundwater to the heat exchanger 4. The heat exchanger 4 performs heat exchange between the groundwater in the piping 3 and the medium flowing through the piping system 101 on the load facility 100 side to cool the groundwater. On the load facility 100 side, the medium heated by the heat exchange in the heat exchanger 4 is fed into the heat source device 110. The heat source device 110 connected to the cooling tower 130 via the second heat exchanger 140 cools the heated medium by heat exchange. The medium cooled by the heat exchange in the heat source device 110 is fed into the heat exchanger 4 again and circulated. In the heat exchanger 4, heat exchange is performed between the cooled medium and the groundwater flowing through

the piping 3, whereby the groundwater is cooled. The geothermal heat utilization system 1 performs cold water heat storage by injecting the cooled groundwater into the water injection well 22 through the piping 3.

[0041]

5 The operation of the control device 80 according to 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 the steps illustrated in FIG. 9.

10 [0042]

 First, when the load facility 100 is operating in the cooling mode or the heating mode, the pump operation control unit 81 adjusts the operation frequency of the inverter control of the pump 31 that feeds groundwater from the pumping well 21 to the water injection well 22 according to a set

15 temperature of the groundwater passed through the heat exchanger 4 and injected into the water injection well 22 (ST01: step of adjusting the operation frequency of the pump). As a result, a flow rate of water injection from the pumping well 21 to the water injection well 22 by the pump 31 is adjusted.

[0043]

20 Following the execution of ST01, the pump operation control unit 81 determines whether the operation frequency of the inverter control of the pump 31 has been decreased to the minimum frequency (ST02: step of determining whether the operation frequency of the pump has been decreased to the minimum frequency).

25 [0044]

 As a result of the determination in ST02, when the operation frequency of the inverter control of the pump 31 has not been decreased to the minimum frequency, the processing returns to ST01, and the pump operation control unit 81 continues to adjust the flow rate of water injection from the pumping well

30 21 to the water injection well 22 by the pump 31.

 As a result of the determination in ST02, when the operation frequency of the inverter control of the pump 31 has been decreased to the minimum frequency, the control valve opening/closing control unit 82 adjusts the opening degree of the control valve 72 to a closing direction according to the set

35 temperature of the groundwater injected into the water injection well 22 (ST03: step of adjusting the opening degree of the control valve). The control valve opening/closing control unit 82 adjusts the flow rate of water injection to the water injection well 22 by adjusting the opening degree of the control valve 72.

At this time, the operation frequency of the inverter control of the pump 31 is kept at the minimum frequency. That is, in a state where the operation frequency of the inverter control of the pump 31 is at the minimum frequency, the control device 80 further reduces the flow rate of the groundwater injected into the water injection well 22 by closing the control valve 72.

[0045]

Following the execution of ST03, the control valve opening/closing control unit 82 determines whether the opening degree of the control valve 72 is at a minimum set opening degree set in advance (ST04: step of determining whether the opening degree of the control valve is at the minimum set opening degree).

As a result of the determination in ST04, when the opening degree of the control valve 72 is not at the minimum set opening degree, the processing returns to ST03, and the control valve opening/closing control unit 82 continues the processing.

As a result of the determination in ST04, when the opening degree of the control valve 72 is at the minimum set opening degree, the load side flow path control unit 83 switches the operation mode on the load facility 100 side to the cooling tower mode (ST05: step of switching the operation mode on the load facility side to the cooling tower mode). In the cooling tower mode, the geothermal heat utilization system 1 injects the groundwater that has exchanged heat with the medium cooled by the cooling water of the cooling tower 130 in the heat exchanger 4 into the water injection well 22. As a result, the groundwater in the piping 3 is cooled and injected into the water injection well 22, whereby cold water heat storage is performed.

For example, when the cold water heat storage by the cooling tower mode cannot be performed due to a high atmospheric temperature, the control device 80 may switch to the refrigerator mode and cold water heat storage by the refrigerator mode may be performed.

[0046]

Actions and Effects

According to the present embodiment, the geothermal heat utilization system 1 feeds groundwater pumped up from the pumping well 21 by the pump 31 to the heat exchanger 4 through the piping 3. Geothermal heat is utilized by performing heat exchange between the groundwater and the medium on the load facility 100 side in the heat exchanger 4. The groundwater that has passed through the heat exchanger 4 is injected into the water injection well 22 through the piping 3. The pump 31 adjusts the flow rate of the groundwater fed

via the piping 3 by inverter control. When the operation frequency of the inverter control of the pump 31 reaches the minimum frequency set in advance, the geothermal heat utilization system 1 can inject groundwater into the water injection well 22 at a flow rate smaller than the flow rate at the minimum
5 frequency of the pump 31 by reducing the flow rate in the piping 3 by the control valve 72. Accordingly, the geothermal heat utilization system 1 can easily control the water injection temperature at the time of low load.

[0047]

According to an example of the present embodiment, the control valve
10 72 is provided on the side of the water injection well 22 of the heat exchanger 4.

Thus, the geothermal heat utilization system 1 can control a flow rate of water injection near the water injection well 22. Accordingly, the geothermal heat utilization system 1 can easily control the water injection temperature of
15 the water injection well 22.

[0048]

Further, according to an example of the present embodiment, when the control device 80 adjusts the flow rate of the groundwater in the piping 3 by throttling the control valve 72, the operation frequency of the inverter control
20 of the pump 31 is kept at the minimum frequency.

In this manner, in a state where the flow rate of the groundwater is adjusted by throttling the control valve 72, the geothermal heat utilization system 1 can efficiently perform flow rate adjustment with the control valve 72 by keeping the operation frequency of the inverter control of the pump 31 at the
25 minimum frequency.

[0049]

According to an example of the present embodiment, when the opening degree of the control valve 72 reaches the minimum set opening degree, the control device 80 performs heat exchange between the medium cooled by the cooling water of the cooling tower 130 and the groundwater in the piping 3 in
30 the heat exchanger 4 and injects the cooled groundwater into the water injection well 22.

When the opening degree of the control valve 72 reaches the minimum set opening degree, the flow rate of the groundwater injected into the water
35 injection well 22 cannot be further reduced. In such a case, the geothermal heat utilization system 1 can use the cooling tower 130 to further adjust the temperature of the groundwater injected into the water injection well 22. As a

result, the geothermal heat utilization system 1 can control the water injection temperature at the time of low load in a wider range.

[0050]

According to an example of the present embodiment, the control device
5 80 includes the pump operation control unit 81 and the control valve opening/closing control unit 82.

According to the control device 80 described above, the pump operation control unit 81 adjusts the operation frequency of the inverter control of the pump 31 according to the temperature of the groundwater injected into the
10 water injection well 22. By adjusting the flow rate of the groundwater injected into the water injection well 22, the control device 80 can adjust the temperature of the groundwater injected into the water injection well 22. When the operation frequency of the inverter control of the pump 31 reaches the minimum frequency set in advance, the control valve opening/closing control
15 unit 82 adjusts the opening degree of the control valve 72 to reduce the flow rate in the piping 3, whereby the groundwater can be injected into the water injection well 22 at a flow rate smaller than the flow rate at the minimum frequency of the pump 31. Accordingly, the control device 80 can easily control the water injection temperature at the time of low load.

20 [0051]

Modified Example

In the embodiment described above, a program for achieving various functions of the control device 80 is recorded in a computer readable recording medium, and a computer system such as a microcomputer is caused to read and
25 execute the program recorded in the recording medium to implement various processing. Here, steps of various processing of a CPU of the computer system are stored in a computer readable recording medium in the form of a program, and the various processing is implemented by a computer reading out and executing the program. The computer readable recording medium refers to a
30 magnetic disk, a magneto-optical disk, a CD-ROM, a DVD-ROM, a 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.

[0052]

35 An example of a hardware configuration of a computer 190 that executes a program for achieving various functions of the control device 80 in the above-described embodiment will be described.

[0053]

As illustrated in FIG. 10, the computer 190 included in the control device 80 includes a processor 195, a memory 196, a storage/playback device 197, an input output interface (hereinafter referred to as the “IO I/F”) 198, and a communication interface (hereinafter referred to as the “communication I/F”) 199.

[0054]

For example, the processor 195 may be a CPU.

For example, the memory 196 may be a medium such as a random access memory (RAM) that temporarily stores data and the like used by the program executed in the control device 80.

For example, the storage/playback device 197 may be a device for storing data and the like in an external medium such as a CD-ROM, a DVD, or a flash memory, for playing back data and the like from the external medium, and the like.

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

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

[0055]

Other Embodiments

Although the embodiment of the present disclosure has been described above, the embodiment has been presented as an example and is not intended to limit the scope of the present disclosure. The 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. The embodiment and modifications thereof are included in the scope and gist of the present disclosure and are also included in the scope of the present disclosure and equivalents thereof.

[0056]

Supplementary Notes

The geothermal heat utilization system 1, the control device 80, the control method, and the program described in the embodiment can be understood as follows, for example.

[0057]

(1) A geothermal heat utilization system 1 according to a first aspect includes: a pumping well 21; a water injection well 22; piping 3 extending from

the pumping well 21 to the water injection well 22; a pump 31 configured to feed groundwater from the pumping well 21 to the water injection well 22 via the piping 3; a heat exchanger 4 provided at the piping 3; a control valve 72 provided at the piping 3 and configured to adjust a flow rate of the groundwater in the piping 3; and a control device 80 configured to, when an operation frequency of inverter control of the pump 31 reaches a minimum frequency, adjust a flow rate of the groundwater injected into the water injection well 22 by controlling the control valve 72 to reduce the flow rate in the piping 3.

[0058]

The geothermal heat utilization system 1 feeds the groundwater pumped up from the pumping well 21 by the pump 31 to the heat exchanger 4 through the piping 3. Geothermal heat is utilized by performing heat exchange between the groundwater and the medium on the load facility 100 side in the heat exchanger 4. The groundwater that has passed through the heat exchanger 4 is injected into the water injection well 22 through the piping 3. The pump 31 adjusts the flow rate of the groundwater fed via the piping 3 by inverter control. When the operation frequency of the inverter control of the pump 31 reaches the minimum frequency set in advance, the geothermal heat utilization system 1 can inject groundwater into the water injection well 22 at a flow rate smaller than the flow rate at the minimum frequency of the pump 31 by reducing the flow rate in the piping 3 by the control valve 72. Accordingly, the geothermal heat utilization system 1 can easily control the water injection temperature at the time of low load.

[0059]

(2) A geothermal heat utilization system 1 according to a second aspect is the geothermal heat utilization system 1 of (1), wherein the control valve 72 may be provided on the side of the water injection well 22 of the heat exchanger 4.

[0060]

Thus, the geothermal heat utilization system 1 can control a flow rate of water injection near the water injection well 22. Accordingly, the geothermal heat utilization system 1 can easily control the water injection temperature of the water injection well 22.

[0061]

(3) A geothermal heat utilization system 1 according to a third aspect is the geothermal heat utilization system 1 of (1) or (2), wherein when the control device 80 adjusts the flow rate of the groundwater in the piping 3 by throttling

the control valve 72, the operation frequency may be kept at the minimum frequency.

[0062]

5 In this manner, in a state where the flow rate of the groundwater is adjusted by throttling the control valve 72, the geothermal heat utilization system 1 can efficiently perform flow rate adjustment with the control valve 72 by keeping the operation frequency of the inverter control of the pump 31 at the minimum frequency.

[0063]

10 (4) A geothermal heat utilization system 1 according to a fourth aspect is the geothermal heat utilization system 1 of any one of (1) to (3), further including a cooling tower 130 on a side of the load facility 100 that uses a medium, the medium being configured to exchange heat with the groundwater in the piping 3 in the heat exchanger 4, wherein when an opening degree of the
15 control valve 72 reaches a minimum set opening degree, the control device 80 may inject, into the water injection well 22, the groundwater that has exchanged heat with the medium cooled by the cooling tower 130 in the heat exchanger 4.

[0064]

20 When the opening degree of the control valve 72 reaches the minimum set opening degree, the flow rate of the groundwater injected into the water injection well 22 cannot be further reduced. In such a case, the geothermal heat utilization system 1 can use the cooling tower 130 to further adjust the temperature of the groundwater injected into the water injection well 22. As a
25 result, the geothermal heat utilization system 1 can control the water injection temperature at the time of low load in a wider range.

[0065]

(5) A control device 80 according to a fifth aspect includes: a pump operation control unit 81 configured to adjust an operation frequency of
30 inverter control of a pump 31 according to a temperature of groundwater pumped up from a pumping well 21, passed through a heat exchanger 4, and injected into a water injection well 22, the pump 31 being configured to feed the groundwater from the pumping well 21 to the water injection well 22; and a control valve opening/closing control unit 82 configured to adjust, when the
35 operation frequency reaches a minimum frequency, an opening degree of a control valve 72 according to the temperature of the groundwater injected into the water injection well 22, the control valve 72 being provided at piping 3 configured to feed the groundwater to the water injection well 22.

[0066]

According to the control device 80 described above, the pump operation control unit 81 adjusts the operation frequency of the inverter control of the pump 31 according to the temperature of the groundwater injected into the water injection well 22. By adjusting the flow rate of the groundwater injected into the water injection well 22, the control device 80 can adjust the temperature of the groundwater injected into the water injection well 22. When the operation frequency of the inverter control of the pump 31 reaches the minimum frequency set in advance, the control valve opening/closing control unit 82 adjusts the opening degree of the control valve 72 to reduce the flow rate in the piping 3, whereby the groundwater can be injected into the water injection well 22 at a flow rate smaller than the flow rate at the minimum frequency of the pump 31. Accordingly, the control device 80 can easily control the water injection temperature at the time of low load.

[0067]

(6) A control method according to a sixth aspect includes: adjusting an operation frequency of inverter control of a pump 31 according to a temperature of groundwater pumped up from a pumping well 21, passed through a heat exchanger 4, and injected into a water injection well 22, the pump 31 being configured to feed the groundwater from the pumping well 21 to the water injection well 22; and adjusting, when the operation frequency reaches a minimum frequency, an opening degree of a control valve 72 according to the temperature of the groundwater injected into the water injection well 22, the control valve 72 being provided at piping 3 configured to feed the groundwater to the water injection well 22.

[0068]

In the control method described above, the operation frequency of the inverter control of the pump 31 is adjusted according to the temperature of the groundwater injected into the water injection well 22. Thus, the temperature of the groundwater injected into the water injection well 22 can be adjusted by adjusting the flow rate of the groundwater. When the operation frequency of the inverter control of the pump 31 reaches the minimum frequency set in advance, the control method adjusts the opening degree of the control valve 72 to reduce the flow rate in the piping 3, whereby the groundwater can be injected into the water injection well 22 at a flow rate smaller than the flow rate at the minimum frequency of the pump 31. Accordingly, the control method can easily control the water injection temperature at the time of low load.

[0069]

(7) A program according to a seventh aspect causes a computer 190 to perform a method, the method including: adjusting an operation frequency of inverter control of a pump 31 according to a temperature of groundwater pumped up from a pumping well 21, passed through a heat exchanger 4, and injected into a water injection well 22, the pump 31 being configured to feed the groundwater from the pumping well 21 to the water injection well 22; and adjusting, when the operation frequency reaches a minimum frequency, an opening degree of a control valve 72 according to the temperature of the groundwater injected into the water injection well 22, the control valve 72 being provided at piping 3 configured to feed the groundwater to the water injection well 22.

[0070]

According to the program described above, the computer 190 adjusts the operation frequency of the inverter control of the pump 31 in accordance with the temperature of the groundwater injected into the water injection well 22. Thus, the temperature of the groundwater injected into the water injection well 22 can be adjusted by adjusting the flow rate of the groundwater. When the operation frequency of the inverter control of the pump 31 reaches the minimum frequency set in advance, the computer 190 adjusts the opening degree of the control valve 72 to reduce the flow rate in the piping 3, whereby the groundwater can be injected into the water injection well 22 at a flow rate smaller than the flow rate at the minimum frequency of the pump 31. Accordingly, the program can easily control the water injection temperature at the time of low load.

25

Industrial Applicability

[0071]

According to the present disclosure, it is possible to provide a geothermal heat utilization system, a control device, a control method, and a program that can easily control a water injection temperature at the time of low load.

30

Reference Signs List

[0072]

35 1 Geothermal heat utilization system

2 Well

2A First well

2B Second well

- 2a Casing
- 2b Strainer
- 2c Opening
- 3 Piping
- 5 4 Heat exchanger
- 6 Well lid
- 7 Temperature adjustment system
- 21 Pumping well
- 22 Water injection well
- 10 31 Pump
- 32 Water injection valve
- 35a to 35d Check valve
- 71 Pump controller
- 72 Control valve
- 15 80 Control device
- 81 Pump operation control unit
- 82 Control valve opening/closing control unit
- 83 Load side flow path control unit
- 100 Load facility
- 20 101 Piping system
- 110 Heat source device
- 120 Air conditioner
- 130 Cooling tower
- 140 Second heat exchanger
- 25 190 Computer
- 195 Processor
- 196 Memory
- 197 Storage/playback device
- 198 IO I/F
- 30 199 Communication I/F
- HOL Borehole
- LY Aquifer
- OG Ground
- ST01 Step of adjusting the operation frequency of the pump
- 35 ST02 Step of determining whether the operation frequency of the pump has been decreased to the minimum frequency
- ST03 Step of adjusting the opening degree of the control valve

ST04 Step of determining whether the opening degree of the control valve is at the minimum set opening degree

ST05 Step of switching the operation mode on the load facility side to the cooling tower mode

Claims

[Claim 1]

A geothermal heat utilization system comprising:

- a pumping well;
- a water injection well;
- piping extending from the pumping well to the water injection well;
- a pump configured to feed groundwater from the pumping well to the water injection well via the piping;
- a heat exchanger provided at the piping;
- a control valve provided at the piping and configured to adjust a flow rate of the groundwater in the piping;
- a control device configured to, when an operation frequency of inverter control of the pump reaches a minimum frequency, adjust a flow rate of the groundwater injected into the water injection well by controlling the control valve to reduce the flow rate in the piping; and
- a cooling tower on a side of a load facility that uses a medium, the medium being configured to exchange heat with the groundwater in the piping in the heat exchanger, wherein

when an opening degree of the control valve reaches a minimum set opening degree, the geothermal heat utilization system injects, into the water injection well, the groundwater that has exchanged heat with the medium cooled by the cooling tower in the heat exchanger.

[Claim 2]

The geothermal heat utilization system according to claim 1, wherein the control device includes a pump operation control unit configured to adjust the operation frequency of inverter control of the pump according to a temperature of groundwater pumped up from the pumping well, passed through the heat exchanger, and injected into the water injection well.

[Claim 3]

The geothermal heat utilization system according to claim 2, wherein

the control device further includes a control valve opening/closing control unit configured to adjust, when the operation frequency reaches the minimum frequency, the opening degree of the control valve according to the temperature.

[Claim 4]

The geothermal heat utilization system according to any one of claims 1 to 3, wherein

the control valve is provided on a side of the water injection well of the heat exchanger.

[Claim 5]

The geothermal heat utilization system according to any one of claims 1 to 4, wherein

when the control device adjusts the flow rate of the groundwater in the piping by throttling the control valve, the operation frequency is kept at the minimum frequency.

[Claim 6]

A control device comprising:

a pump operation control unit configured to adjust an operation frequency of inverter control of a pump being configured to feed groundwater from a pumping well to a water injection well, via piping extending from the pumping well to the water injection well, and the piping provided with a heat exchanger which exchanges heat between the groundwater and a medium used by a load facility; and

a control valve opening/closing control unit configured to adjust, when the operation frequency reaches a minimum frequency, an opening degree of a control valve, the control valve being provided at the piping configured to feed the groundwater to the water injection well, wherein

when the opening degree of the control valve reaches a minimum set opening degree, the pump injects, into the water injection well, the groundwater that has exchanged heat with the medium cooled by a cooling

tower provided on a side of the load facility in the heat exchanger.

[Claim 7]

A control method comprising:

adjusting an operation frequency of inverter control of a pump being configured to feed the groundwater from a pumping well to a water injection well, via piping extending from the pumping well to the water injection well, and the piping provided with a heat exchanger which exchanges heat between the groundwater and a medium used by a load facility; and

adjusting, when the operation frequency reaches a minimum frequency, an opening degree of a control valve, the control valve being provided at the piping being configured to feed the groundwater to the water injection well, wherein

when the opening degree of the control valve reaches a minimum set opening degree, injecting, into the water injection well, the groundwater that has exchanged heat with the medium cooled by a cooling tower provided on a side of the load facility in the heat exchanger.

[Claim 8]

A program configured to cause a computer to perform a method, the method comprising:

adjusting an operation frequency of inverter control of a pump being configured to feed the groundwater from a pumping well to a water injection well, via piping extending from the pumping well to the water injection well, and the piping provided with a heat exchanger which exchanges heat between the groundwater and a medium used by a load facility; and

adjusting, when the operation frequency reaches a minimum frequency, an opening degree of a control valve, the control valve being provided at the piping configured to feed the groundwater to the water injection well, wherein

when the opening degree of the control valve reaches a minimum set opening degree, injecting, into the water injection well, the groundwater that has exchanged heat with the medium cooled by a cooling tower provided on a side of the load facility in the heat exchanger.