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United States Patent Application Publication 20250264248
Kind Code A1
Publication Date August 21, 2025
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LOW-EMISSIONS HEATING, COOLING, AND HOT WATER SYSTEM

Abstract

A hydronic system includes a control unit configured to monitor a volume of water and an outlet temperature using flowmeters and temperature sensors, respectively. The control unit is configured to operate a heat pump to recharge a storage tank when a respective predetermined limit is reached for the volume of water or the outlet temperature. The control unit is configured to determine a time period based on the volume, the outlet temperature, and an operation cycle that may be on-peak or off-peak. The operation cycle is determined using day-ahead hourly prices, a temperature forecast, or a greenhouse gas emissions forecast. During an on-peak operation cycles, the control unit is configured to operate the heat pump unit instantaneously within the determined time-period. In an off-peak operation cycle, the control unit is configured to operate the heat pump unit selectively based on a cost and a schedule of a power source.

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Family ID: **1000008576688**

Appl. No.: **19/198019**

Filed: **May 03, 2025**

Related U.S. Application Data

parent US continuation-in-part 18332329 20230609 parent-grant-document US 12313301 child US 19198019
parent US division 16544402 20190819 parent-grant-document US 12013152 child US 18332329

Publication Classification

Int. Cl.: **F24H9/20** (20220101); **F24D17/00** (20220101); **F24D17/02** (20060101); **F24D19/10** (20060101); **F24H15/375** (20220101)

U.S. Cl.:

CPC **F24H9/2014** (20130101); **F24D17/0089** (20130101); **F24D17/02** (20130101); **F24D19/1006** (20130101); **F24H15/375** (20220101);

Background/Summary

TECHNICAL FIELD

[0001] The present disclosure relates to systems and methods for operating a hydronic heating, cooling, and domestic hot water system.

BACKGROUND

[0002] Hydronic systems are typically thermo-fluid dynamic systems, which are configured for home, commercial, and/or industrial use. The hydronic systems employ water as a heat transfer fluid for heating or cooling the interiors of homes, commercial buildings, or industrial facilities. More often, the hydronic systems are used to supply domestic hot water for use in washbasins, showers, and baths.

[0003] Conventional hydronic systems use fossil energy sources, such as gas, propane, fuel oil, and the like, or electricity for operation. Electric hydronic systems utilize the energy generated by power plants, many of them powered by the combustion of fossil fuels, which generates greenhouse gases (GHG) and other air pollution including particulates, ozone, nitrogen dioxide, Sulphur dioxide, etc. Emissions from grid-supplied electricity vary by time of day and day of the year and can range from zero when the marginal generator is renewable, hydro, or nuclear, to very high when the marginal generator is a peak power plant at times of peak grid demand.

[0004] Further, as time-varying electricity rates become increasingly common, the cost incurred for operating electric hydronic systems also varies by time of operation. Thus, for an efficient, low-emissions, and cost-effective operation of an electric hydronic system, the user may be required to keep track of the cost and emissions of the energy source, which is a mundane, cumbersome, and time-consuming process. Moreover, energy losses such as diffusion loss and standby loss, may occur which is uneconomical. An example of a time-varying electricity rate is a time-of-use schedule where the price varies by hour of day but is fixed from day to day, or only varies between weekends and weekdays, and seasons. Another example is an hourly variable rate which changes from hour to hour and from day to day, potentially reflecting wholesale electricity prices and transmission and distribution grid constraints.

[0005] To reduce the use of hydronic systems employing fossil fuels, while minimizing operating costs and emissions, attempts have been made to employ electrical systems with thermal storage. However, the electrical systems with thermal storage have been uneconomical and impractical to use in residential applications, due to high installation costs, efficiency losses in thermal storage, and complexity in piping design and controls that operate the heat pump.

[0006] Therefore, there is a need for techniques that can overcome one or more limitations stated above in addition to providing other technical advantages.

SUMMARY

[0007] Various embodiments of the present disclosure provide methods and systems for operating a hydronic system.

[0008] According to an aspect of the present disclosure, there is provided a hydronic system. The hydronic system includes a control unit that includes a memory including stored instructions, and a processor configured to execute the stored instructions. The processor causes the control unit to, at least, monitor a volume of hot water in a hot storage tank via a first set of flowmeters. Furthermore, the control unit is caused to monitor a first outlet temperature of the hot water within the hot storage tank via a first temperature sensor. The control unit is further caused to operate a heat pump unit for recharging the hot water within the hot storage tank, the heat pump unit operated when a respective predetermined limit is attained for at least one of the volume of hot water or the first outlet temperature. The control unit is also caused to determine a time period required for recharging the volume of hot water, the time period determined based on the volume of hot water, the first outlet temperature, and an operation cycle, the operation cycle being at least an on-peak operation cycle or an off-peak operation cycle. In that regard, the control unit is configured to determine the operation cycle to be the on-peak operation cycle or the off-peak operation cycle based on one or more of day-ahead hourly prices, a temperature forecast, or a day-ahead greenhouse gas emissions forecast. The control unit is also configured to operate the heat pump unit instantaneously for recharging the hot water within the time period, when at least one of the volume of hot water or the first outlet temperature has reached the respective predetermined limit, and the operation cycle is the on-peak operation cycle.

[0009] According to another aspect of the present disclosure, there is provided a hydronic system. The hydronic system includes a control unit that includes a memory including stored instructions, and a processor configured to execute the stored instructions. The processor causes the control unit to, at least, monitor a volume of chilled water in a cold storage tank via a second set of flowmeters. Furthermore, the control unit is caused to monitor a second outlet temperature of the chilled water within the cold storage tank via a second temperature sensor. The control unit is further caused to operate a heat pump unit for recharging the chilled water within the cold storage tank, the heat pump unit operated when a respective predetermined limit is attained for at least one of the volume of chilled water or the second outlet temperature. The control unit is also caused to determine a time period required for recharging the volume of chilled water, the time period determined based on the volume of chilled water, the second outlet temperature, and an operation cycle, the operation cycle being at least an on-peak operation cycle or an off-peak operation cycle. In that regard, the control unit is configured to determine the operation cycle to be the on-peak operation cycle or the off-peak operation cycle based on one or more of day-ahead hourly prices, a temperature forecast, or a day-ahead greenhouse gas emissions forecast. The control unit is also configured to operate the heat pump unit instantaneously for recharging the chilled water within the time period, when at least one of the volume of chilled water or the second outlet temperature has reached the respective predetermined limit, and the operation cycle is the on-peak operation cycle.

[0010] According to another aspect of the present disclosure, there is provided a method for operating a hydronic system. The method performed by a control unit includes monitoring a volume of hot water in a hot storage tank via a first set of flowmeters. Furthermore, the method includes monitoring a first outlet temperature of the hot water within the hot storage tank via a first temperature sensor. The method further includes operating a heat pump unit for recharging the hot water within the hot storage tank, the heat pump unit operated when a respective predetermined limit is attained for at least one of the volume of hot water or the first outlet temperature. The method also includes determining a time period required for recharging the volume of hot water, the time period determined based on the volume of hot water, the first outlet temperature, and an operation cycle, the operation cycle being at least an on-peak operation cycle or an off-peak operation cycle. In that regard, the control unit further determines the operation cycle to be the on-peak operation cycle or the off-peak operation cycle based on one or more of day-ahead hourly prices, a temperature forecast, or a day-ahead greenhouse gas emissions forecast. Furthermore, the control unit operates the heat pump unit instantaneously for recharging the hot water within the time period, when at least one of the volume of hot water or the first outlet temperature has reached the respective predetermined limit, and the operation cycle is the on-peak operation cycle.

Description

BRIEF DESCRIPTION OF THE FIGURES

[0011] The following detailed description of illustrative embodiments is better understood when read in conjunction with the appended drawings. For the purpose of illustrating the present disclosure, exemplary constructions of the disclosure are shown in the drawings. However, the present disclosure is not limited to a specific device or a tool and instrumentalities disclosed herein. Moreover, those in the art will understand that the drawings are not to scale. Wherever possible, like elements have been indicated by identical numbers:

[0012] FIG. **1** is an example representation of an environment related to at least some example embodiments of the present disclosure;

[0013] FIG. **2**A is a schematic representation of a hydronic system, in accordance with an example embodiment of the present disclosure;

[0014] FIG. **2**B is a schematic representation of a hydronic system, in accordance with another example embodiment of the present disclosure;

[0015] FIG. **3** is a block diagram representation of a control unit of the hydronic system of FIGS. **2**A and **2**B, in accordance with an example embodiment of the present disclosure;

[0016] FIG. **4** is a flow diagram illustrating a method of operating the hydronic system by the control unit during an on-peak operation cycle and an off-peak operation cycle, in accordance with an example embodiment of the present disclosure;

[0017] FIG. **5** is a flow diagram illustrating a method of operating the hydronic system by the control unit using dynamic hourly charging, in accordance with another example embodiment of the present disclosure;

[0018] FIG. **6**A is a flow diagram for a method for operating the hydronic system, in accordance with an embodiment of the present disclosure;

[0019] FIG. **6**B is a flow diagram for a method for operating the hydronic system, in accordance with another embodiment of the present disclosure; and

[0020] FIG. **7** is a block diagram of a server capable of implementing at least some embodiments of the present disclosure.

[0021] The drawings referred to in this description are not to be understood as being drawn to scale except if specifically noted, and such drawings are only exemplary in nature.

DETAILED DESCRIPTION

[0022] In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present disclosure. It will be apparent, however, to one skilled in the art that the present disclosure can be practiced without these specific details. Descriptions of well-known components and processing techniques are omitted so as to not unnecessarily obscure the embodiments herein. The examples used herein are intended merely to facilitate an understanding of ways in which the embodiments herein may be practiced and to further enable those of skill in the art to practice the embodiments herein. Accordingly, the examples should not be construed as limiting the scope of the embodiments herein.

[0023] Reference in this specification to “one embodiment” or “an embodiment” means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present disclosure. The appearance of the phrase “in an embodiment” in various places in the specification does not necessarily all refer to the same embodiment, nor are separate or alternative embodiments mutually exclusive of other embodiments. Moreover, various features are described which may be exhibited by some embodiments and not by others. Similarly, various requirements are described which may be requirements for some embodiments but not for other embodiments.

[0024] Moreover, although the following description contains many specifics for the purposes of illustration, anyone skilled in the art will appreciate that many variations and/or alterations to said details are within the scope of the present disclosure. Similarly, although many of the features of the present disclosure are described in terms of each other, or in conjunction with each other, one skilled in the art will appreciate that many of these features can be provided independently of other features. Accordingly, this description of the present disclosure is set forth without any loss of generality to, and without imposing limitations upon, the present disclosure.

Overview

[0025] Various embodiments of the present disclosure provide a method for operating a hydronic system configured to condition an enclosure as per requirement, while also supplying hot water for domestic use. The method includes monitoring by a control unit a volume of a hot water in a hot storage tank via a first set of flowmeters. The hot water is routed to an enclosure for at least conditioning the enclosure and the domestic water use. The control unit is also configured to monitor volume of chilled water in a cold storage tank via a second set of flowmeters. The chilled water is routed to the enclosure for at least conditioning the enclosure. Further, the control unit is configured to monitor a first outlet temperature of the hot water exiting or within the hot water tank via a first set of temperature sensors and a second outlet temperature of the cold water exiting or within the tank via a second set of temperature sensors. As such, based on the aforementioned parameters monitored by the control unit, a state of charge (SoC) or condition of the hot water and the cold-water present in the hot storage tank and the cold storage tank respectively, is determined. When the SoC of the hot water and the cold water reaches a predetermined limit, the control unit can in certain embodiments be configured to operate a heat pump unit for recharging the hot water and the cold water respectively. Further, the control unit may also consider a temperature of the hot water exiting or within the hot water tank and the temperature of the cold water exiting or within the cold water tank to the enclosure, for monitoring the predetermined limit.

[0026] As such, when the temperature of the hot water exiting or within the hot water tank reduces to a minimum threshold value and the temperature of the cold water exiting or within the cold water tank increases to a maximum threshold value, the control unit can in certain embodiments be configured to operates the heat pump suitably for recharging the hot water and the cold water. The control unit further determines a time period required for recharging the hot water and the cold water via the heat pump, based on their SoC and an operation cycle. The operation cycle may be at least an on-peak operation cycle and an off-peak operation cycle. The operation cycle is determined to be the on-peak operation cycle or the off-peak operation cycle based on any of, or the combination of, day-ahead hourly prices, a temperature forecast to optimize heat pump efficiency, or a day-ahead greenhouse gas emissions forecast. In that regard, the day-ahead hourly prices, the temperature forecast, or the day-ahead greenhouse gas emissions forecast may be blended into a single hourly signal, and then the single hourly signal may be segmented into on-peak and off-peak time periods that maximize signal value arbitrage taking into account storage capacity. During the on-peak operation cycle, the heat pump instantaneously operates the heat pump unit for recharging the hot water within the time period, until the operating temperatures of the hot water and the cold water are restored. Further, during the off-peak operation cycle, the heat pump is selectively operated based on a cost, emissions, a schedule of operation of a power source and the like, until the operating temperatures of the hot water and the cold water are restored. This configuration ensures that the heat pump can be efficiently operated, thereby optimizing the use of the power source. Consequently, reducing the emissions and the costs associated with the operation of the system.

[0027] The present disclosure also provides a hydronic system. The hydronic system includes processing capabilities for implementing the aforesaid method.

[0028] Although process steps, method steps, or the like in the disclosure may be described in sequential order, such processes and methods may be configured to work in alternate orders. In other words, any sequence or order of steps that may be described in this patent application does not, in and of itself, indicate a requirement that the steps be performed in that order. The steps of the described processes may be performed in any order practical. Further, some steps may be performed simultaneously despite being described or implied as occurring non-simultaneously (e.g., because one step is described after the other step). Moreover, the illustration of a process by its depiction in a drawing does not imply that the illustrated process is exclusive of other variations and modifications thereto, does not imply that the illustrated process or any of its steps are necessary to one or more of the invention(s), and does not imply that the illustrated process is preferred.

DESCRIPTION OF FIGURES

[0029] Various embodiments with respect to methods and systems for controlling the operation of a hydronic system are described in FIG. **1** to FIG. **7**.

[0030] FIG. **1** is an example representation of an environment **100** related to at least some example embodiments of the present disclosure. The environment **100** includes a user **102** (collectively referred for plurality of users) interacting with a system **108** configured for operating a hydronic system **200** (for e.g. as shown in FIG. **2**A). The user **102** may be an individual or an entity, who is in need of a hot water supply or a chilled water supply from the hydronic system **200** or who is need of conditioning an enclosure **212** (for e.g. as shown in FIG. **2**A). The user **102** is associated with a device **104**, for providing an input information required for operating the system **108** via a network **106**. The input information from the user **102** may include such as, but not limited to, a requirement of hot water, a variation in a temperature of the hot water supply or the chilled water supply, a variation in the temperature of conditioning the enclosure or any other information required for operation of the system **108**. The user **102** may provide the input information to the system **108** using an interactive analytic application **116** (hereinafter referred to as ‘application **116**’) made available at the device **104**. The device **104** may include devices, such as laptops, tablets, desktops, smartphones, wearable devices, workstation terminals or other computing devices with network interfaces, such as micro-PCs, smart watches, etc. The network **106** may also be a centralized network or a decentralized network or may include a plurality of sub-networks that may establish a direct communication between the user **102** and the system **108** or may offer indirect communication between the user **102** and the system **108**. Typical examples of the network **106** include, but are not limited to, a wireless or wired Ethernet-based intranet, a local or wide-area network (LAN or WAN), and/or global communications network known as the Internet, which may accommodate many different communications media and protocols.

[0031] The environment **100** also includes a server **114** configured for operating the hydronic system **200**, which is described in subsequent paragraphs of the description. The system **108** may be embodied within the server **114** or may be a standalone component associated with the server **114**. The system **108** is configured to host and manage the application **116**, which is accessible to the device **104**. The application **116** may be accessible through a website associated with the server **114**, so that the user **102** may access the website over the network **106** using Web browser applications installed in the device **104** and, thereafter perceive to operate the hydronic system **200**. In an embodiment, the server **114** is configured to facilitate instances of the application **116** to the device **104**, upon receiving a request for accessing the application **116**. The server **114** upon receiving the request allows instances of the application **116** to be downloaded into the device **104** for accessing the application **116**. In an embodiment, the application **116** may include the Application Programming Interface (API) and other components, which may rest on the server **114**. In this scenario, the application **116** can be made available at application stores, such as Google play store managed by Google®, Apple app store managed by Apple®, etc., and are downloadable from the application stores to be accessed on devices such as the device **104**. In some alternate embodiments, the application **116** may be pre-installed on the device **104** as per the factory settings. In one configuration, the application **116** is also configured to generate and dynamically update a dashboard (not shown in Figures) by including the input information provided by the user

102. In another configuration, the application **116** is also configured to generate and dynamically update the dashboard by including estimated costs associated with operation of the hydronic system **200** based on the input information provided.

[0032] In an embodiment, the input information may be provided by the user **102** frequently via the application **116**, and the estimated costs for operating the hydronic system **200** may be fetched through another endpoint in the application **116** (not shown in Figures).

[0033] The environment **100** further includes a database **112** configured to store information pertaining to the input information provided by the user **102**. The input information may be the information provided by the user **102** pertaining to the conditioning of the enclosure and the temperature requirements of the hot water and the cold water, to the hydronic system **200**. The database **112** may also be configured to store data pertaining to the determined temperatures, capacities of the storage tanks, and the like. The database **112** may be maintained by a third party or embodied within the server **114**.

[0034] In an example, the server **114** is configured to monitor a volume of the hot water and the cold water in a hot storage tank and a cold storage tank respectively. The server **114** is also configured to monitor the first outlet temperature of the hot water and the second outlet temperature of the cold water. The server **114** may operate a heat pump unit for recharging the hot water and the chilled water suitably when a respective predetermined limit is reached for at least one of the state of charge of the hot water, the state of charge of the chilled water, the first outlet temperature and the second outlet temperature. In one configuration, the server **114** may use the parameters, the volume of hot water and the first outlet temperature to determine a State of Charge (SoC) of the hot water. In another configuration, the server **114** may use the parameters the volume of chilled water and the second outlet temperature to determine a State of Charge (SoC) of the chilled water. As such, the server **114** may be configured to operate the heat pump unit based on the SoC of the hot water and the chilled water.

[0035] Additionally, the server **114** is configured to determine a time period required for recharging the volume of hot water. Thus, the server **114** operates the heat pump unit based on the time period determined. The time period may be determined by the server **114** based on the SoC of the hot water and an operation cycle which may be an on-peak operation cycle or an off-peak operation cycle. During the on-peak operation cycle, the server **114** may operate the heat pump unit instantaneously for recharging the hot water within the time period, which is explained in detail in subsequent sections. During the off-peak operation cycle, the heat pump unit is selectively operated based on a cost and schedule of a power source for recharging the hot water. The cost, emissions and schedule of the power source may be stored in the database **112** directly, or as a look up table (not shown in Figures). In one implementation, the cost of the power source may represent the price of the power source, the emissions duc to that power source, or any other parameter. In one configuration, the heat pump unit is operated when at least one of the SoC of the hot water or the first outlet temperature has reached the respective predetermined limit.

[0036] Further, the server **114** is configured to determine a time period required for recharging the volume of chilled water. Thus, the server **114** operates the heat pump unit based on the time period determined. The time period may be determined by the server **114** based on the SoC of the chilled water and the operating cycle. During the on-peak operation cycle, the server **114** operates the heat pump unit instantaneously for recharging the chilled water within the time period, which is explained in detail in subsequent section. During the off-peak operation cycle, the heat pump unit is selectively operated based on the cost, emissions and schedule, or other parameters, for the power source for recharging the chilled water. In one configuration, the heat pump unit is operated when at least one of the SoC of the chilled water or the second outlet temperature has reached the respective predetermined limit.

[0037] In either of the scenario, whether recharging the volume of hot water or the volume of chilled water, the server **114** may determine the operation cycle to be the on-peak operation cycle or the off-peak operation cycle based on one or more of day-ahead hourly prices, a temperature forecast, or a day-ahead greenhouse gas emissions forecast. In that regard, the server **114** may blend the one or more of the day-ahead hourly prices, the temperature forecast, or the day-ahead greenhouse gas emissions forecast into a single hourly signal, and segment the single hourly signal to on-peak and off-peak time periods. This configuration ensures that the heat pump unit is operated selectively, thereby reducing the cost of operation, emissions generated during use of the power or other relevant parameter, while also optimizing the performance of operation of the hydronic system **200**.

[0038] FIGS. **2**A and **2**B are schematic representations of the hydronic system **200**, in accordance with some example embodiments of the present disclosure. The system **200** includes a thermal storage tank **202** configured to store fluid therein. The thermal storage tank **202** may be divided into a compartment **202***a* (i.e. a top portion) for storing the hot water, a compartment **202***b* for storing lukewarm water, and a compartment **202***c* (i.e. a bottom portion) for storing the chilled water. The thermal storage tank **202** may be configured with a thermal shielding surface for maintaining the temperature of the water therein. In one configuration, in the portion **202***c*, cold water may also be stored, as per design feasibility and requirement. The portions **202***a*-**202***c* may be formed due to a thermocline layer (referenced as a line within the tank **202**) formed due to the temperature difference between the hot water, the lukewarm water, and the chilled water. In one implementation, the hot water may be the water heated to a temperature from about 130° F. to about 200° F. or any other temperature as per feasibility and requirement. In another implementation, the lukewarm water may be the water available at room temperature, with the temperature range of about 25° C. to about 30° C. or any other temperature as per requirement. In yet another implementation, the chilled water may be the water cooled to the temperature 10° C. or any other temperature as per requirement. In another implementation, the cold water may be the water cooled to the temperature range of about 11° C. to about 20° C. or any other temperature as per requirement.

[0039] The thermal storage tank **202** is fluidically coupled to a pump **204**. The pump **204** is further fluidically coupled via conduits, to a thermal distributor **206**, a heat pump unit **208**, a domestic hot water tank **210**, and the enclosure **212**. As such, the pump **204** is configured to circulate or route the hot water, the chilled water, and the lukewarm water suitably within the hydronic system **200**. In one configuration the pump **204** may be a unit selected from a group consisting of a positive displacement pump, a peristaltic pump, a centrifugal pump, or any other pump as per design feasibility and requirement.

[0040] In one configuration, the thermal storage tank **202** may be divided into a hot storage tank **202***d* and a cold storage tank **202***e* (e.g. as shown in FIG. **2**B). The hot storage tank **202***d* may be configured to store the hot water (for e.g., at a top portion **202***a* as shown in FIG. **2**A) and the cold water (for e.g. at a bottom portion **202***c* as shown in FIG. **2**A). The thermocline layer will separate the hot water and the cold water. The cold storage tank **202***e* may be configured to store the lukewarm water and the chilled water. The thermocline layer will separate the lukewarm water and the cold water. The hot storage tank **202***d* and the cold storage tank **202***e* may be fluidically coupled to the pump **204** to enable the circulation of the hot water and the chilled water suitably.

[0041] Further, the system **200** may be configured with a first set of flowmeters **222***a*, **222***b*, and **222***c* mounted at the inlet and exit of the hot water tank. The first set of flowmeters **222***a*, **222***b*, and **222** care configured to monitor the volume of the water entering and exiting the hot storage tank **202***d* over time and allow the control unit **214** to determine the volume of hot water in the tank. The first flowmeters **222***a*, **222***b*, and **222***c* may be one of an optical sensor, a mechanical sensor, or any other sensor configured for monitoring the water flow within the conduits entering and exiting the hot storage tank **202***d*. The system **200** may also include a first set of temperature sensors **218***a* and **218***b* (hereinafter referred to as temperature sensors **218**) mounted to the conduit exiting and entering the portion of the tank containing the hot water. The first set of temperature sensor **218** is configured to monitor the temperature of the water exiting or entering the hot storage tank **202***d*. In one configuration, the flowmeters **222***a*, **222***b* and **222***c* and the temperature sensors **218** may also be suitably incorporated in the thermal storage tank **202** (not shown in Figures).

[0042] The cold storage tank **202***e* may be configured with a second set of flowmeters **228***a* and **228***b* mounted at the inlet and exit of the portion containing the chilled water. The second set of flowmeters **228***a* and **228***b* are configured to monitor the volume of chilled water entering and exiting the cold storage tank **202***e* over time and allow the control unit **214** to determine the volume of hot chilled water in the tank. The second flowmeters **228***a* and **228***b* may be one of an optical sensor, a mechanical sensor, or any other sensor configured for monitoring the chilled water flow within the conduits entering and exiting the cold storage tank **202***c*. The system **200** also includes a second set of temperature sensors **220***a* and **220***b* (e.g. as shown in FIG. **2**B) mounted to conduit exiting or entering the portion of the tank containing the chilled water and exiting or entering the portion of the tank containing the lukewarm water. The second set of temperature sensors **220***a* and **220***b* (hereinafter referred to as temperature sensors **220**) is configured to monitor the temperature of the water exiting or entering the cold storage tank **202***c*. In one configuration, the flowmeters **228***a* and **228***b* (e.g. as shown in FIG. **2**B) and the temperature sensors **220***a* and **220***b* may be suitably incorporated in the thermal storage tank **202**.

[0043] Further, the system **200** includes a first temperature sensor **226** mounted to the tank **202***d*. The first temperature sensor **226** is configured to monitor the temperature of the hot water within the tank **202***d*. This configuration for example can be used to calibrate the SoC calculation. In one configuration the conduit extending from the hot storage tank **202***d* for supplying the hot water may be directly connected to the enclosure **212** (not shown in Figures). In one configuration the conduit extending from the cold storage tank **202***e* for supplying the chilled water to the thermal distributor **206** may be directly connected instead to a domestic supply tank **210** (not shown in Figures). The thermal distributor **206** on receiving either the hot water or the chilled water via the pump **204** distributes the heat content to the enclosure **212** for conditioning. The thermal distributor **206** may be a blower (not shown in the Figures) configured for distributing the heat content into the enclosure **212**.

[0044] The system **200** also includes the heat pump unit **208** configured for generating either the hot water or the chilled water. The hot water and the cold water generated in the heat pump unit **208** are routed back to the thermal storage tank **202** or the hot storage tank **202***d* and the cold storage tank **202***e* respectively. In one configuration, the heat pump unit **208** receives cold water from (i.e. the bottom portion) the hot storage tank **202***d* which would be heated to generate the hot water. The generated hot water is routed to the hot storage tank **202***d* (i.e. the top portion), for recharging the hot water. In another configuration, the heat pump unit **208** receives lukewarm water from (i.e. the top portion) the cold storage tank **202***e*, which would be cooled to generate the chilled water. The chilled water is circulated back to the cold storage tank **202***e* (i.e. to the bottom portion).

[0045] In one implementation, recharging the hot water and/or the cold water may refer to increasing the volume of hot water and/or the cold water for use in the system **200**. In another implementation, recharging the hot water and/or the cold water may refer to raising the heat content in the hot water and/or the cold water for use in the system **200**. In other words, the heat pump unit **208** may heat the hot water to increase its temperature or may cool the chilled water to reduce its temperature, thereby increasing its heat content. Thus, the term recycling may be considered to apply, based on the necessity or requirement of the system **200**.

[0046] The system **200** also includes a control unit **214** communicably coupled with the thermal storage tank **202**, the hot storage tank **202***d*, the cold storage tank **202***e*, the pump **204**, the thermal distributor **206**, the domestic hot water **210**, the heat pump unit **208** and the enclosure **212**. The control unit **214** is configured to control operations of the components in the system **200** to ensure optimal operational efficiency while incurring minimal operation costs, emissions, or any other parameter, which will be further explained with reference to FIG. **4**. The control unit **214** is also configured to receive the input information from the user **102**, based on which the control unit **214** may operate the system **200**. The input information provided by the user **102**, which relates to the temperatures is received through a thermostat **216**. The thermostat **216** may record the required thermal value or temperature value in the system **200** suitably, and provide such data to the control unit **214**. In one implementation, the control unit **214** may automatically determine the requirements of the enclosure **212** and accordingly, operate the system **200** for conditioning the enclosure **212** suitably.

[0047] FIG. **3** in one exemplary embodiment of the present disclosure, is a block diagram representation **300** of the control unit **214** (shown in FIG. **2**) configured for operating the hydronic system **200**. The control unit **214** includes various processing modules for operating the hydronic system **200**. The processing modules described herein may be implemented by a combination of hardware, software, and firmware components.

[0048] The system **200** includes a processor **302**, a memory **304**, an input/output module **306**, and a database **308**. The processor **302** includes a temperature monitoring module **310** and a load prediction module **312**. It is noted that although the control unit **214** is depicted to include only one processor **302**, the control unit **214** may include a number of processors. Moreover, it shall be noted that the components are shown for exemplary purposes and the control unit **214** may include fewer or additional modules than those depicted in FIG. **6**.

[0049] In an embodiment, the memory **304** is capable of storing machine-executable instructions. Further, the processor **302** is capable of executing the machine executable instructions to perform the functions described herein. The processor **302** embodies or is in communication with the components, such as the temperature monitoring module **310** and the load prediction module **312**. In an embodiment, the processor **302** may be embodied as a multi-core processor, a single core processor, or a combination of one or more multi-core processors and one or more single core processors. For example, the processor **302** may be embodied as one or more of various processing devices, such as a coprocessor, a microprocessor, a controller, a digital signal processor (DSP), a processing circuitry with or without an accompanying DSP, or various other processing devices including integrated circuits such as an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), a microcontroller unit (MCU), a hardware accelerator, a special-purpose computer chip, or the like. In an embodiment, the processor **302** may be configured to execute hard-coded functionality. In an embodiment, the processor **302** is embodied as an executor of software instructions, wherein the instructions may specifically configure the processor **302** to perform the algorithms and/or operations described herein when the instructions are executed.

[0050] The memory **304** may be embodied as one or more volatile memory devices, one or more non-volatile memory devices, and/or a combination of one or more volatile memory devices and non-volatile memory devices. For example, the memory **304** may be embodied as magnetic storage devices (such as hard disk drives, floppy disks, magnetic tapes, etc.), optical magnetic storage devices (e.g. magneto-optical disks), CD-ROM (compact disc read only memory), CD-R (compact disc recordable), CD-R/W (compact disc rewritable), DVD (Digital Versatile Disc), BD (Blu-ray® Disc), and semiconductor memories (such as mask ROM, PROM (programmable ROM), EPROM (erasable PROM), flash memory, RAM (random access memory), etc.).

[0051] In an embodiment, the input/output module **306** may include mechanisms configured to receive input information or inputs form the user **102** and also provide output to the user **102** via the application **116**. To that effect, the input/output module **306** may include at least one interface and/or at least one output interface. The input/output module **306** may be configured to receive the input information from the user **102** for operating the hydronic system **200**.

[0052] The temperature monitoring module **310** may be configured to monitor the temperatures associated with the hot water and the cold water. Particularly, the module **310** is configured to monitor the operating temperatures of the hot water and the cold water within, entering or exiting the hot storage tank **202***d* and the cold storage tank **202***e*. The module **310** may monitor the operating temperatures of the hot water and the cold water, based on the temperature measured by the temperature sensors **218** and **220** respectively. Additionally, the module **310** is communicably coupled to the first temperature sensor **226** for monitoring the temperature at which the hot water is being delivered to either the domestic water supply tank **210** or the thermal distributor **206**. This configuration enables a user to ascertain the temperature given thermal losses associated with the ambient temperature while the water is in the tank, and during flow of the hot water in the conduits. This allows the system **200** to compensate for the thermal losses. This configuration also provides information to calculate the SoC of the water in the tank. The module **310** also monitors the temperature at which the chilled water is being delivered to either the domestic water supply tank **210** or the thermal distributor **206**. This configuration enables a user to ascertain the temperature given thermal losses associated with the ambient temperature while the water is in the tank, and during the flow of water in the conduits. This configuration also provides information to calculate the SoC of the water in the tank **202***d*. This allows the system **200** to compensate for the thermal losses. In one implementation, the module **310** may determine the operating temperatures of the hot water and the cold water, based on the climatic conditions or the operation cycle of the system **200**.

[0053] The load prediction module **312** may be configured to determine the load during operation of the system **200**. The load may be the amount or volume of hot water or the cold water being dispensed from the tanks **202***d* and **202***e*, or may be the expected demand of the user **102** or any other parameter as per feasibility. Typically, during operation of the system **200**, the hot water and the cold water may be dispensed at a steady rate from the tanks **202***d* and **202***c*. As such, based on the demand, and the thermal losses associated with the flow of the hot water and the cold water, the module **312** may be configured to determine the required SoC of hot water and/or the cold water to be maintained in their respective storage tanks. The module **312** may determine the load, based on the storage capacity for the hot water and the cold water in the tanks **202***d* and **202***c*. The module **312** may be thus associated with the flowmeters **222***a*, **222***b*, **222***c*, **228***a*, and **228***b*, for monitoring the flow of the hot water and the cold water respectively.

[0054] Additionally, the control unit **214** includes the database **308** configured for storing information pertaining to the input information provided by the user **102**. The database **308** may also be configured to store information exchanged or generated during each step of the analysis by the processor **302**, for operating the hydronic system **200**. The database **308** may also be configured to store information pertaining to the costs associated with use of the power source along with its operation cycle. The database **308** may be encrypted suitably for ensuring the security of the stored information. The database **308** may also be configured to maintain log of the data processed by each of the modules (such as the temperature monitoring module **310** and the load prediction module **312**) within the processor **302**. The log allows the user **102** to track and understand the analysis performed by the processor **302**.

[0055] The various modules of the control unit **214**, such as the processor **302**, the memory **304**, the I/O module **306**, the database **308**, the temperature monitoring module **310**, and the load prediction module **312** may be configured to communicate with each other through a centralized circuit system (not shown in Figures). The centralized circuit system may be various devices configured to, among other things, provide or enable communication between the components (**302-312**) of the control unit **214**. In certain embodiments, the centralized circuit system may be software-based, a central printed circuit board (PCB) such as a motherboard, a main board, a system board, or a logic board. The centralized circuit system may also, or alternatively, include other printed circuit assemblies (PCAs) or communication channel media. In some embodiments, the centralized circuit system may include appropriate communication interfaces to facilitate communication between the processor **302** and the components **304** to **312**. The database **308** may communicate with the processor **302** using suitable storage interface such as, for example, an Advanced Technology Attachment (ATA) adapter, a Serial ATA (SATA) adapter, a Small Computer System Interface (SCSI) adapter, a RAID controller, a SAN adapter, a network adapter, and/or any component providing processor **302** with access to the data stored in the database **308**.

[0056] FIG. **4** in one exemplary embodiment of the present disclosure, is a flow diagram **400** illustrating a method of operating the hydronic system **200** by the control unit **214** during an on-peak operation cycle and an off-peak operation cycle. The control unit **214** may monitor the condition of the hot water and/or the chilled water (hereinafter referred to as State of Charge (SoC)) for operating the system **200**. On determining the SoC, the control unit **214** determines the operation cycle, for operating the heat pump unit **208** suitably. The operation cycle includes the on-peak operation cycle and the off-peak operation cycle. In one implementation, the on-peak operation cycle may be the time period in which the demand for use of the system **200** will be the highest. As an example, the time period between 6 AM to 9 AM and 6 PM to 9 PM of a day, where the user **102** is engaged in daily activities, may be considered as the on-peak operation cycle. In another implementation, the on-peak operation cycle may be the time at which the cost of energy is highest.

[0057] As an example, the time period between 5 pm and 9 pm, may be the time at which the cost of energy is highest. Another example is when the combination of energy price, outdoor air temperature, and greenhouse gas emissions are the most favorable. The off-peak operation cycle may be the remainder time period of the day. In one implementation, the on-peak operation cycle may also be based on the load acting or the demand for the hot water and/or cold water for the enclosure **212**. The control unit will trigger the operation of the system **200** to bring the SoC of the tank up to a number of different levels, for example levels A, B, or C, depending on the operation cycle, SoC and user load requirements or expected requirements.

[0058] At step **402**, the control unit **214** determines whether the operation cycle is the on-peak operation cycle. The control unit **214** may determine the operation cycle to be the on-peak operation cycle or the off-peak operation cycle based on any of, or the combination of, day-ahead hourly prices, a temperature forecast to optimize the efficiency of the heat pump unit **208**, or a day-ahead greenhouse gas emissions forecast. Generally, in many countries or jurisdictions, electricity prices fluctuate throughout the day. On-peak hours typically correspond to periods of high demand and, therefore, higher prices. Off-peak hours have lower demand and lower prices. The control unit **214** may schedule the operation of the heat pump unit **208**, during off-peak hours (lower prices) to minimize electricity costs. If the day-ahead hourly prices are high, the corresponding time period is determined to be on-peak. If the day-ahead hourly prices are low, the corresponding time period is determined to be off-peak.

[0059] Furthermore, the control unit **214** may schedule the operation of the heat pump unit **208** during periods with favorable temperatures (e.g., moderate temperatures) to maximize the efficiency of the heat pump unit **208**. In one example scenario, if the temperature forecast shows that the heat pump unit **208** will have a high efficiency in a certain time period, then that time period could be determined to be an off-peak period for the operation of the heat pump unit **208**, even if the electrical prices are not at their lowest. For example, if the temperature forecast predicts a very cold period, the control unit **214** might prioritize recharging before or after that period to avoid operating under inefficient conditions. Furthermore, the carbon footprint of electricity generation varies throughout the day, depending on the energy sources used (e.g., renewables vs. fossil fuels). The control unit **214** may schedule the operation of the heat pump unit **208** during periods with lower emissions to minimize the environmental impact. In that regard, the control unit **214** may use the day-ahead greenhouse gas emissions forecast to determine when the electrical grid is producing the least amount of emissions. Then the control unit **214** can set those times to be off-peak times for the operation of the heat pump unit **208**.

[0060] The control unit **214** blends the day-ahead hourly prices, the temperature forecast, or the day-ahead greenhouse gas emissions forecast into a single hourly signal, then segments the single hourly signal into on-peak and off-peak time periods that maximizes signal value arbitrage taking into account storage capacity. For example, a weighted average could be used. High price values, high emissions values, and low-efficiency values would push the average higher. Then the highest averages would be determined to be on-peak, and the lowest averages would be determined to be off-peak. If the control unit **214** determines the on-peak operation cycle, the method proceeds to step **404**.

[0061] At step **404**, the control unit **214** monitors the SoC of the hot water and/or the chilled water. That is, the control unit **214** determines the SoC of the hot water and/or the chilled water (hereinafter referred to as water) in the tanks **202*d*** and **202*e*** respectively. In step **404**, the control unit **214** monitors whether the current SoC (i.e. reserve, R) of the water is greater than a min reserve R.sub.min of the water and whether the flow temperature T of the water is greater than the required temperature T.sub.req by the user **102** (or 'shed minimum temperature'). In one implementation, for hot water, the flow temperature is required to be greater than the shed minimum temperature, while for chilled water the flow temperature is required to be less than the shed maximum temperature, for complying with the condition in step **404**. If the condition specified in step **404** is met, the control unit **214** maintains the idle condition of the heat pump unit **208** at step **406**. This scenario may be considered as 'load shedding' in the system **200**. If the condition specified in step **404** is not met, the control unit **214** operates the heat pump unit **208** to recharge the water to reach a SoC level A (which can be the expected hot water or chilled water needed over the remainder of the peak period plus a reserve R.sub.min). For operating the heat pump unit **208**, the control unit **214** determines the time period required for recharging the water, and accordingly operates the heat pump unit **208**. This scenario may be considered as 'peak recovery', since the recovery of recharge is occurring during the on-peak operation cycle.

[0062] Further, when the control unit **214** determines that the current operation cycle is the off-peak operation cycle, the method proceeds to step **410**. At step **410**, the control unit **214** determines whether a load-up or recharging of the water is required. If the load-up is required, the heat pump unit **208** is operated for recharging the water at step **414**. In this scenario, the SoC of the water is now raised to level B, which is greater than the level A (as per step **408**). Recharging the water to level B provides a buffer for the system **200** to be idle until the volume of the water is reduced or the temperature of the water is reduced. This mechanism, prevents frequent operation of the heat pump unit **208**, thereby employing minimal power from the power source. Consequently, incurring a lower operational cost of the system **200**. If the control unit **214** determines that the load-up is not required, the method proceeds to step **412**.

[0063] At step **412**, the control unit **214** determines whether the SoC of the water, Lis greater than the reserve, R (or normal reserve) or whether the flow temperature, T.sub.outlet (or outlet temperature) of the water is greater than a minimum temperature, T.sub.min specified by the user **102**. If the condition in step **412** is satisfied, the method proceeds to step **416**, where the control unit **214** maintains the idle condition of the heat pump unit **208**. If the condition specified in step **412** is not met, the method proceeds to step **418**.

[0064] At step **418**, the control unit **214** operates the heat pump unit **208** to raise the volume or amount of the water to level C, while meeting the minimum operation duration (as described for step **414**).

[0065] In one implementation, the each of the levels A, B, and C indicated in the FIG. **2**B, may be the volume of the water required to meet a certain user requirement. For example, the level C may be the expected requirement of the hot water and/or the cold water from the tank **202** until the start of the next on-peak period plus the reserve volume R. The volume of the water may be the volume of the water and the temperature of the water required for complying the with the user requirement. Similarly, the level A may be the expected requirement of the volume of hot water and/or the cold water from the tank **202** during the off-peak period. The level B may be the expected buffer volume of the hot water and/or cold water from the tank **202**. The level D may be the maximum volume of the hot water and/or the cold water that can be contained in the tank **202** for use.

[0066] FIG. **5** in one exemplary embodiment of the present disclosure is a flow diagram **500** illustrating a method of operating the hydronic system by the control unit **214** using dynamic hourly price optimization. The flow diagram **500** may also be considered as a method for computing the load to be circulated within the system **200**.

[0067] At step **502**, the control unit **502** determines whether there is a draw of water from any of the tanks **202***d* and **202***e*, via the flowmeters **222** and **228**. In one implementation, the control unit **214** may determine the flow of the water from the tanks **202***d* and **202***e* via flowmeters **222**, and **228** that may be configured in the conduits suitably.

[0068] At step **504**, the control unit **214** determines whether the outlet temperature of the water (T.sub.outlet) is lesser than a minimum threshold value (Th.sub.min) defined by the user **102** for the tank **202***d*. For the tank **202***c*, the control unit **214** determines whether the outlet temperature (T.sub.outlet) is greater than a maximum threshold value (Th.sub.max) defined by the user **102**. If this condition of step **504** is satisfied, the control unit moves ahead to step **508** described below. If this condition is not satisfied, the control unit **214** moves ahead to step **506**, where it decides whether it is time to refresh the charging plan. The charging plan may be a model employed by the control unit **214** for determining the optimum and cost-effective means for recharging the water in the tanks **202***d* and **202***e*. If the condition in the step **506** is satisfied, the method proceeds to step **508**, which is the charging plan. Otherwise, the method proceeds to step **516**.

[0069] The charging plan illustrated in FIG. **5** examines the charging need for the following 24 hours iteratively, starting with the next hour. The plan with references **508***a*-**514***a* ensures there is enough charge for hours 1 and 2, the plan with references **508***b*-**514***b* is an iterative plan ensuring that there is enough charge to meet the need from hours 1 to 3, 1 to 4, 1 to n+land the plan with references **508***c*-**514***c* is the last plan ensures there is enough charge from hours 1 to 24 hours.

[0070] At step **508***a*, the control unit **214** computes the current SoC. The SoC may be computed based on the data collated during operation of the system **200** in the previous cycles, or via the input information provided by the user **102**.

[0071] In step **510***a* the control unit compares the SoC to the load that system **200** is required to deliver for hours 1 and 2. If the SoC is sufficient to meet the expected load for hours 1 and 2 then the method proceeds to step **508***b*. If the SoC is not sufficient to meet the expected load for hours 1 and 2, then the method proceeds to step **512***a*. At step **512***a*, the control unit **214** now calculates the expected charge amount or volume needed to meet the expected load for hours 1 and 2. Upon computation of the difference, that is required to achieve the charge calculated in step **510***a*, the control unit determines the cheapest or lowest emissions or other parameter time for charging the tanks **202***d* and **202***e* at step **514***a*. That is, the control unit **214** determines the operation cycle based on any of, or the combination of, day-ahead hourly prices, the temperature forecast to optimize heat pump efficiency or the day-ahead greenhouse gas emissions forecast. The control unit **214** blends these signals into a single hourly signal, then segments it into on-peak and off-peak time periods that maximize signal value arbitrage taking into account storage capacity. The cheapest time may be stored or made available in the database **308** or **112**, may be in the form of a look-up table. As such, the control unit **214** may access the look-up table for ascertaining the time periods at which the cost of use of power source (or electricity) is the cheapest. Accordingly, the heat pump unit **208** is operated for recharging.

[0072] As described above, steps **510***b*-**514***b* and steps **510***c*-**514***c* operate similar to the steps **510***a*-**514***a*, with the difference being the time period considered for computations. In an example of this embodiment, the iterative steps may increase the charge requirement for the earlier time periods, but may not decrease it. The process of refresh the charging plan ends at **520**.

[0073] FIG. **6**A is a flow diagram for a method **600** for operating the hydronic system **200**, in accordance with an embodiment of the present disclosure. The method **600** depicted in the flow diagram may be executed by, for example, the server **114** or the system **108**. Operations of the method **600** and combinations of operation in the flow diagram, may be implemented by, for example, hardware, firmware, a processor, circuitry and/or a different device associated with the execution of software that includes one or more computed program instructions.

[0074] At operation **602** of method **600**, the control unit **214** monitors the volume of hot water in the hot storage tank **202***d* via the first set of flowmeters **222***a*, **222***b*, and **222***c*. Furthermore, the control unit **214** monitors a first outlet temperature of the hot water within the hot storage tank **202***d* via the first temperature sensor **226**.

[0075] At operation **604** of the method **600**, the control unit **214** determines an operation cycle to be the on-peak operation cycle or the off-peak operation cycle, as discussed in relation to FIG. **4**.

[0076] At operation **606** of method **600**, the control unit **214** determines a time period for recharging the volume of hot water.

[0077] At operation **608** of method **600**, the control unit **214** validates whether the operation cycle is the on-peak operation cycle or the off-peak operation cycle. In the case of the operation cycle being the on-peak operation cycle, the method **600** proceeds to operation **610**. In the case of the operation cycle being the off-peak operation cycle, the method **600** proceeds to operation **612**.

[0078] At operation **610** of the method **600**, the control unit **214** operates the heat pump unit **208** instantaneously for recharging the hot water within the time period, when at least one of the volume of hot water or the first outlet temperature has reached the respective predetermined limit. Following operation **610**, the method **600** returns to operation **602**.

[0079] At operation **612** of the method **600**, the control unit **214** operates the heat pump unit **208** selectively based on a cost and a schedule of operation of a power source for recharging the hot water when at least one of the volume of hot water or the first outlet temperature has reached the respective predetermined limit. The cost and the schedule of operation of the power source are defined in the look-up table configured in the database **308** or **112**. Following operation **612**, the method **600** returns to operation **602**.

[0080] FIG. **6**B is a flow diagram for a method **650** for operating the hydronic system **200**, in accordance with another embodiment of the present disclosure. The method **650** depicted in the flow diagram may be executed by, for example, the server **114** or the system **108**. Operations of the method **650** and combinations of operation in the flow diagram, may be implemented by, for example, hardware, firmware, a processor, circuitry and/or a different device associated with the execution of software that includes one or more computed program instructions.

[0081] At operation **652** of method **650**, the control unit **214** monitors the volume of chilled water in the cold storage tank **202***e* via the second set of flowmeters **228***a* and **228***b*. Furthermore, the control unit **214** monitors a second outlet temperature of the chilled water within the cold storage tank **202***e* via the second temperature sensor **220**.

[0082] At operation **654** of the method **650**, the control unit **214** determines an operation cycle to be the on-peak operation cycle or the off-peak operation cycle, as discussed in relation to FIG. **4**.

[0083] At operation **656** of method **650**, the control unit **214** determines a time period for recharging the volume of chilled water.

[0084] At operation **658** of method **650**, the control unit **214** validates whether the operation cycle is the on-peak operation cycle or the off-peak operation cycle. In the case of the operation cycle being the on-peak operation cycle, the method **650** proceeds to operation **660**. In the case of the operation cycle being the off-peak operation cycle, the method **650** proceeds to operation **662**.

[0085] At operation **660** of the method **650**, the control unit **214** operates the heat pump unit **208** instantaneously for recharging the chilled water within the time period, when at least one of the volume of chilled water or the second outlet temperature has reached the respective predetermined limit. Following operation **660**, the method **650** returns to operation **652**.

[0086] At operation **662** of the method **660**, the control unit **214** operates the heat pump unit **208** selectively based on a cost and a schedule of operation of a power source for recharging the chilled water, when at least one of the volume of chilled water or the second outlet temperature has reached the respective predetermined limit. The cost and the schedule of operation of the power source are defined in the look-up table configured in the database **308** or **112**. Following operation

662, the method **650** returns to operation **652**.
[0087] FIG. **7** illustrates a block diagram representation of a server **700** capable of implementing at least some embodiments of the present disclosure. The server **700** is configured to host and manage the application **116** that is provided to an electronic device such as the device **104**, in accordance with an example embodiment of the disclosure. An example of the server **700** is the server **114** shown and described with reference to FIG. **1**. The server **700** includes a computer system **705** and a database **710**.
[0088] The computer system **705** includes at least one processor **715** for executing instructions. Instructions may be stored in, for example, but not limited to, a memory **720**. The processor **715** may include one or more processing units (e.g., in a multi-core configuration).
[0089] The memory **720** is a storage device embodied as one or more volatile memory devices, one or more non-volatile memory devices, and/or a combination of one or more volatile memory devices and non-volatile memory devices, for storing micro-contents information and instructions. The memory **720** may be embodied as magnetic storage devices (such as hard disk drives, floppy disks, magnetic tapes, etc.), optical magnetic storage devices (e.g., magneto-optical disks), CD-ROM (compact disc read only memory), CD-R (compact disc recordable), CD-R/W (compact disc rewritable), DVD (Digital Versatile Disc), BD (Blu-ray® Disc), and semiconductor memories (such as mask ROM, PROM (programmable ROM), EPROM (erasable PROM), flash ROM, RAM (random access memory), etc.).
[0090] The processor **715** is operatively coupled to a communication interface **725** such that the computer system **705** is capable of communicating with a mobile device, for example, the device **104**, or communicates with any entity within the network **106** via the communication interface **725**.
[0091] The processor **715** may also be operatively coupled to the database **710**. The database **710** is any computer-operated hardware suitable for storing and/or retrieving data, such as, but not limited to, the input information, the temperature data, the load data, data obtained during operation of the system **200** and the like. The database **710** may include multiple storage units such as hard disks and/or solid-state disks in a redundant array of inexpensive disks (RAID) configuration. The database **710** may include a storage area network (SAN) and/or a network attached storage (NAS) system.
[0092] In some embodiments, the database **710** is integrated within the computer system **705**. For example, the computer system **705** may include one or more hard disk drives as the database **710**. In other embodiments, the database **710** is external to the computer system **705** and may be accessed by the computer system **705** using a storage interface **730**. The storage interface **730** is any component capable of providing the processor **715** with access to the database **710**. The storage interface **730** may include, for example, an Advanced Technology Attachment (ATA) adapter, a Serial ATA (SATA) adapter, a Small Computer System Interface (SCSI) adapter, a RAID controller, a SAN adapter, a network adapter, and/or any component providing the processor **715** with access to the database **710**.
[0093] The processor **715** is communicably coupled with the memory **720** and the communication interface **725**. The processor **715** is capable of executing the stored machine executable instructions in the memory **720** or within the processor **715** or any storage location accessible to the processor **715**. The processor **715** may be embodied in a number of different ways. In an example embodiment, the processor **715** may be embodied as one or more of various processing devices, such as a coprocessor, a microprocessor, a controller, a digital signal processor (DSP), processing circuitry with or without an accompanying DSP, or various other processing devices including integrated circuits such as, for example, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), a microcontroller unit (MCU), a hardware accelerator, a special-purpose computer chip, or the like. The processor **715** performs various functionalities of the server **700** as described herein.
[0094] The disclosed methods with reference to FIGS. **1** to **7**, or one or more operations of the flow

diagrams **400** and **500** may be implemented using software including computer-executable instructions stored on one or more computer-readable media (e.g., non-transitory computer-readable media, such as one or more optical media discs, volatile memory components (e.g., DRAM or SRAM), or nonvolatile memory or storage components (e.g., hard drives or solid-state nonvolatile memory components, such as Flash memory components) and executed on a computer (e.g., any suitable computer, such as a laptop computer, net book, Web book, tablet computing device, smart phone, or other mobile computing devices). Such software may be executed, for example, on a single local computer or in a network environment (e.g., via the Internet, a wide-area network, a local-area network, a remote web-based server, a client-server network (such as a cloud computing network), or other such networks) using one or more network computers. Additionally, any of the intermediate or final data created and used during the implementation of the disclosed methods or systems may also be stored on one or more computer-readable media (e.g., non-transitory computer-readable media) and are considered to be within the scope of the disclosed technology. Furthermore, any of the software-based embodiments may be uploaded, downloaded, or remotely accessed through a suitable communication means. Such suitable communication means include, for example, the Internet, the World Wide Web, an intranet, software applications, cable (including fiber optic cable), magnetic communications, electromagnetic communications (including RF, microwave, and infrared communications), mobile communications, or other such communication means.
[0095] Various embodiments of the disclosure, as discussed above, may be practiced with steps and/or operations in a different order, and/or with hardware elements in configurations, which are different than those which, are disclosed. Therefore, although the disclosure has been described based upon these exemplary embodiments, it is noted that certain modifications, variations, and alternative constructions may be apparent and well within the spirit and scope of the disclosure.
[0096] Although various exemplary embodiments of the disclosure are described herein in a language specific to structural features and/or methodological acts, the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as exemplary forms of implementing the claims.

Claims

1. A hydronic system, comprising: a control unit, comprising: a memory comprising stored instructions; and a processor configured to execute the stored instructions to cause the control unit to perform at least: monitoring a volume of hot water in a hot storage tank via a first set of flowmeters; monitoring a first outlet temperature of the hot water within the hot storage tank via a first temperature sensor; operating a heat pump unit for recharging the hot water within the hot storage tank, wherein the heat pump unit operated when a respective predetermined limit is attained for at least one of the volume of hot water or the first outlet temperature; and determining a time period required for recharging the volume of hot water, the time period determined based on the volume of hot water, the first outlet temperature, and an operation cycle, the operation cycle being at least an on-peak operation cycle or an off-peak operation cycle, wherein the control unit is configured to: determine the operation cycle to be the on-peak operation cycle or the off-peak operation cycle based on one or more of day-ahead hourly prices, a temperature forecast, or a day-ahead greenhouse gas emissions forecast, and operate the heat pump unit instantaneously for recharging the hot water within the time period, when at least one of the volume of bot water or the first outlet temperature has reached the respective predetermined limit, and the operation cycle is the on-peak operation cycle.
2. The hydronic system as claimed in claim 1, wherein the control unit is configured to blend the one or more of the day-ahead hourly prices, the temperature forecast, or the day-ahead greenhouse

gas emissions forecast into a single hourly signal, and segment the single hourly signal to on-peak and off-peak time periods.
3. The hydronic system as claimed in claim 1, wherein the hot storage tank comprises the hot water settled on a top portion of the hot storage tank and cold water settled on a bottom portion of the hot storage tank, the cold water routed to the heat pump unit for generating the hot water, wherein the hot water generated in the heat pump unit is routed to the top portion of the hot storage tank for recharging the hot water within the hot storage tank.
4. The hydronic system as claimed in claim 1, wherein the hot water is selectively routed to an enclosure via a pump fluidically coupled to the hot storage tank and the enclosure.
5. The hydronic system as claimed in claim 4, wherein the control unit is configured to determine a temperature of the hot water routed into a thermal distributor via a first temperature sensor configured in a conduit connecting the hot storage tank and the thermal distributor.
6. The hydronic system as claimed in claim 5, wherein the control unit is configured to operate the heat pump unit for recharging the hot water within the hot storage tank, when the temperature of the hot water reaches a minimum threshold value.
7. The hydronic system as claimed in claim 1, wherein the control unit is configured to selectively operate the heat pump unit based on a cost and a schedule of operation of a power source for recharging the hot water, when at least one of the volume of hot water or the first outlet temperature attains the respective predetermined limit, and the operation cycle is the off-peak operation cycle, the cost and the schedule of operation of the power source is defined in a look-up table configured in a database communicably coupled to the control unit.
8. The hydronic system as claimed in claim 1, wherein the control unit is configured to: monitor a volume of chilled water in a cold storage tank via a second set of flowmeters; monitor a second outlet temperature of the chilled water within the cold storage tank via a second temperature sensor; and operate the heat pump unit for recharging the chilled water within the cold storage tank, wherein the heat pump unit is operated when a respective predetermined limit is attained for at least one of the volume of chilled water or the second outlet temperature; determine a time period required for recharging the volume of chilled water, the time period determined based on the volume of chilled water, the second outlet temperature, and the operation cycle; and operate the heat pump unit instantaneously for recharging the chilled water within the time period, when at least one of the volume of chilled water or the second outlet temperature has reached the respective predetermined limit, and the operation cycle is the on-peak operation cycle.
9. The hydronic system as claimed in claim 8, wherein the cold storage tank comprises lukewarm water settled on a top portion of the cold storage tank and the chilled water settled on a bottom portion of the cold storage tank, the lukewarm water is routed to the heat pump unit for generating the chilled water, the chilled water generated in the heat pump unit is routed to the bottom portion of the cold storage tank for recharging the chilled water within the cold water tank.
10. The hydronic system as claimed in claim 8, wherein the control unit is configured to: determine a temperature of the chilled water routed from an enclosure via a second temperature sensor configured in a conduit connecting the cold storage tank and the enclosure, and operate the heat pump unit for recharging the chilled water within the cold storage tank, when the temperature of the chilled water reaches a maximum threshold value.
11. The hydronic system as claimed in claim 8, wherein the control unit is configured to selectively operate the heat pump unit based on a cost and a schedule of operation of a power source for recharging the chilled water, when at least one of the volume of chilled water or the second outlet temperature has reached the respective predetermined limit, and the operation cycle is the off peak operation cycle, the cost and the schedule of operation of the power source is defined in a look-up table configured in a database communicably coupled to the control unit.
12. A hydronic system, comprising: a control unit, comprising: a memory comprising stored instructions; and a processor configured to execute the stored instructions to cause the control unit

to perform at least: monitoring a volume of chilled water in a cold storage tank via a second set of flowmeters; monitoring a second outlet temperature of the cold water within the cold storage tank via a second temperature sensor; operating a heat pump unit for recharging the chilled water within the cold storage tank, the heat pump unit operated when a respective predetermined limit is attained for at least one of the volume of chilled water or the second outlet temperature; and determining a time period required for recharging the volume of chilled water, the time period determined based on the volume of chilled water, the second outlet temperature, and an operation cycle, the operation cycle being at least an on-peak operation cycle or an off-peak operation cycle, wherein the control unit is configured to: determine the operation cycle to be the on-peak operation cycle or the off-peak operation cycle based on one or more of day-ahead hourly prices, a temperature forecast, or a day-ahead greenhouse gas emissions forecast, and operate the heat pump unit instantaneously for recharging the chilled water within the time period, when at least one of the volume of chilled water or the second outlet temperature has reached the respective predetermined limit, and the operation cycle is the on-peak operation cycle.

13. The hydronic system as claimed in claim 12, wherein the control unit is configured to operate the heat pump unit selectively based on a cost and a schedule of operation of a power source for recharging the chilled water, when at least one of the volume of chilled water or the second outlet temperature has reached the respective predetermined limit, and the operation cycle is the off-peak operation cycle, the cost and the schedule of operation of the power source is defined in a look-up table configured in a database communicably coupled to the control unit.

14. The hydronic system as claimed in claim 12, wherein the control unit is configured to: determine a temperature of the chilled water routed from an enclosure via a second temperature sensor configured in a conduit connecting the cold storage tank and the enclosure, and operate the heat pump unit for recharging the chilled water within the cold storage tank, when the temperature of the chilled water reaches a maximum threshold value.

15. A method for operating a hydronic system, comprising: monitoring, by a control unit, a volume of hot water in a hot storage tank via a first set of flowmeters; monitoring, by the control unit, a first outlet temperature of the hot water within the hot storage tank via a first temperature sensor; operating, by the control unit, a heat pump unit for recharging the hot water within the hot storage tank, wherein the heat pump unit is operated when a respective predetermined limit is attained for at least one of the volume of hot water or the first outlet temperature; and determining, by the control unit, a time period required for recharging the volume of hot water, the time period determined based on the volume of hot water, the first outlet temperature, and an operation cycle, the operation cycle being at least an on-peak operation cycle or an off peak operation cycle, wherein determining the time period for recharging the volume of hot water comprises: determining, by the control unit, the operation cycle to be the on-peak operation cycle or the off-peak operation cycle based on one or more of day-ahead hourly prices, a temperature forecast, or a day-ahead greenhouse gas emissions forecast, and operating, by the control unit, the heat pump unit instantaneously for recharging the hot water within the time period, when at least one of the volume of hot water or the first outlet temperature has reached the respective predetermined limit, and the operation cycle is the on-peak operation cycle.

16. The method as claimed in claim 15, further comprising blending, by the control unit, the one or more of the day ahead hourly prices, the temperature forecast, or the day ahead greenhouse gas emissions forecast into a single hourly signal, and segmenting, by the control unit, the single hourly signal to on-peak and off-peak time periods.

17. The method as claimed in claim 15, further comprising: selectively routing, by the control unit, the hot water to an enclosure via a pump fluidically coupled to the hot storage tank and the enclosure; determining, by the control unit, a temperature of the hot water routed into a thermal distributor via a first temperature sensor configured in a conduit connecting the hot storage tank and the thermal distributor; and operating, by the control unit, the heat pump unit for recharging the hot water within the hot storage tank, when the temperature of the hot water reaches a minimum threshold value.

18. The method as claimed in claim 15, further comprising selectively operating, by the control unit, the heat pump unit based on a cost and a schedule of operation of a power source for recharging the hot water, when at least one of the volume of hot water or the first outlet temperature attains the respective predetermined limit, and the operation cycle is the off-peak operation cycle, the cost and the schedule of operation of the power source is defined in a look-up table configured in a database communicably coupled to the control unit.

19. The method as claimed in claim 15, further comprising: monitoring, by the control unit, a volume of chilled water in a cold storage tank via a second set of flowmeters; monitoring, by the control unit, a second outlet temperature of the chilled water within the cold storage tank via a second temperature sensor; operating, by the control unit, the beat pump unit for recharging the chilled water within the cold storage tank, wherein the heat pump unit is operated when a respective predetermined limit is attained for at least one of the volume of chilled water or the second outlet temperature; determining, by the control unit, a time period required for recharging the volume of chilled water, the time period determined based on the volume of chilled water, the second outlet temperature, and the operation cycle; and operating, by the control unit, the heat pump unit instantaneously for recharging the chilled water within the time period, when at least one of the volume of chilled water or the second outlet temperature attains the respective predetermined limit, and the operation cycle is the on-peak operation cycle.

20. The method as claimed in claim 19, further comprising selectively operating, by the control unit, the heat pump unit based on a cost and a schedule of operation of a power source for recharging the chilled water, when at least one of the volume of chilled water or the second outlet temperature attains the respective predetermined limit, and the operation cycle is the off-peak operation cycle, the cost and the schedule of operation of the power source is defined in a look-up table configured in a database communicably coupled to the control unit.