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(54) METHOD FOR OPERATING AN HVAC SYSTEM

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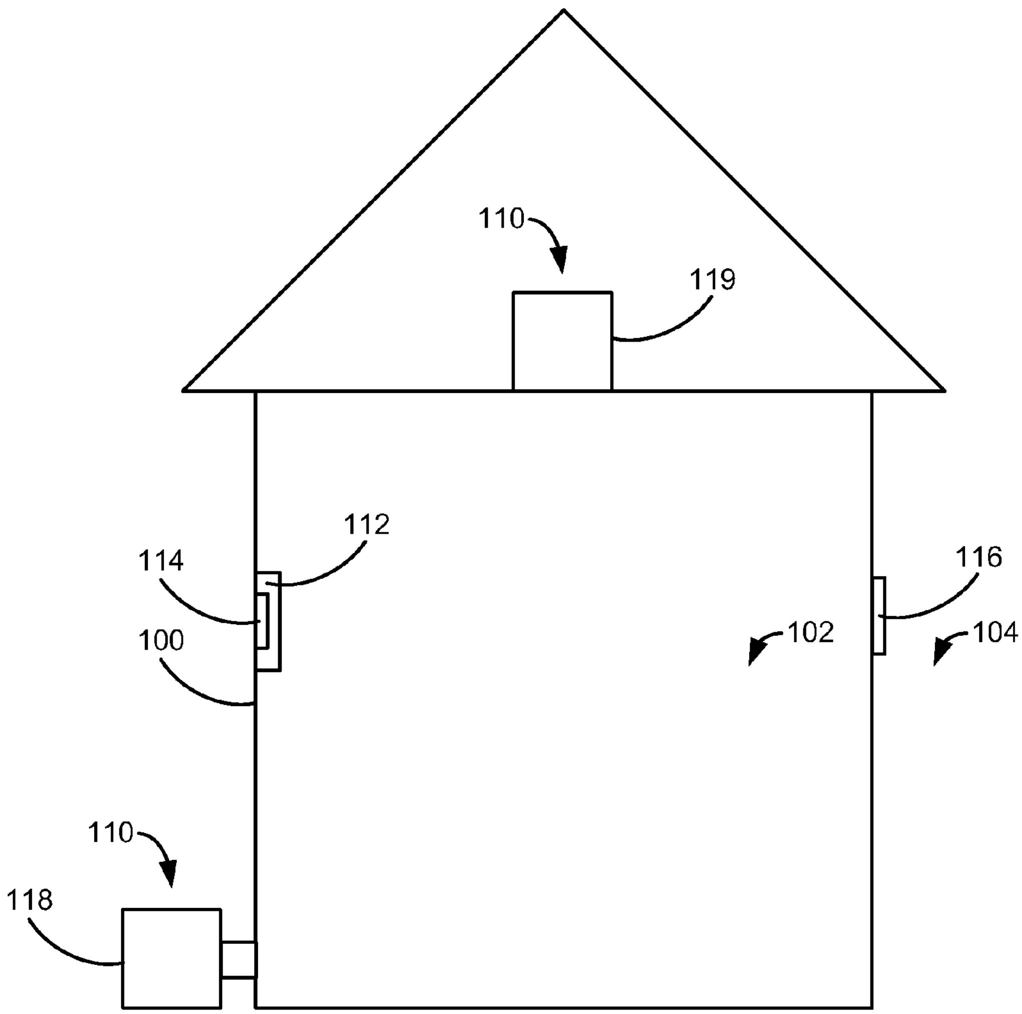
(57) ABSTRACT

A method for operating an HVAC system is provided. The method includes providing a model for an indoor temperature, y, of a building, providing predicted future outdoor temperatures, and calculating an activation time or an adjustment time interval for the HVAC system utilizing at least the model for y and the predicted future outdoor temperatures. Operation of the HVAC system can be improved with the activation time or the adjustment time interval.



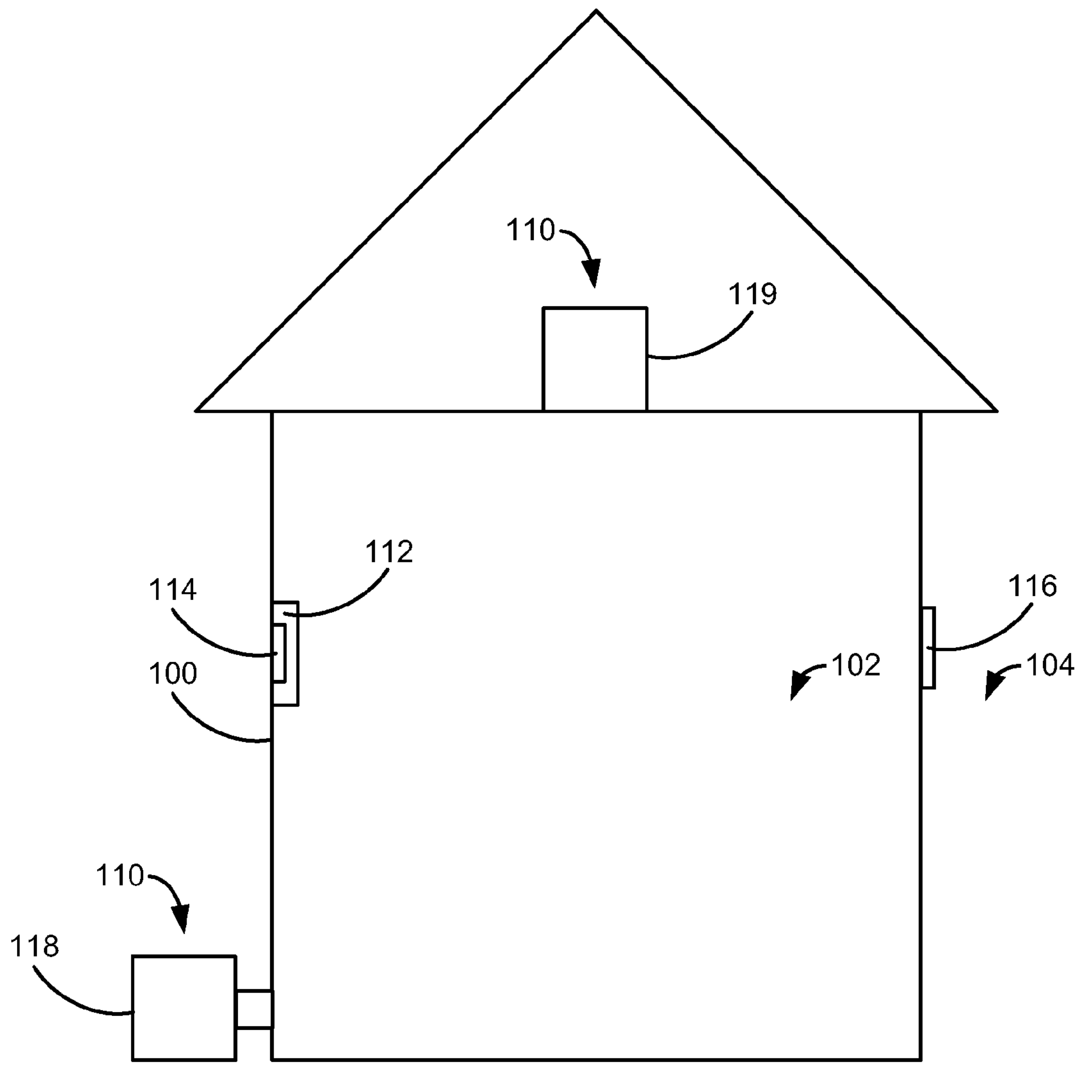


FIG. 1

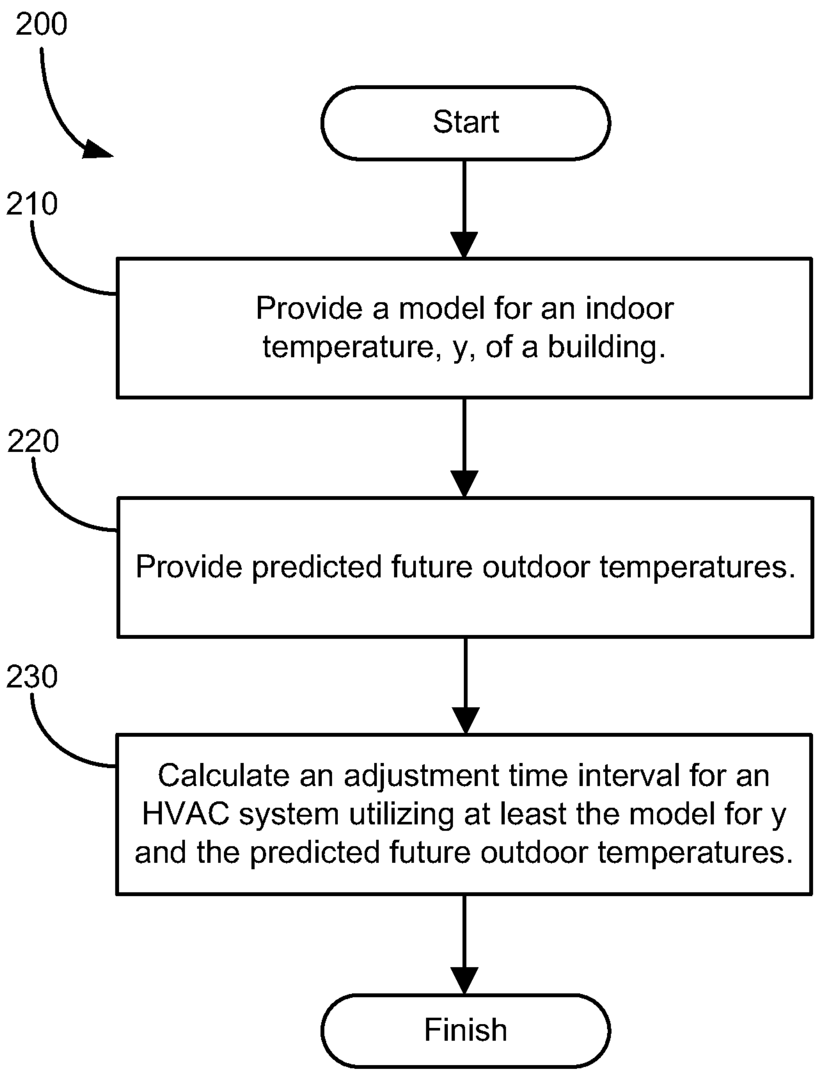

200
Start
210
Provide a model for an indoor temperature, y, of a building.
220
Provide predicted future outdoor temperatures.
230
Calculate an adjustment time interval for an HVAC system utilizing at least the model for y and the predicted future outdoor temperatures.
Finish

FIG. 2

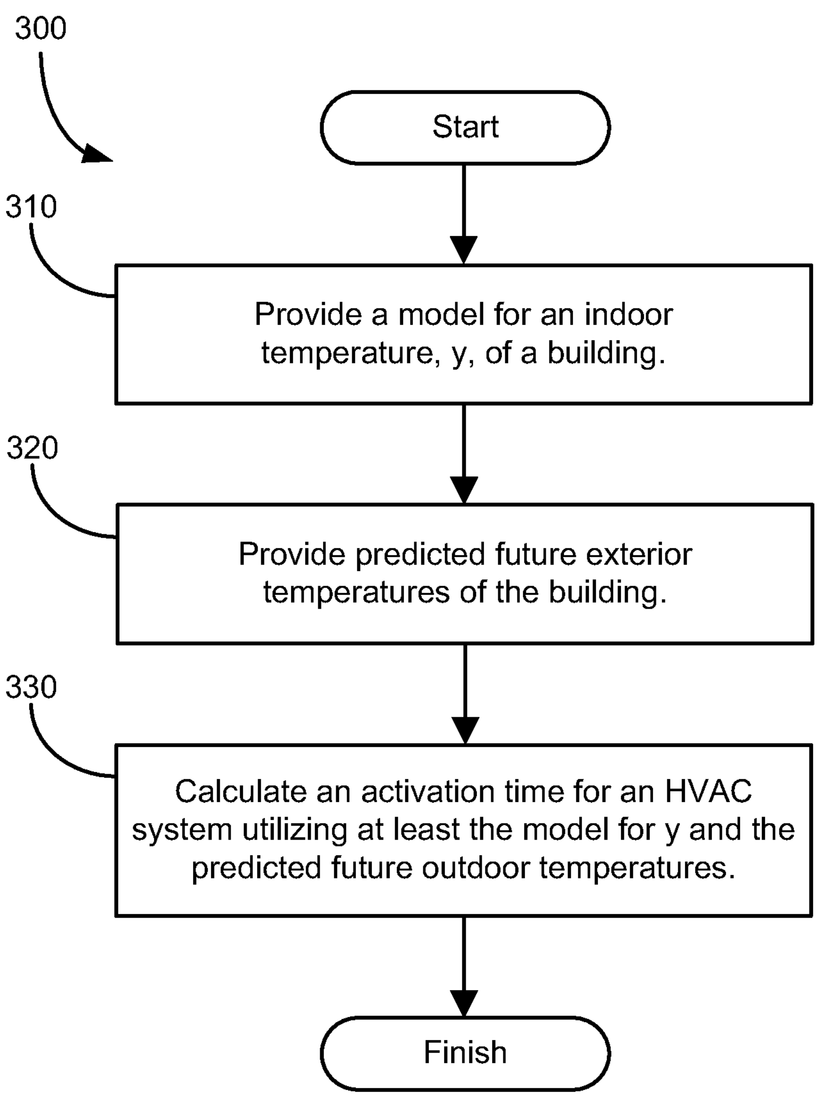

300
Start
310
Provide a model for an indoor temperature, y, of a building.
320
Provide predicted future exterior temperatures of the building.
330
Calculate an activation time for an HVAC system utilizing at least the model for y and the predicted future outdoor temperatures.
Finish

FIG. 3

METHOD FOR OPERATING AN HVAC SYSTEM

FIELD OF THE INVENTION

[0001] The present subject matter relates generally to HVAC systems, such as residential or commercial HVAC systems, and methods for operating the same.

BACKGROUND OF THE INVENTION

[0002] Commercial and residential buildings or structures are commonly equipped with systems for regulating the temperature of air within the building for purposes of e.g., comfort, protection of temperature sensitive contents, etc. Sometimes referred to as heating, ventilating, and air conditioning or HVAC systems, such systems typically include one or more components for changing the temperature of air (i.e. air treatment components as used herein) along with one or more components for causing movement of air (i.e. blowers as used herein). For example, a refrigerant based heat pump may be provided for heating or cooling air. Alternatively, or in addition thereto, electrically resistant heat strips and/or gas burners may be provided for heating air. One or more blowers or fans may be provided for causing the heated or cooled air to circulate within the building in an effort to treat all or some controlled portion of air in the building. Ducting and vents may be used to help distribute and return air from different rooms or zones within the building.

[0003] During heating and/or cooling of air, HVAC systems consume energy. In particular, HVAC systems' energy consumption can account for more than fifty percent of a building's total energy consumption. Despite consuming large amounts of energy, HVAC systems are generally set to a specific operating temperature, and the HVAC systems operate to maintain an associated building at the specific operating temperature.

[0004] Certain HVAC systems also include features for switching the specific operating temperature between a high set temperature and a low set temperature to conserve energy. In particular, such HVAC systems can be programmed to switch between the high set temperature and the low set temperature at specific times. However, switching between the high and low set temperatures can create certain problems. In particular, HVAC systems require a certain amount of time to heat and or cool the building. Thus, the associated building's temperature can lag behind the specific operating temperature of the HVAC system, and such temperature lag can be uncomfortable or unpleasant to occupants of the associated building.

[0005] Accordingly, methods for operating HVAC systems that can account for temperature lags between various operating temperatures of the HVAC system would be useful. In particular, methods for operating HVAC systems that that can preheat and/or precool an associated building in order to account for temperature lags between various operating temperatures of the HVAC system would be useful.

BRIEF DESCRIPTION OF THE INVENTION

[0006] The present subject matter provides a method for operating an HVAC system. The method includes providing a model for an indoor temperature, y, of a building, providing predicted future outdoor temperatures, and calculating an activation time or an adjustment time interval for the HVAC system utilizing at least the model for y and the predicted future outdoor temperatures. Operation of the HVAC system can be improved with the activation time or the adjustment time interval. 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.

[0007] In a first exemplary embodiment, a method for operating an HVAC system is provided. The HVAC system is configured for cooling air within a building, heating air within the building, or both. The method includes providing a model for an indoor temperature, y, of the building, providing predicted future outdoor temperatures, and calculating an adjustment time interval for the HVAC system utilizing at least the model for y and the predicted future outdoor temperatures.

[0008] In a second exemplary embodiment, a method for operating an HVAC system is provided. The HVAC system is configured for cooling air within a building, heating air within the building, or both. The method includes providing a model for an interior temperature, y, of the building, providing predicted future exterior temperatures of the building, calculating an activation time for the HVAC system utilizing at least the model for y and the predicted future outdoor temperatures.

[0009] 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

[0010] 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.

[0011] FIG. **1** provides a schematic representation of an exemplary building as may be used with the present subject matter.

[0012] FIG. **2** illustrates a method for operating an HVAC system according to an exemplary embodiment of the present subject matter.

[0013] FIG. **3** illustrates a method for operating an HVAC system according to an additional exemplary embodiment of the present subject matter.

DETAILED DESCRIPTION

[0014] 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.

[0015] FIG. **1** provides a schematic representation of an exemplary building **100** as may be used with the present subject matter. Building **100** includes an HVAC system **110**.

HVAC system **110** is configured for providing heated air to building **100**, providing cooled air to building **100**, or both. In particular, building **100** defines an inside or interior **102**. Interior **102** of building **100** is separated or segregated from an exterior or outside **104**. HVAC system **110** can heat and/or cool interior **102** of building **100**.

[0016] As will be understood by those skilled in the art, HVAC system **110** can be any suitable mechanism for heating and/or cooling interior **102** of building **100**. In the exemplary embodiment shown in FIG. **1**, HVAC system **110** includes an air treatment component **118** for heating and/or cooling air and at least one blower **119** for directing heated and/or cooled air into interior **102** of building **100**, e.g., via a duct system within building **100**. As an example, air treatment component **118** can be a heat pump that provides for both heating and cooling of the air circulated by blower **119** of HVAC system **110**. Alternatively, air treatment component **118** of HVAC system **110** can be a heater based on e.g., one or more gas burners or electric strips.

[0017] HVAC system **110** also includes a thermostat **112** for controlling HVAC system **110** and measuring a temperature of interior **102**. A user can set an operating temperature of HVAC system **110** with thermostat **112**, and HVAC system **110** can operate to maintain interior **102** of building **100** at the operating temperature. Further, HVAC system **110** includes a temperature sensor **116**, such as a thermocouple or thermistor, for measuring a temperature of exterior **104** of building **100**.

[0018] HVAC system **110** also includes a processing device or controller **114**, e.g., positioned within thermostat **112**. Various operational processes or methods for operating HVAC system **110** can be programmed into controller **114**. As used herein, "controller" may include a memory and one or more microprocessors, CPUs or the like, such as general or special purpose microprocessors operable to execute programming instructions or micro-control code associated with operation of HVAC system **110**. The memory may represent random access memory such as DRAM, or read only memory such as ROM or FLASH. In one embodiment, the processor executes programming instructions stored in memory. The memory may be a separate component from the processor or may be included onboard within the processor.

[0019] It should be understood that the shape and configuration of building **100** shown in FIG. **1** is provided by way of example only. Buildings having different shapes, configurations, different numbers of rooms, hallways, etc.—both residential and commercial—may be used with the present subject matter. Further, the location of HVAC system **110** relative to building **100** is also provided by way of example only.

[0020] As will be understood by those skilled in the art, HVAC system **110** can operate to maintain building **100** at a first operating temperature when building **100** is unoccupied. Conversely, HVAC system **110** can operate to maintain building **100** at a second operating temperature when building **100** is occupied. Controller **114** can adjust HVAC system **110** between the first and second operating temperatures, e.g., in order to conserve energy and/or reduce operating costs of HVAC system **110**. However, the first operating temperature can be uncomfortable, e.g., too hot or too cold, to occupants of building **100** relative to the second operating temperature.

[0021] HVAC system **110** requires time to heat and/or cool interior **102** of building **100** and adjust a temperature of interior **102**. As discussed in greater detail below, the present subject matter provides methods for operating an HVAC system, such as HVAC system **110**. Such methods can assist with improving performance of HVAC system **110**, e.g., during heating and/or cooling of interior **102** of building **100** between the first and second operating temperatures.

[0022] FIG. **2** illustrates a method **200** for operating an HVAC system according to an exemplary embodiment of the present subject matter. Method **200** can be used to operate any suitable HVAC system, such as HVAC system **110** (FIG. **1**). As an example, controller **114** of HVAC system **110** can be programmed to implement method **200**. Utilizing method **200**, an adjustment time interval for HVAC can be calculated. The adjustment time interval can assist with improving operation of HVAC system **110** as discussed in greater detail below.

[0023] At step **210**, a model for an indoor temperature, y, of building **100** is provided. The model for y can be programmed into controller **114** such that controller **114** can calculate a predicted future indoor temperature of building **100**, e.g., a predicted future temperature of interior **102**. The model for y can utilize any suitable input to calculate y. For example, y can be calculated based at least in part upon a previous indoor temperature of building **100**, a previous outdoor temperature of building **100**, and/or a previous operational state of HVAC system **110**, e.g., whether HVAC system **110** is on or off.

[0024] The model for y can be any suitable model for simulating or modeling the heat dynamics of building **100**. As an example, the model for y can be a second order linear model, e.g., such that the model for y is given as

$$y_k=a_1y_{k-1}+a_2y_{k-2}+b_1v_{k-1}+b_2u_{k-1}$$

[0025] where

[0026] y_k is an indoor temperature of building **100** at time k,

[0027] y_{k-1} is an indoor temperature of building **100** at time k−1,

[0028] y_{k-2} is an indoor temperature of building **100** at time k−2,

[0029] v_{k-1} is an outdoor temperature at time k−1,

[0030] u_{k-1} is an operating state of HVAC system **110** at time k−1, and

[0031] a_1, a_2, b_1, and b_2 are constants.

As will be understood by those skilled in the art, the model for y provided above is a discrete-time auto-regressive model with exogenous inputs, and constants a_1, a_2, b_1, and b_2 can be determined utilizing recursive least-square techniques or any other suitable technique. As an example, controller **114** can receive indoor temperature measurements from thermostat **112**, outdoor temperature measurements from temperature sensor **116**, and operating states from HVAC system **110** over time and calculate constants a_1, a_2, b_1, and b_2 in order to identify the model for y.

[0032] The model for y provided above can also be provided as a state space model. Thus, the model for y can be given as

$$X_{k+1}=AX_k+BU_k$$

[0033] where

$$X_k=[y_k y_{k-1}]^T,$$

and

$$U_k=[v_k u_k]^T.$$

As discussed above, the model for y can be any suitable model in alternative exemplary embodiments. Thus, the model provided above is not intended to limit the present subject matter in any aspect and is provided by way of example only.

[0034] At step **220**, predicted future outdoor temperatures are provided. As an example, controller **114** can receive the predicted future outdoor temperatures, e.g., predicted future temperatures of exterior **104** of building **100**, at step **220**. The predicted future outdoor temperatures can come from any suitable source. For example, the predicted future outdoor temperatures can be based on weather forecast data or historical weather data.

[0035] As an example, weather forecast data generally includes a daily maximum temperature and a daily minimum temperature. Further, outdoor temperatures generally have a sinusoidal shape between the daily maximum temperature and the daily minimum temperature. Thus, the predicted future outdoor temperatures can be provided using the following:

$$f(t) = \begin{cases} \frac{T_{max}(k)+T_{min}(k)}{2} - \frac{T_{max}(k)-T_{min}(k)}{2}\cos\left(\frac{\pi(t-t_{min}(k))}{t_{max}(k)-t_{min}(k)}\right) & t \in [t_{min}(k), t_{max}(k)) \\ \frac{T_{max}(k)+T_{min}(k+1)}{2} + \frac{T_{max}(k)-T_{min}(k+1)}{2}\cos\left(\frac{\pi(t-t_{max}(k))}{t_{min}(k+1)-t_{max}(k)}\right) & t \in [t_{max}(k), t_{min}(k+1)) \end{cases}$$

[0036] where

[0037] $T_{max}(k)$ is a maximum temperature on day k,

[0038] $T_{min}(k)$ is a minimum temperature on day k,

[0039] $t_{max}(k)$ is a time of day for $T_{max}(k)$, and

[0040] $t_{min}(k)$ is a time of day for $T_{min}(k)$.

Utilizing the above formula, the predicted future outdoor temperatures can be provided throughout the day despite only having the daily maximum temperature and the daily minimum temperature from the weather forecast data. As discussed above, the predicted future outdoor temperatures can be determined in any suitable manner. Thus, the formula provided above is provided by way of example only and is not intended to limit the present subject matter.

[0041] At step **230**, the adjustment time interval for HVAC system **110** is calculated. The adjustment time interval can correspond to a period of time required for HVAC system **110** to adjust an indoor temperature of building **100** from an initial temperature, T_0, to a final temperature, T_f, where T_0 and T_f are unequal. Thus, HVAC system **110** can heat and/or cool interior **102** of building **100** between T_0 and T_f within the adjustment time interval.

[0042] As an example, controller **114** can calculate the adjustment time interval at step **230** utilizing at least the model for y of step **210** and the predicted future outdoor temperatures of step **220**. In particular, controller **114** can calculate the adjustment time interval with the following:

$$y_f = CA^k x_{k_0} + \sum_{i=0}^{N-1} CA^{N-i-1} BU_i$$

-continued

where

$$C = [1 \quad 0],$$

$$A = \begin{bmatrix} a_1 & a_2 \\ 1 & 0 \end{bmatrix},$$

$$B = \begin{bmatrix} b_1 & b_2 \\ 1 & 0 \end{bmatrix},$$

$$x_{k_0} = \begin{bmatrix} y_{k_0} \\ y_{k_0-1} \end{bmatrix},$$

$$U_i = \begin{bmatrix} v_i \\ u_i \end{bmatrix},$$

[0043] and

[0044] $N=k_f-k_0$ where k_0 is an initial time at which the indoor temperature of building **100** is an initial temperature, y_{k_0}, and k_f is a final time at which the indoor temperature of building **100** is a final temperature, y_{k_f}.

Further, utilizing the above process, the adjustment time interval can be calculated in order to minimize energy consumption of HVAC system **110**. For example, the adjustment time interval can be calculated with the following:

$$T \leftarrow CA^N x_{k_0} + \sum_{i=0}^{N-1} (CA^{N-i-1}B)_1 v_i$$

$$k^* \leftarrow k_f - 1$$

while $T < T_f$ do

$$T \leftarrow T + (CA^{k_f-k^*}B)_2$$

$$k^* \leftarrow k^* - 1$$

end while

[0045] where

[0046] T is the indoor temperature of building **100** and

[0047] k* is a time value.

With the adjustment time interval calculated at step **230**, operation of HVAC system **110** can be improved. For example, controller **114** can determine an initial time, k* or t_0, at which the indoor temperature of building **100** is T_0 and a final time, t_f, at which the indoor temperature of building **100** is T_f. The adjustment time interval can correspond to the difference between t_0 and t_f. Controller **114** can also activate HVAC system **110** at t_0 such the indoor temperature of building **100** is T_f at t_f. In such a manner, method **200** can assist with preheating and/or precooling interior **102** of building **100**.

[0048] As will be understood by those skilled in the art, controller **114** can be programmed to adjust the operating temperature of HVAC system **110** between T_0 and T_f. As an example, HVAC system **110** can operate to maintain building **100** at one of T_0 or T_f when building **100** is unoccupied. Conversely, HVAC system **110** can operate to maintain building **100** the other of T_0 and T_f when building **100** is occupied. Controller **114** can adjust HVAC system **110** between T_0 and T_f, e.g., in order to conserve energy and/or reduce operating costs of HVAC system **110**.

[0049] With the activation time interval calculated at step **230**, controller **114** can operate HVAC system **110** to pre-heat and/or pre-cool interior **102** of building **100** between T_0 and

T_f. Such pre-heating or pre-cooling can increase comfort of occupants within building **100** and improve satisfaction of such occupants with HVAC system **110**. For example, before such occupants enter or return to building **100**, controller **114** can operate to adjust interior **102** of building **100** from T_0 to T_f such the building **100** is pre-heated or pre-cooled and comfortable for such occupants.

[0050] FIG. **3** illustrates a method **300** for operating an HVAC system according to an additional exemplary embodiment of the present subject matter. Method **300** can be used to operate any suitable HVAC system, such as HVAC system **110** (FIG. **1**). As an example, controller **114** of HVAC system **110** can be programmed to implement method **300**. Utilizing method **300**, an activation time for HVAC system **110** can be calculated. The activation time can assist with improving operation of HVAC system **110** as discussed in greater detail below.

[0051] Like in step **210** of method **200** (FIG. **2**), a model for an indoor temperature, y, of building **100** is provided at step **310**. The model for y provided in step **310** can be any suitable model for y, such as the model for y discussed above in method **200**. The model for y can be programmed into controller **114** such that controller **114** can calculate a predicted future indoor temperature of building **100**, e.g., a predicted future temperature of interior **102**.

[0052] Like in step **220** of method **200** (FIG. **2**), predicted future outdoor temperatures are provided at step **320**. The predicted future outdoor temperatures can come from any suitable source, such as described above in method **200**. As an example, controller **114** can receive the predicted future outdoor temperatures, e.g., predicted future temperatures of exterior **104** of building **100**, at step **320**.

[0053] At step **330**, the activation time for HVAC system **110** is calculated. The activation time can correspond to a time at which HVAC system **110** is activated in order to adjust an indoor temperature of building **100** from an initial temperature, T_0, to a final temperature, T_f, where T_0 and T_f are unequal. Thus, HVAC system **110** can heat and/or cool interior **102** of building **100** between T_0 and T_f by activating HVAC system **110** at the activation time.

[0054] As an example, controller **114** can calculate the activation time at step **330** utilizing at least the model for y of step **310** and the predicted future outdoor temperatures of step **320**. In particular, controller **114** can calculate the activation time with the following:

$$y_f = CA^k x_{k_0} + \sum_{i=0}^{N-1} CA^{N-i-1} BU_i$$

where

$$C = [\,1 \quad 0\,],$$

$$A = \begin{bmatrix} a_1 & a_2 \\ 1 & 0 \end{bmatrix},$$

$$B = \begin{bmatrix} b_1 & b_2 \\ 1 & 0 \end{bmatrix},$$

$$x_{k_0} = \begin{bmatrix} y_{k_0} \\ y_{k_0-1} \end{bmatrix},$$

$$U_i = \begin{bmatrix} v_i \\ u_i \end{bmatrix},$$

[0055] and

[0056] $N=k_f-k_0$ where k_0 is the activation time at which the indoor temperature of building **100** is an initial temperature, y_{k_0}, and k_f is a final time at which the indoor temperature of building **100** is a final temperature, y_{k_f}.

Further, utilizing the above process, the activation time can be calculated in order to minimize energy consumption of HVAC system **110**. For example, the activation time can be calculated with the following:

$$T \leftarrow CA^N x_{k_0} + \sum_{i=0}^{N-1} (CA^{N-i-1}B)_1 v_i$$

$$k^* \leftarrow k_f - 1$$

while $T < T_f$ do

$$T \leftarrow T + \left(CA^{k_f-k^*}B\right)_2$$

$$k^* \leftarrow k^* - 1$$

end while

[0057] where

[0058] T is the indoor temperature of building **100** and

[0059] k* is the activation time.

With the activation time calculated at step **330**, operation of HVAC system **110** can be improved. For example, controller **114** can activate or turn on HVAC system **110** at the activation time such the indoor temperature of building **100** is T_f at a final time, t_f. In such a manner, method **300** can assist with preheating and/or precooling interior **102** of building **100**, e.g., in a similar manner as described above for method **200**.

[0060] 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 operating an HVAC system, the HVAC system configured for cooling air within a building, heating air within the building, or both, the method comprising:

providing a model for an indoor temperature, y, of the building;

providing predicted future outdoor temperatures;

calculating an adjustment time interval for the HVAC system utilizing at least the model for y and the predicted future outdoor temperatures.

2. The method of claim **1**, wherein the adjustment time interval corresponds to a period of time required for the HVAC system to adjust the indoor temperature of the building from an initial temperature, T_0, to a final temperature, T_f, wherein T_0 and T_f are unequal.

3. The method of claim **2**, further comprising:

determining an initial time, t_0, at which the indoor temperature of the building is T_0 and a final time, t_f, at which the indoor temperature of the building is T_f, the adjustment time interval corresponding to the difference between t_0 and t_f; and

activating the HVAC system at t_0 such the indoor temperature of the building is T_f at t_f.

4. The method of claim 1, wherein the model for y comprises a second order linear model.

5. The method of claim 4, wherein the model for y comprises

$$y_k=a_1y_{k-1}+a_2y_{k-2}+b_1v_{k-1}+b_2u_{k-1}$$

where

y_k is an indoor temperature of the building at time k,

y_{k-1} is an indoor temperature of the building at time k−1,

y_{k-2} is an indoor temperature of the building at time k−2,

v_{k-1} is an outdoor temperature at time k−1,

u_{k-1} is an operating state of the HVAC system at time k−1, and

a_1, a_2, b_1, and b_2 are constants.

6. The method of claim 1, wherein said step of calculating comprises calculating the adjustment time interval with the following:

$$y_f = CA^k x_{k_0} + \sum_{i=0}^{N-1} CA^{N-i-1} BU_i$$

where

$$C = [\,1 \quad 0\,],$$

$$A = \begin{bmatrix} a_1 & a_2 \\ 1 & 0 \end{bmatrix},$$

$$B = \begin{bmatrix} b_1 & b_2 \\ 1 & 0 \end{bmatrix},$$

$$x_{k_0} = \begin{bmatrix} y_{k_0} \\ y_{k_0-1} \end{bmatrix},$$

$$U_i = \begin{bmatrix} v_i \\ u_i \end{bmatrix},$$

and

$N=k_f-k_0$ where k_0 is an initial time at which the indoor temperature of the building is an initial temperature, y_{k_0}, and k_f is a final time at which the indoor temperature of the building is a final temperature, y_{k_f}.

7. The method of claim 1, wherein said step of calculating comprises calculating the adjustment time interval in order to minimize energy consumption of the HVAC system.

8. The method of claim 7, wherein said step of calculating comprises calculating the adjustment time interval with the following:

$$T \leftarrow CA^N x_{k_0} + \sum_{i=0}^{N-1} (CA^{N-i-1}B)_1 v_i$$

$$k^* \leftarrow k_f - 1$$

while $T < T_f$ do

$$T \leftarrow T + \left(CA^{k_f-k^*}B\right)_2$$

$$k^* \leftarrow k^* - 1$$

end while

where

T is the indoor temperature of the building and

k* is a time value.

9. The method of claim 1, wherein said step of providing predicted future outdoor temperatures comprises determining predicted future outdoor temperatures based upon weather forecast data.

10. The method of claim 9, wherein said step of providing predicted future outdoor temperatures comprises providing predicted future outdoor temperatures using the following:

$$f(t) = \begin{cases} \dfrac{T_{max}(k)+T_{min}(k)}{2} - \dfrac{T_{max}(k)-T_{min}(k)}{2} \cos\left(\dfrac{\pi(t-t_{min}(k))}{t_{max}(k)-t_{min}(k)}\right) & t \in [t_{min}(k), t_{max}(k)) \\ \dfrac{T_{max}(k)+T_{min}(k+1)}{2} + \dfrac{T_{max}(k)-T_{min}(k+1)}{2} \cos\left(\dfrac{\pi(t-t_{max}(k))}{t_{min}(k+1)-t_{max}(k)}\right) & t \in [t_{max}(k), t_{min}(k+1)) \end{cases}$$

where

$T_{max}(k)$ is a maximum temperature on day k,

$T_{min}(k)$ is a minimum temperature on day k,

$t_{max}(k)$ is a time of day for $T_{max}(k)$, and

$t_{min}(k)$ is a time of day for $T_{min}(k)$.

11. A method for operating an HVAC system, the HVAC system configured for cooling air within a building, heating air within the building, or both, the method comprising:

providing a model for an interior temperature, y, of the building;

providing predicted future exterior temperatures of the building;

calculating an activation time for the HVAC system utilizing at least the model for y and the predicted future outdoor temperatures.

12. The method of claim 1, further comprising:

turning on the HVAC system at the activation time; and

running the HVAC system in order to adjust the indoor temperature of the building from an initial temperature, T_0, to a final temperature, T_f, after said step of turning on.

13. The method of claim 1, wherein the model for y comprises a second order linear model.

14. The method of claim 13, wherein the model for y comprises

$$y_k=a_1y_{k-1}+a_2y_{k-2}+b_1v_{k-1}+b_2u_{k-1}$$

where

y_k is an indoor temperature of the building at time k,

y_{k-1} is an indoor temperature of the building at time k−1,

y_{k-2} is an indoor temperature of the building at time k−2,

v_{k-1} is an outdoor temperature at time k−1,

u_{k-1} is an operating state of the HVAC system at time k−1, and

a_1, a_2, b_1, and b_2 are constants.

15. The method of claim **1**, wherein said step of calculating comprises calculating the activation time with the following:

$$y_f = CA^k x_{k_0} + \sum_{i=0}^{N-1} CA^{N-i-1} BU_i$$

where

$$C = [\,1 \quad 0\,],$$

$$A = \begin{bmatrix} a_1 & a_2 \\ 1 & 0 \end{bmatrix},$$

$$B = \begin{bmatrix} b_1 & b_2 \\ 1 & 0 \end{bmatrix},$$

$$x_{k_0} = \begin{bmatrix} y_{k_0} \\ y_{k_0 - 1} \end{bmatrix},$$

$$U_i = \begin{bmatrix} v_i \\ u_i \end{bmatrix},$$

and

$N=k_f-k_0$ where k_0 is the activation time at which the indoor temperature of the building is an initial temperature, y_{k_0}, and k_f is a final time at which the indoor temperature of the building is a final temperature, y_{k_f}.

16. The method of claim **1**, wherein said step of calculating comprises calculating the activation time in order to minimize energy consumption of the HVAC system.

17. The method of claim **16**, wherein said step of calculating comprises calculating the activation time with the following:

$$T \leftarrow CA^N x_{k_0} + \sum_{i=0}^{N-1} (CA^{N-i-1} B)_1 v_i$$

$$k^* \leftarrow k_f - 1$$

-continued

while $T < T_f$ do

$$T \leftarrow T + \left(CA^{k_f - k^*} B\right)_2$$

$$k^* \leftarrow k^* - 1$$

end while

where

T is the indoor temperature of the building and

k* is the activation time.

18. The method of claim **1**, wherein said step of providing predicted future outdoor temperatures comprises determining predicted future outdoor temperatures based upon weather forecast data.

19. The method of claim **18**, wherein said step of providing predicted future outdoor temperatures comprises providing predicted future outdoor temperatures using the following:

$$f(t) = \begin{cases} \dfrac{T_{max}(k) + T_{min}(k)}{2} - \dfrac{T_{max}(k) - T_{min}(k)}{2} \cos\left(\dfrac{\pi(t - t_{min}(k))}{t_{max}(k) - t_{min}(k)}\right) & t \in [t_{min}(k), t_{max}(k)) \\ \dfrac{T_{max}(k) + T_{min}(k+1)}{2} + \dfrac{T_{max}(k) - T_{min}(k+1)}{2} \cos\left(\dfrac{\pi(t - t_{max}(k))}{t_{min}(k+1) - t_{max}(k)}\right) & t \in [t_{max}(k), t_{min}(k+1)) \end{cases}$$

where

$T_{max}(k)$ is a maximum temperature on day k,

$T_{min}(k)$ is a minimum temperature on day k,

$t_{max}(k)$ is a time of day for $T_{max}(k)$, and

$t_{min}(k)$ is a time of day for $T_{min}(k)$.

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