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(54) **COMMUNICATING THERMOSTAT RECOVERY ALGORITHM**

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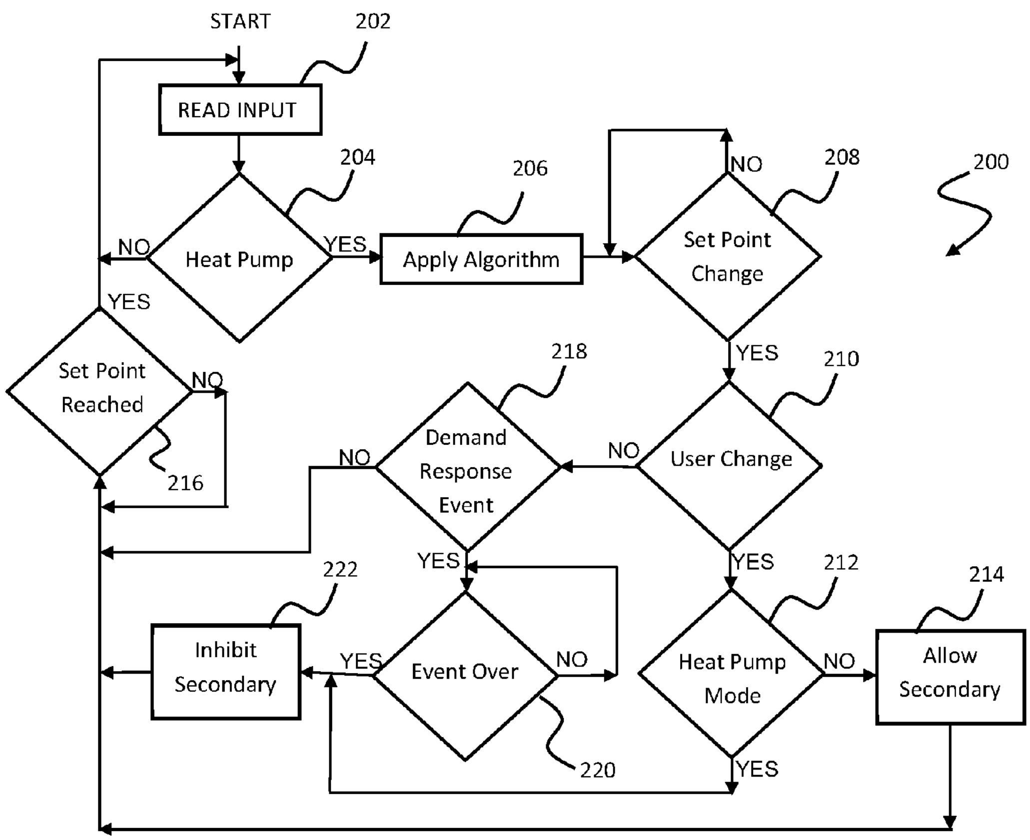
(57) **ABSTRACT**

The present subject matter relates methods and systems for operation of an HVAC system including a heat pump and a secondary energy source (electric or gas) where a utility's demand response server may issue demand response event instructions. Upon receipt of a demand response event instruction as set point for controlling the HVAC system may be changed and, upon expiration of the demand response event, the HVAC system is controlled so that operation of its secondary energy source is inhibited until recovery of the system to its user established set point is obtained.



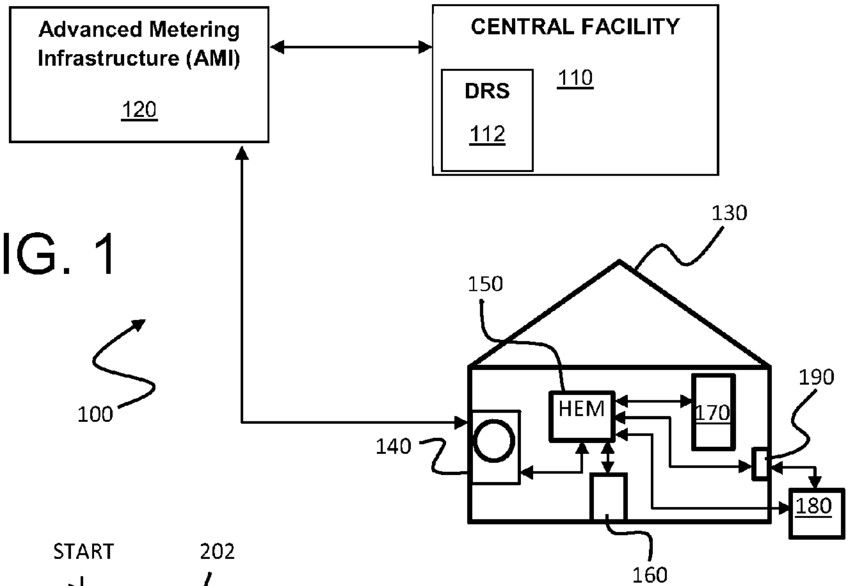

Advanced Metering Infrastructure (AMI)
120
CENTRAL FACILITY
DRS
112
110
130
150
190
HEM
170
100
140
180
160

FIG. 1

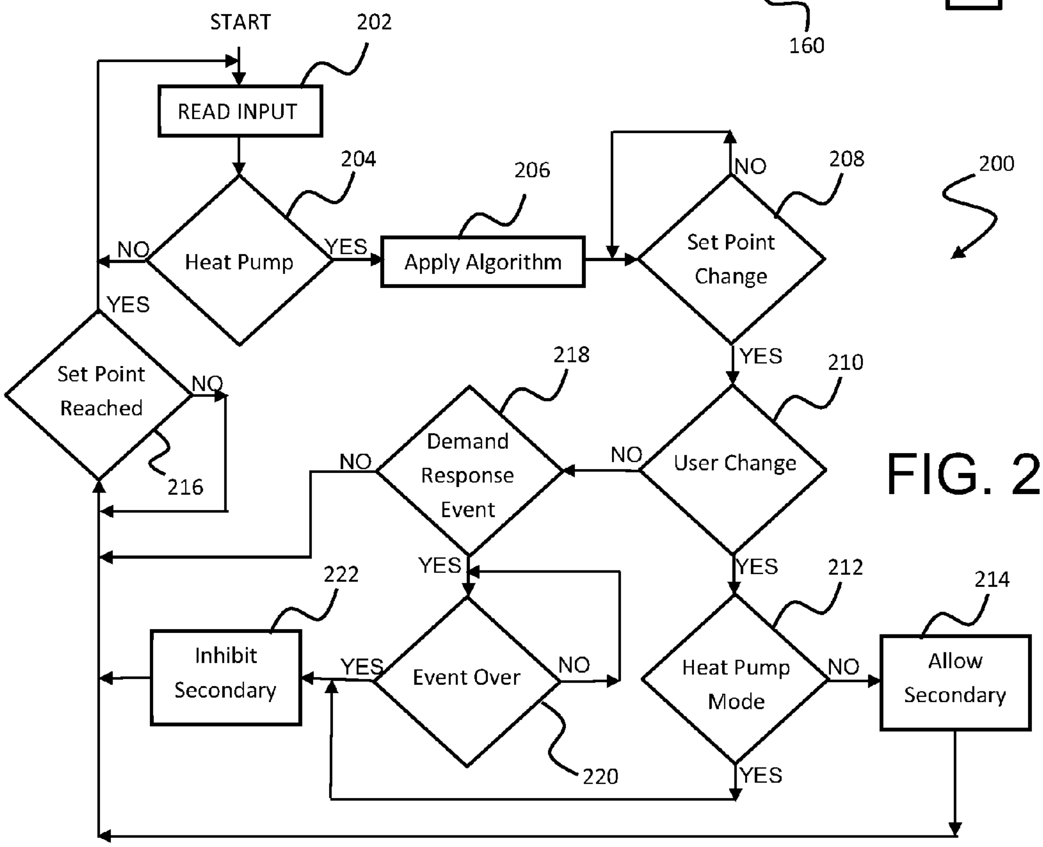

START
202
READ INPUT
204
206
208
200
NO
Heat Pump
YES
Apply Algorithm
NO
Set Point Change
YES
Set Point Reached
NO
216
218
210
Demand Response Event
NO
User Change
NO
YES
YES
212
222
214
Inhibit Secondary
YES
Event Over
NO
Heat Pump Mode
NO
Allow Secondary
220
YES

FIG. 2

COMMUNICATING THERMOSTAT RECOVERY ALGORITHM

FIELD OF THE INVENTION

[0001] The present subject matter relates to heating system control methodologies. More particularly, the present subject matter relates to methodologies for controlling a Heat Pump type heating, ventilation, and air conditioning (HVAC) system.

BACKGROUND OF THE INVENTION

[0002] Many manufacturers have started developing "smart" communicating thermostats. These thermostats are designed to communicate via various protocols including, for example, Zigbee, wifi, Bluetooth, Ethernet, and others, to gather information from a number of sources such as various websites accessed over the Internet, directly from utilities, etc.

[0003] Many utilities are introducing and/or already have in place time of use pricing where the price for electricity varies over the course of the day, depending on grid demand. The newly available "smart" communicating thermostats are designed to receive this time of use price (rate/tier) from the utility and to offset their temperature set point to help reduce energy consumption during higher cost periods. Required offsets (demand responses) may be established in a number of ways including, as offset required by the utility, set by the thermostat manufacturer, or programmed by a user. Generally such offsets vary but in exemplary configurations vary on the order of 2-8 degrees Fahrenheit.

[0004] Heat Pump HVAC systems are becoming more commonplace as they are more efficient than existing electric/gas systems. The heat pump system uses a small amount of energy to transfer heat from one location to another. Such systems will attempt to use the heat pump alone to regulate the temperature set point of the home however if the set point cannot be reached or a large difference exists between the actual set point and the programmed set point, the heat pump HVAC system will utilize its backup heating source, generally electric and/or gas, in order to meet the programmed set point. Generally the backup heating sources will respond when the difference between the actual set point and the programmed set point is around 3-4 degrees.

[0005] When a heat pump HVAC system is used with a smart communicating thermostat, the user set point is adjusted during a demand response event. A problem may occur, however, when the demand response event is over and the set point suddenly jumps **2-8** degrees Fahrenheit back to the user's programmed set point. The heat pump system is not able to quickly recover so it defaults to the energy intensive (and expensive) backup heat. The cost of electricity could still be quite high and the user, often times, would prefer to use the heat pump to reach their set temperature.

[0006] In view of such recognized issues, it would be advantageous to provide a mechanism that would address operational characteristics of the HVAC system when correcting (recovering) from relatively large changes in set points for heat pump HVAC systems.

BRIEF DESCRIPTION OF THE INVENTION

[0007] Additional aspects and advantages of the invention will be set forth in part in the following description, or may be apparent from the description, or may be learned through practice of the invention.

[0008] The present subject matter relates to methods for managing energy usage in an HVAC system that include a heat pump and a secondary energy source. According to such method the HVAC system is monitored for a change in a temperature set point. If such monitoring determines that a detected change in temperature set point is due to a demand response event then the method calls for inhibiting operation of the secondary energy source.

[0009] The present subject matter also relates to an energy management system. Such a system includes a central facility comprising a demand response server, an HVAC system comprising a heat pump and a secondary energy source, a thermostat configured to control operation of said HVAC system, and a communications system coupling the thermostat and the demand response server for communications there between. In such systems, the demand response server is configured to transmit instructions to the thermostat to change its set point, and if such instructions are received, the HVAC system is inhibited from operating its secondary energy source.

[0010] These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures, in which:

[0012] FIG. **1** provides an overview of a Demand Response Managements System (DRMS) in accordance with an exemplary embodiment of the present subject matter; and

[0013] FIG. **2** provides a flow chart of an exemplary method in accordance with the present subject matter.

[0014] Repeat use of reference characters throughout the present specification and appended drawings is intended to represent same or analogous features or elements.

DETAILED DESCRIPTION OF THE INVENTION

[0015] Reference now will be made in detail to embodiments of the invention, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

[0016] The present subject matter is directed to methodology for operating a heating system. In some embodiments the methodology may be carried out by way of a software algorithm stored in the memory of a "smart" thermostat which will control a heat pump HVAC system to provide an energy efficient temperature recovery after a demand response (price or load control) event.

[0017] With initial reference to FIG. **1**, there is provided an overview of a Demand Response Managements System (DRMS) **100** in accordance with an exemplary embodiment of the present subject matter. In accordance with exemplary embodiments of the present subject matter, Demand Response Managements System (DRMS) **100** includes a Central Facility **110** that, from time to time may send, by way of a Demand Response Server (DRS) **112**, requests to modify overall system usage demand. Such requests are sent from Demand Response Server **112** as system level signals by way of DRS **112** to Advanced Metering Infrastructure (AMI) **120** and then to individual homes representatively illustrated as home **130**. In accordance with the present subject matter, in some instance requests from DRS **112** may be routed via Home Energy Management (HEM) system **150** located in association with individual homes or, in the present case may be routed directly or indirectly to a smart thermostat **190** within home **130**.

[0018] Those of ordinary skill in the art will appreciate that AMI **120** may correspond to a vast number of devices including transmission lines over which power and possibly communications signals may flow to a large number of individual homes and other facilities or locations. AMI **120** may also include various communications related features including wireless communications or power line communications systems that may be employed to exchange information between individual home or other locations and a central facility relating to consumption and control of such utilities all in accordance with well-known and commonly used AMI arrangements as are fully understood by those of ordinary skill in the art. Such communications systems may also be used in conjunction with the present subject matter to transmit demand request signals from Demand Response Server **112** to individual home energy management systems.

[0019] It should also be appreciated that while the present disclosure is particularly directed to home heating system management and control, such may also be applied to heating system management for other facilities including without limitation, commercial and public facilities whose energy consumption may also be controlled at least in part based on the technology of the present subject matter. Thus in the context of the present disclosure, the use of the terms "home" or "house" is fully intended to include other structures whether used as a residential facility or for some other purpose as long as such facility contains or has associated therewith, heating system management devices including smart thermostats and or HEM systems.

[0020] With continued reference to FIG. **1**, there are representatively illustrated home **130** which is supplied with electrical power from a utility and includes associated therewith systems providing bidirectional communications with Central Facility **110** by way of AMI **120**. In an exemplary arrangement, home **130** is provided with an electric utility meter **140** containing metrology components as well as communication components that operate to monitor and report energy consumption information to Central Facility **110**. Home **130** may also be provided with a Home Energy Management (HEM) system **150** configured to receive instructions from Central Facility **110**, or, more specifically, from Demand Response Server (DRS) **112**. Such HEM systems **150** may then provide instructions to individual appliances associated with the individual home **130**. In an alternative configuration, HEM systems may be incorporated directly in electric utility meters **140** or, as illustrated, may correspond to stand alone units. Further it should be appreciated that while HEM system **150** is illustrated as connected to various home appliances and devices including representatively, dryer **160**, refrigerators **170**, HVAC system **180**, and smart thermostat **190**, such connections may correspond to either wired or wireless connections over which control signals may be uni-directionally or bi-directionally transmitted.

[0021] In an exemplary arrangement of the present subject matter, each home appliance **160**, **170**, **180** may be controlled by HEM **150** in accordance with commands received from DRS **112**. In addition, DRS **112** may also send commands directly or indirectly by way of HEM **150**, instructing smart thermostat **190** to adjust its temperature set point, that is, to offset its temperature set point to help reduce energy consumption during selected periods. As previously noted, such periods may correspond to more expensive time of use periods but could also be based on other consideration including emergency periods resulting from unexpected loss of utility generating capacity. Events causing such instructions to be given, regardless of the cause, are referred to as demand response events.

[0022] With continued reference to FIG. **1**, it should be appreciated that HVAC **180** may correspond in general to any type system but for purposes of the present subject matter, HVAC **180** is a heat pump type system having particular operational aspects that require proper attention in order to maximize energy savings. The present subject matter addresses such issues.

[0023] As previously noted, heat pump HVAC systems generally include electric or gas secondary systems that are designed to assist the heat pump at particular times. In general operation, heat pumps are not designed to quickly accommodate significant increases in demand, that is, significant increase in the set point of their controlling thermostats. If, for whatever reason, the thermostat set point is raised above some pre-established amount above the current temperature, the secondary (supplemental) heat system will ordinarily be activated.

[0024] In accordance with the present subject matter, an algorithm has been developed to control operation of a smart thermostat whereby such secondary heating systems may be inhibited under certain circumstances from operating in order to save the user from the higher cost of their operation. In accordance with the present subject matter, it has been found that a particular advantage of such circumstance is found in association with a demand response event. There are events that occur by direction of the utility. In accordance with the present subject matter, DRS **112** may transmit instructions directly to home smart thermostat **190** directly or such signals may be relayed to smart thermostat **190** through HEM **150**. In some embodiments of the present subject matter, software embodying the decision making algorithm to be described later with respect to FIG. **2**, is maintained within smart thermostat **190** while in other embodiments of the present subject matter, such software may be embodied within HEM **150**. In either embodiment, additional functionality for smart thermostat **190** is provided resulting in energy and cost savings following demand response events.

[0025] With present reference to FIG. **2**, there is illustrated a flow chart **200** illustrating exemplary steps to carrying out a process in accordance with the present subject matter. The present exemplary process starts at step **202** where a reading is made to determine at step **204** whether the thermostat is connected to a heat pump type HVAC system. In exemplary configurations such a determination may be made by having the software examine whether a manually operable configuration switch has been set on the thermostat during installation thereof indicating that the thermostat is being used with a heat pump. In alternative installations, there may be provided manual entry functionality associated with the thermostat to allow a user to program necessary information into the thermostat.

[0026] If the determination is made that the thermostat is being used in a heat pump system, a decision is made in step **206** to apply the algorithm of the present subject matter. The process then goes to step **208** where it loops (waits) until there is detected a set point change. That is, the process determines that, for whatever reason, a change in thermostat setting has been made. At step **210**, the process, in accordance with the present subject matter, seeks to determine what caused the set point change and to decide what steps should then be taken to return the heat pump HVAC system back to the user's set temperature in an energy friendly and cost effective way.

[0027] When a change in set point occurs, such change ordinarily will be due to one of three reasons: 1) the programming schedule, 2) the user, or 3) as a result of a demand response event. Demand response events may generally correspond to price or load control events initiated by the utility company.

[0028] Following determination that a set point change has occurred at step **208**, the algorithm then determines at step **210** whether such change came from a user change. If such is the case, in certain embodiments of the present subject matter, the user may then indicate at step **212** whether the system should be operated in "Heat Pump" mode. That is, the user is given the choice of operating the HVAC system in heat pump mode for maximum energy savings and, if that is the user's decision at step **212**, the secondary heat source is inhibited at step **222** and the HVAC system is operated (step **216**) until the original set point is reached using only the heat pump to provide the necessary energy.

[0029] Alternatively the user may decide at step **212** not to operate in heat pump mode so that at step **214** the operation of secondary source heating is permitted until, at step **216**, the original set point is reached. Of course costs associated with such decision may be higher but may also result in faster return to the original thermostat set point.

[0030] If at step **210** the algorithm determines that the set point change found at step **208** is not a user change, the algorithm determines at step **218** whether the change is in response to a demand response event. If this is not the case, the algorithm proceeds to step **216** where again the heat pump is operated until the desired set point is reached. On the other hand, if at step **218** the algorithm determines that the set point has been changed in response to a demand response event, the algorithm causes a delay at step **210** until such time as the demand response event is over. Following that delay period any secondary heat sources are inhibited at step **222** and the process returns again to step **216** where the heat pump alone is used to return the thermostat to its user original temperature.

[0031] In this manner a new functionality has been provided to smart thermostats directly or alternately by way of incorporation of software within home energy management (HEM) devices that allows them to determine whether a demand response has caused a set point change and, if so, to limit costs to the consumer for returning to previous thermostat set points by limiting their HVAC systems to operation of their heat pump only. It may be noticed from the above that the algorithm of the present subject matter does not respond to programming schedule changes by design.

[0032] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A method for managing energy usage in an HVAC system comprising a heat pump and a secondary energy source, comprising:
- monitoring the HVAC system for a change in temperature set point;
- determining whether a detected change in temperature set point is due to a demand response event; and
- inhibiting operation of the secondary energy source if the temperature set point are due to a demand response event.

2. A method as in claim **1**, further comprising:
- delaying operation the heat pump until the demand response event has expired.

3. A method as in claim **1**, further comprising:
- determining whether a detected change in temperature set point is due to a user change;
- selecting whether to operate the system using only the heat pump; and
- allowing operation of the secondary energy source if a selection is made to not operate using only the heat pump.

4. A method as in claim **1**, wherein monitoring for a change in temperature set point is conducted by a thermostat.

5. A method as in claim **4**, wherein the steps of determining and inhibiting are performed within the thermostat.

6. A method as in claim **4**, wherein the steps of determining and inhibiting are performed within a home energy management device.

7. The method of claim **1**, wherein the secondary energy source corresponds to at least one of an electric and gas energy source.

8. An energy management system, comprising:
- a central facility comprising a demand response server;
- an HVAC system comprising a heat pump and a secondary energy source;
- a thermostat configured to control operation of said HVAC system; and
- a communications system coupling said thermostat and said demand response server for communications there between,
- wherein said demand response server is configured to transmit instructions to said thermostat to change its set point, and wherein said HVAC system is inhibited from operating its secondary energy source following receipt of thermostat change instructions from said demand response server.

9. A system as in claim **8**, wherein said thermostat is configured to inhibit operation of said secondary energy source.

10. A system as in claim **9**, wherein the transmitted instructions correspond to a demand response event and said thermostat is configured to inhibit operation of said HVAC system until said demand response event has expired.

11. A system as in claim **8**, further comprising:

a home energy management device,

wherein said home energy management device is configured to inhibit operation of said secondary energy source.

12. A system as in claim **11**, wherein the transmitted instructions correspond to a demand response event and said home energy management device is configured to inhibit operation of said HVAC system until said demand response event has expired.

13. A system as in claim **8**, wherein said secondary energy source corresponds to at least one of an electric and gas energy source.

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