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12/839,522 20 July 2010 (20.07.2010) US(71) Applicant (for all designated States except US): **COOPER TECHNOLOGIES COMPANY** [US/US]; 600 Travis, Suite 5600, Houston, TX 77002 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **COFFEL, James, A.** [US/US]; 1946 Parkway Avenue, Shakopee, MN 55379 (US). **ROGNLI, Roger, W.** [US/US]; 8928 Ohland Avenue, Otsego, MN 55330 (US). **ALLMARAS, Kevin, C.** [US/US]; 345-65th Avenue NE, Carrington, ND 58421 (US). **SIMONSON, Brock, M.** [US/US]; 503-4th Street South, Carrington, ND 58421 (US).(74) Agents: **PEDERSEN, Brad, D.** et al.; Patterson Thuent Christensen Pedersen, P.A., 4800 IDS Center, 80 South Eighth Street, Minneapolis, MN 55402-2100 (US).

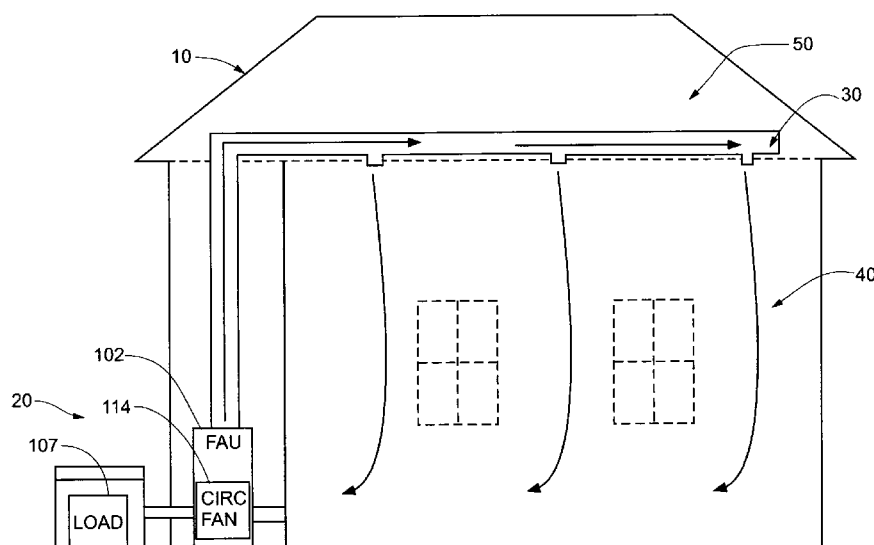
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(54) Title: LOAD MANAGEMENT AWARE FAN CONTROL

Fig. 1

(57) Abstract: A fan-control device for overriding normal operation of a circulation fan delivering conditioned air through duct-work in an unconditioned space. The fan-control device includes a detection circuit and a fan relay. The detection circuit is configured to detect a cooling system control voltage and a cooling system control current and to output a fan control override signal when the cooling system control voltage is detected and the cooling system control current is absent.

LOAD MANAGEMENT AWARE FAN CONTROL

FIELD OF THE INVENTION

5 The present invention relates generally to management of electrical loads. More particularly, the present invention relates to control of circulation fans in a load-managed system for conditioning air.

BACKGROUND OF THE INVENTION

10 To manage electricity usage during times of peak demand, utility companies enroll consumers in load management, or load-shedding, programs. Participants of load-management programs agree to allow utility companies to reduce their power consumption by controlling operation of high-energy usage appliances such as air conditioners, hot water heaters, pool heaters and so on. Control of such appliances may be accomplished through the use of a
15 controller integrated into, or cooperating with, a utility meter, thermostat, load-control device, or other such device.

 One of the most common high-energy-consuming appliances targeted for load control is a compressor of an air-conditioner. In a traditional forced-air heating and cooling system, air is heated or cooled and forced through a network of air ducts by a circulation fan. Based upon a
20 temperature set point, a thermostat calls for heating or cooling, and in the case of cooling, causes the compressor to turn on, and the circulation fan to circulate cooled air through the ductwork to various points about the structure, such as rooms in a residence, or offices in a commercial building.

 When a load management system is introduced to the forced-air HVAC system, a load-
25 management controller or device may take control of the thermostat or the appliances themselves in order to regulate operation of the HVAC system and reduce energy consumption. In some load management systems, the temperature set point may be modified, for example, by being slowly ramped up so as to not call for cooling. In some systems, power to the energy-consuming appliances may be cycled on and off by means of a relay switch located between the appliance
30 and its power source.

 One such relay switch is described in U.S. Patent 7,355,301 (the '301 Patent), commonly assigned to the owners of the present application, and incorporated herein by reference. In the '301 Patent, a load control receiver (LCR) responds to remote commands and detected power line parameters to remove power to selected appliances.

In many known systems having a thermostat controlling a forced air unit, when power to a controlled appliance, such as an air-conditioning compressor, is interrupted by use of an LCR or other such load-management device, the thermostat typically continues to call for cool air from the forced air unit. A circulation fan of the forced air unit continues to run, circulating air throughout the building or structure, despite the lack of power to the compressor, and despite an effective cooling effect.

If the conditioned air circulating throughout the space warms at a relatively low rate, which is most often the case for structures having air ducts located in basements, and between first and second floors of multi-story buildings, the continued recirculation of air throughout the space while the compressor remains unpowered does not result in a significant temperature rise given the generally short time that the compressor is cycled off. However, in those buildings having air ducts located primarily in uncooled attic spaces, the continued operation of the circulation fan may cause the temperature of the space to be cooled to rise relatively quickly, especially in very hot weather conditions. This relatively fast rise in temperature is a result of recirculated air continually passing through the higher-temperature attic space and warming the residential space. This accelerated warming effect is especially problematic in high-temperature climates, such as those in the southern and western parts of the United States.

One method to address the accelerated warming effect is to install a local area network, such as a home area network or other localized control system that centrally controls all of the power-consuming appliances in a residence. A local area network may be configured to communicate directly with a circulation fan, turning the circulation fan at the same time it turns off the compressor.

In one example of a such a home area network, US Patent 7,010,363, entitled "Electrical Appliance Energy Consumption Control Methods and Electrical Energy Consumption Systems" describes a system of microprocessor-controlled relays and software that controls not only high-energy usage appliances such as an air-conditioning compressor, but also directly controls power to the circulation fan.

In another example, known "smart" thermostats, utility meters, or other such controllers may be introduced to the building to establish a local network. The circulation fan may be modified to receive communications from the controller as part of a local network, such as a Zigbee® network.

While installing such relatively extensive and complex networks into a building to directly control all appliances, including a circulation fan, may be one way to avoid the accelerated warming effect described above, this option remains relatively expensive and often impractical.

SUMMARY OF THE INVENTION

In one embodiment, the invention comprises a load-management-aware fan-control device for overriding normal operation of a circulation fan delivering conditioned air through ductwork in an unconditioned space. The circulation fan is normally controlled by a thermostat of an HVAC system that includes a load management device controlling an electrical load of the system. The load-management-aware fan-control device includes a detection circuit and a fan relay. The detection circuit is configured to detect an HVAC system control voltage and an HVAC system control current and to output a fan control override signal when the HVAC system control voltage is detected and the HVAC system control current is absent. The control voltage is detected by the detection circuit when the HVAC system requests that a load under control of a load-management device be powered, and the control current is detected as absent when the HVAC system requests that the load be powered and the load-management device is activated such that the load is not powered.

In some embodiments, the fan relay is configured to receive the fan control override signal from the detection circuit and to break an electrical connection between a thermostat of the HVAC system and the fan in response to the fan control override signal, thereby overriding normal control of the fan by the thermostat and preventing operation of the fan and circulation of unconditioned air when the load-management device is activated.

In another embodiment, the invention comprises a method of controlling a circulation fan of an HVAC system, the HVAC system having ductwork located in an unconditioned space and a load-management device controlling a compressor. The method of controlling the circulation fan includes detecting an HVAC system control voltage when the HVAC system requests an electrical load under control of a load-management device be powered, and detecting an absence of an HVAC system control current when the HVAC system requests the load be powered and when the load-management device is activated such that the load is not powered. The method also includes generating a fan control override signal for overriding a fan control signal of a thermostat requesting operation of a circulation fan, breaking an electrical connection between the thermostat and the circulation fan by receiving the fan control override signal at the fan relay and causing the fan relay to open, thereby overriding the fan control signal of the thermostat and preventing operation of the circulation fan.

In yet another embodiment, the present invention comprises a method of optimizing cooling efficiency when managing multiple electrical loads of cooling systems of buildings included in a load-management program, at least some of the cooling systems including above-ground ductwork. The method includes providing a load-management device to each of a plurality of buildings having cooling systems, providing a fan control device to the at least one of

the plurality of buildings including the cooling system having above-ground ductwork, and transmitting a load-management command to the plurality of load-management devices, the command causing each of the load-management devices to interrupt power to the compressor and unconditioned air from being distributed through the above-ground ductwork in that building.

Each of the load-management devices of this method is configured to cause power to a compressor of the cooling system to be interrupted in response to a load-management command, and at least one of the plurality of buildings includes a cooling system having above-ground ductwork for distributing conditioned air. Further, the fan control device is configured to communicate with the load-management device provided to the building and to prevent operation of a circulation fan when power to the compressor is interrupted.

BRIEF DESCRIPTION OF DRAWINGS

The invention may be more completely understood in consideration of the following detailed description of various embodiments of the invention in connection with the accompanying drawings, in which:

FIG. 1 is an illustration of a building with an HVAC system that includes above-ground ductwork;

FIG. 2 is a block diagram of a fan control system according to an embodiment of the present invention;

FIG. 3 is a block diagram of a fan control system according to another embodiment of the present invention;

FIG. 4 is a circuit diagram of a fan control device according to an embodiment of the present invention;

FIG. 5 is a block diagram of a dual-relay fan control system according to an embodiment of the present invention;

FIG. 6 is a block diagram of the dual-relay fan control system of FIG. 5 enclosed in a common housing;

FIG. 7 is a diagram depicting a load-management command being transmitted to a plurality of buildings, some of which include cooling systems having above-ground ductwork.

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents,

and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION

5 Referring to FIG. 1, a cross-section of a building 10 with an HVAC system 20 that includes ductwork 30 located in an unconditioned space, is depicted. Building 10, though depicted as a residential building or home, may also be a commercial building, industrial building, or any such building or structure having an interior space 40 requiring heating or cooling, and an attic or similar such space 50 located above space 40, and not receiving
10 conditioned air. Though the term “HVAC” is generally understood to mean “heating, ventilating, and air conditioning”, it will be understood that HVAC system 20 may comprise heating and cooling capability, just cooling capability, or just heating capability. As such, when specific reference is made to a cooling configuration and operation, it will be understood that the same configuration and operation may exist and operate as a heating configuration and
15 operation.

Ductwork 30 is connected to HVAC system 20, with portions of ductwork 30 located in attic space 50 of building 10. As indicated by the arrows in FIG. 1, conditioned air from HVAC system 20 flows through attic space 50 of building 10 via ductwork 30 and is distributed into an interior space of building 10, thereby conditioning space 40. A portion of the conditioned air,
20 along with a portion of fresh air, is drawn back into forced air unit (FAU) 102 of HVAC system 20, and the cycle repeated.

Referring also to FIG. 2, load-management-aware (LMA) fan control system 100 of HVAC system 20 in the depicted embodiment includes FAU 102, thermostat 104, contactor 106, load 107, load-management device 108, and LMA fan control device 110 with current-sensing
25 coil 112.

FAU 102 includes circulation fan 114, and electrical control circuitry having several electrical terminals, including common terminal COMMON, and terminal FAN'. FAU 102 may be any of several known types of forced air units used to condition and circulate air. FAU 102 may also include heating and cooling elements, filters, dampers, and other related HVAC
30 equipment not depicted. FAU 102 and circulation fan 114 are connected to ductwork 30 for distributing the conditioned air throughout space 40 of building 10 to be conditioned.

Thermostat 104 may be any of known thermostats used for regulating a temperature within a space, such as one or more rooms of a residence or other building. As such, thermostat 104 may be programmable, non-programmable, digital, mechanical, communicative, and so on.
35 Thermostat 104 may operate on 24VAC, line voltage, or another voltage as needed. As depicted,

and as described in further detail below, thermostat 104 includes terminal FAN which provides an electrical signal requesting circulation fan 114 to be turned on or off. Thermostat 104 also includes terminals COOL and HEAT (not shown), used to call for cooling and heating of the conditioned space, respectively.

5 Contactor 106 may be one of many known contactors or other known controlling devices for switching the power of load 107, wherein load 107 may be an air-conditioning compressor, heat pump, or other such generally high-current-load device of a heating or cooling circuit. Contactor 106 may operate on alternating current (AC) or direct current (DC), and at a control circuit voltage appropriate for the particular control circuit. In one embodiment, a control
10 voltage for contactor 106 may be 24VAC.

 Contactor 106 is in electrical communication with FAU 102 through load-management device 108 via control lines 118, 120, and 122. As depicted, terminal 124 of contactor 106 is electrically connected to terminal 128 of load-management device 108 via control line 118. Terminal 130 of load-management device 108 is electrically connected to terminal COOL of
15 thermostat 104 via control line 120. Terminal 126 of contactor 106 is electrically connected to terminal COMMON of FAU 102.

 Contactor 106 is connected to Line Voltage which, which unlike the control voltage at lines 118 and 122, is typically a higher voltage alternating voltage source. In one embodiment, Line Voltage is 240VAC. In another embodiment, Line Voltage is 120VAC. It will be
20 understood that Line Voltage may comprise any voltage, current, and frequency appropriate for operating load 107. Contactor 106 is in electrical communication with load 107 through one or more switches, providing power to load 107 via power lines 133 and 134.

 In one embodiment, system 100 operates on a 24VAC control voltage, such that contactor 106 is a 24VAC contactor, and the voltage potential across terminals 124 and 126, and
25 control lines 120/118 and 122 is also 24VAC. In other embodiments, other AC or DC voltages may be used.

 In other embodiments, rather than a contactor 106, another form of switching device, such as a relay, for a load such as a compressor, or other electrical load of system 100 may be used. In yet another embodiment, system 100 may not include contactor 106, and load-
30 management device 108 and FAU 102 may be in direct electrical communication with a load 107, such as a compressor or other electrical load of system 100.

 Load-management device 108 as depicted includes terminals 128 and 130, and a switching device, such as relay 132. Load-management device 108 may also include other control and communication circuits adapted to interface and communicate with other portions of

system 100, including meters, gateways, and other devices forming part of a local wired or wireless network.

Generally, load-management device 108 functions as an on-off switch for a control line. Load-management device 108 may be controlled by a local internal or external control circuit that monitors and senses conditions and parameters relating to system 100. Such conditions and parameters may include monitoring of voltage and frequency of power lines providing power to system 100 and its components. An example of one such load-management device 108 is a load-control receiver (LCR) as described in US Patent 7,355,301 (the '301 Patent). The LCR of the '301 Patent may be locally controlled, and switches a load-management device/LCR 108 off, thereby interrupting power to a load 107 when voltages and frequencies fall below a detected threshold level. Such conditions often occur during times of peak electrical consumption.

Load-management device 108 may also be controlled by a device or a network as part of a greater load management, or demand response system, as known to those skilled in the art. A local controller such as a thermostat, meter, or other communicative device, may communicate with, and control operation of, load-management device 108. In such a load-management system, load-management device 108 will be used to interrupt power to an intended load, thereby cycling the load on and off for energy-saving purposes. As discussed further below, and with respect to FIG. 7, electric utility companies may broadcast commands to a controller of load-management device 108, or directly to a load-management device 108, thereby providing operational instructions on managing load 107.

As depicted, system 100 includes a single load management device 108 coupled to a single load 107. However, in alternate embodiments, system 100 may include a second load management device 108b connected to a second load 107b. In such an embodiment, the first load 107 may be a cooling load, and the second load 107 may be a heating load.

LMA fan control device 110 as depicted in FIG. 2 includes, in addition to current-sensing coil 112, detection circuit 140, and normally-closed fan relay 142, enclosed in housing 144. In the embodiment depicted, current-sensing coil 112 is a device separate from LMA fan control device 110, though in other embodiments, as discussed further below with respect to FIG. 3, current sensing coil 112 may be an integral part of LMA fan control device 110. In some embodiments, LMA fan control device 110 may also include time delay devices 143 and 145.

LMA fan control device 110 is electrically coupled to thermostat 104 via control line 146 and to FAU 102 at control line 148, such that terminal FAN of thermostat 104 is in electrical communication with terminal FAN' of FAU 102 through fan relay 142.

Detection circuit 140 of LMA fan control device 110 is electrically coupled to terminal COOL of thermostat 104 via sensing line 150 and control line 120, and to terminal COMMON

of FAU 102 via sensing line 152 and control line 122. Detection circuit 140 is also electrically connected to switch or relay 142. Current sensing coil 112 is in electrical communication with control line 122, and detects current flow in control line 122.

In operation, when load 107 is not being managed by load-management device 108, relay 132 of load-management device 108 is closed. As will be explained further below, relay 142 of LMA fan control device 110, is also closed. FAU 102 in conjunction with thermostat 104 operates normally to heat or cool air so as to maintain a relatively constant air temperature in the conditioned space. A temperature set point of thermostat 104 may be set manually by a user, automatically by a programmed thermostat 104, or by an external controller in communication with thermostat 104. Thermostat 104 senses the space temperature of building 10, and as cool air is needed to lower or maintain a temperature, thermostat 104 signals circulation fan 114 via terminal COOL to operate, and for cool air to be delivered by FAU 102. Similarly, in heating mode, thermostat 104 signals FAU 102 via terminal HEAT to operate, and for heated air to be delivered by FAU 102. For the purposes of explanation operation of system 100, it will be assumed that system 100 is operating in a cooling mode, though it will be understood that system 100 may alternatively operate in a heating mode, utilizing terminal HEAT, Iheat, I cool, and so on.

In the embodiment depicted, when thermostat 104 requests cool air, terminals COOL and FAN of thermostat 104 switch logic states, typically to a positive 24VAC control voltage. As discussed further below, when load 107 is not being managed by load-management device 108, relay 142 remains closed, such that a voltage at terminal FAN' of FAU 102 becomes the same as a voltage at terminal FAN.

A fan signal from thermostat 104 at terminals FAN and FAN' turns on circulation fan 114, and air is forced through ductwork 30 connected to FAU 102 to the space to be cooled. Thermostat 104 has called for load 107 to be powered by causing a cooling system control voltage Vcool to be across terminals COOL and COMMON. In one embodiment, control voltage Vcool may be 24VAC, or another voltage appropriate for switching contactor 106. In the depicted embodiment, when control voltage Vcool exists across terminals COOL and COMMON, cooling system control current Icool flows through the current path formed of control line 120, relay 132, control line 118, contactor 106 and control line 122. It will be understood that although control voltage Vcool is depicted with a positive or "+" symbol at line 120 and a corresponding negative, or "-" symbol, and control current Icool is depicted as current flow in a particular direction, the actual polarity of control voltage Vcool and direction of control voltage Icool will alternate when an AC current is used. This will also be understood to be true

of other references to positive and negative voltages or directional current flow, throughout this description, unless otherwise indicated.

Under these conditions, control voltage V_{cool} is also at contactor 106 terminals 124 and 126, switching power on to load 107. When load 107 is a cooling device such as a compressor, the compressor operates and cools the air forced into the ductwork by FAU 102 for circulation throughout the building space.

Detection circuit 140 of LMA fan control device 110 is electrically connected to terminals COOL and COMMON, and thereby monitors and detects voltage potential V_{cool} . Detection circuit 140 also detects control current I_{cool} flowing through control line 122, via current-sensing coil 112. In other embodiments, current I_{cool} is detected elsewhere in the circuit, such as at any of lines 107, 118, 120, 133, 134, or other such locations that would indicate current flowing to contactor 106. As long as control voltage V_{cool} and control current I_{cool} both remain above a threshold value, relay 142 remains closed such that terminals FAN and FAN' remain electrically connected, such that thermostat 104 remains in control of circulation fan 114, and LMA fan control device 110 does not override thermostat 104.

When the building 10 space reaches the desired temperature, thermostat 104 removes the logic signal from terminals CCOL and FAN, turning off circulation fan 114, and removing control voltage V_{cool} from terminals COOL and COMMON. Without control voltage V_{cool} between terminals 124 and 126, contactor 106 switches power to load 107 off, and load 107 powers down.

As long as load-management device 108 is not activated, the heating and cooling cycle described above continues, with thermostat 104 controlling operation of circulation fan 114.

However, when a load management situation occurs, and load-management device 108 is activated, operation of system 100 changes. For example, when load 107 is managed, relay 132 of load-management device 108 makes or breaks, thereby cycling power to load 107 on and off. During this load management mode, with relay 132 of load-management device 108 open, terminal 124 of contactor 106 floats, the previously-described current path is broken, and control current I_{cool} is zero, regardless of the voltage potential across control lines 120 and 122.

In system 100, load-management device 108 is generally controlled independent of the operation of thermostat 104 and FAU 102. Therefore, thermostat 104 and FAU 102 will attempt to control the space temperature regardless of the status of load-management device 108.

Consequently, when load 107 is being controlled, such that relay 132 is open, and when the desired air temperature rises above the desired set point, thermostat 104 and FAU 102 will attempt to operate normally.

In previously-known load-managed HVAC systems not including LMA fan control device 110, when an LCR relay opens to remove power to a load, and the space temperature is above the desired set point, the thermostat continues to call for cool, and the circulation fan operates continuously. As discussed above, the circulation fan forces air through the ductwork into the building space, then draws return air from the space back to the FAU for conditioning. If heat is transferred to the circulated air in the ductwork as it passes an unconditioned space, such as an attic, the circulated air temperature rises. As this cycle of constant fan with no cooling mechanism continues, the space temperature may rise rapidly.

However, unlike such previously-known cooling systems, system 100 employing LMA fan control device 110 controls operation of circulation fan 114 during those times that LCR 132 is open such that circulation fan 114 generally does not run, and a rapid rise in space temperature is avoided, reduced or delayed.

More specifically, and still referring to FIG. 2, under this managed-load condition, where load-management device 108 is activated, and thermostat 104 calls for cool due to a space temperature rising above a set point, thermostat 104 provides a control voltage at line 146, requesting that circulation fan 114 turn on. The call for cool causes a control voltage V_{cool} to appear across terminals COOL and COMMON. However, control current I_{cool} is zero because relay 132 is open and the current path of control current I_{cool} is broken. Detection circuit 140 monitoring voltage V_{cool} and current I_{cool} detects the presence of control voltage V_{cool} , and detects the absence of control current I_{cool} .

To avoid the accelerated heating effect that occurs when circulation fan 114 operates during a managed-load condition, detection circuit 140 sends a fan control override signal to fan relay 142 causing relay 142 to open. Doing so breaks the electrical connection between terminals FAN and FAN'. Under these conditions, circulation fan 114 will not be turned on by thermostat 104, even though thermostat 104 calls for circulation fan 114 to be operated.

In some embodiments, LMA fan control device 110 may include time delay devices 143 and/or 145, in electrical communication with detection circuit 140 and fan relay 142. In such an embodiment, time delay device 143 may delay the break of the electrical connection between the thermostat 104 of the cooling system and the fan 114 for a predetermined time period after the detection of a cooling system control voltage and the detection of the absence of the cooling system control current. Allowing circulation fan 114 to operate for a relatively short period of time after load-management device 108 is activated provides the benefit of allowing fan 114 to force conditioned air already located in ductwork 30, into space 40, rather than allowing such conditioned air to be warmed in ductwork 30 while awaiting fan 114 to restart.

The period of delay may be adjustable, and may be calculated to be the amount of time required to displace conditioned air with unconditioned air in ductwork 30. In one embodiment, the timer period of delay ranges from 30 seconds to 3 minutes.

Another optional delay may be utilized via time delay device 145. Time delay device 145, in electrical communication with detection circuit 140 and fan relay 142, may be configured to restart fan 114 after a predetermined period of time has passed in order to ensure a minimum amount of fresh air continues to be drawn into building 10. More specifically, time delay device 145 begins a countdown starting from the activation of load-management device 108. After a predetermined time period, if circulation fan 114 continues to be overridden by fan control device 110, time delay device 145 may override fan relay 142, thereby causing fan 114 to operate for a brief period of time. The specific time interval may be dependent on a minimum desired air exchange rate.

Referring to non-delayed operation again, when load-management device 108 is no longer activated, and load 107 is no longer in a managed state, relay 132 closes or makes. Assuming the space temperature remains above the desired setpoint, thermostat 104 continues to call for cool, and detection circuit 140 continues to detect control voltage V_{cool} . Further, with the closing of relay 132, control current I_{cool} begins to flow, and is also detected by detection circuit 140. Under these conditions, relay 142 closes, terminals FAN and FAN' become electrically connected again, such that the control voltage at terminal FAN is also at FAN', and circulation fan 114 is turned on, thereby circulating cooled air.

When load-management device 108 is later activated to open relay 132, the cycle repeats.

Table 1 below summarizes the operation of system 100:

TABLE 1

System 100 State		Voltage V_{cool} Present?	Current I_{cool} Present?	Fan Relay 142 Position	Fan 114 On/Off
1	Calling for cool, load-management device 108 not activated	Yes	Yes	Closed	On
2	Calling for cool, load-management device 108 activated	Yes	No	Open	Off
3	Not calling for cool, load-management device 108 not	No	No	Closed	Off

	activated				
4	Not calling for cool, load-management device 108 activated	No	No	Open	Off

Referring to system 100 state 1, “calling for cool, load-management device 108, not activated”, during this state, system 100 operates normally such that LMA fan control device 110 does not interfere with the call for cool. Control voltage Vcool is present at terminals COOL and COMMON, and detected by detection circuit 140. Current Icool is present flowing through closed relay 132 and current sensing coil 112, and detected by detection circuit 140. Fan relay 142 of LMA fan control device 110 is closed, and thermostat 104 signals fan 114 to be turned on.

Referring to system 100, state 2, “calling for cool, load-management device 108 activated”, during this managed-load state, load-management device 108 relay 132 is open, thereby interrupting power to load 107. Voltage Vcool is present at terminals COOL and COMMON and detected by detection circuit 140. Current Icool is not present, or does not flow, as relay 132 is open. The lack of current Icool is detected by detection circuit 140, and relay 142 is open. With relay 142 open, terminals FAN and FAN' are not electrically connected. Although thermostat 104 is calling for circulation fan 114 to be turned on by causing a control voltage to appear at terminal FAN, the control signal does not appear at terminal FAN', and circulation fan 114 is not automatically turned on.

Referring to system 100, state 3, “not calling for cool, load-management device 108 not activated”, load-management device 108 is not activated, such that relay 132 is closed. FAU 102 and thermostat 104 are not calling for cool, and thus, neither control voltage Vcool nor control current Icool are present. Therefore, although relay 142 is closed, circulation fan 114 is not turned on, and air is not circulated.

Referring to system 100, state 4, “not calling for cool, load-management device 108 activated”, similar to state 3 discussed above, system 100 is not calling for cool, such that cooling system control voltage Vcool and cooling system control current Icool are not present, and circulation fan 114 is not turned on.

Referring also to FIG. 3, in another embodiment, system 100 operates essentially the same as described in the embodiment of FIG. 2, but in the embodiment of FIG. 3, system 100 does not include external current-sensing coil 112. Rather, current-sensing capability is internal to detection circuit 160.

When LMA fan control device 110 is installed on an existing HVAC system, it may be more convenient to install external current-sensing coil 112, as is the case of system 100 of FIG. 2. In such a retrofit application, minimal rewiring may be required to add LMA fan control device 110 to the HVAC system as current-sensing coil 112 may not require breaking or disconnecting control line 122 in order to sense current I_{cool} in line 122.

Referring to FIG. 3, in other applications, whether new installations, or retrofit situations, LMA fan control device 110 includes detection circuit 160. As depicted in FIG. 3, detection circuit 160 does not include external current-sensing coil 112. Rather, detection circuit 160 includes internal current-sensing circuitry enclosed within housing 144. In such an embodiment, LMA fan control device 110 may be a unitary, modular device easily integrated into a new or existing HVAC system.

When installed, control line 122 is broken such that a first portion line 122a electrically connects terminal COMMON of FAU 102 to detection circuit 160. Second portion, line 122b, electrically connects detection circuit 160 to terminal 126 of contactor 106. Consequently, I_{cool} flows through detection circuit 160.

Referring to FIG. 4, a circuit diagram 162 of an embodiment of LMA fan control device 110 is depicted. Circuit 162 includes detection circuit 160 as described above with respect to FIG. 3, and fan relay 142. As also described above with respect to FIG. 3, relay 142 is electrically connected to terminals FAN of thermostat 104, and terminal FAN' of FAU 102. Detection circuit 160 is electrically connected to FAU 102 terminals COOL and COMMON, and terminal 126 of cooling contactor 126.

Under the conditions described above with respect to FIGS. 1 and 2, control voltage V_{cool} appears across terminals COOL and COMMON, and control current I_{cool} flows through a circuit path that includes terminal 126 and terminal COMMON. It will be understood that although control voltage V_{cool} and control current I_{cool} are depicted with a particular polarity and direction, respectively, the polarity and direction will alternate when system 100 uses an AC voltage, for example, when control voltage V_{cool} is 24VAC.

In the embodiment depicted, detection circuit 160 includes a pair of diodes D1 and D2, transformer T, full-wave rectifier FWR, current-limiting resistor R, capacitor C, relay 164, and relay 166.

Diodes D1 and D1 are located in parallel across terminals 126 and COMMON and in parallel to the inputs to transformer T. The anode of diode D1 is electrically connected to terminals COMMON and to terminals 182 and 186 of relay 166. The cathode of diode D1 is electrically connected to diode D2 and to terminal COMMON. The anode of diode D2 is

electrically connected to terminal 126 and the cathode of diode D2, while the cathode of diode D2 is electrically connected to terminal COMMON and terminals 182 and 186 of relay 166.

Diodes D1 and D2 may have typical forward bias voltages in the 0.7 to 1.0V range, with relatively high breakdown voltages, for example, 520V. In other embodiments, the forward and reverse voltages may be higher or lower, depending on the particular requirements of system 100.

Transformer T as depicted is electrically connected in parallel to diodes D1 and D2. In one embodiment, transformer T is a step-up transformer, stepping up the forward bias voltage of diodes D1 and D2 to a higher voltage output. In one embodiment, transformer T is a 1:13 step-up transformer. The winding ratio of transformer T may vary in other embodiments, dependent in part on the characteristics of relays 164 and 166.

Full-wave rectifier FWR is electrically connected to the output terminals of transformer for rectification of the output of transformer T. Full-wave rectifier FWR is any of those known to those skilled-in-the art, and although is depicted as a known arrangement of four diodes, may comprise other configurations.

Current-limiting resistor R and capacitor C electrically connect full-wave rectifier FWR to relay 164. In one embodiment, current-limiting resistor R is a 1.5 k-ohm resistor, and capacitor C is a 22 microfarad capacitor with a 50V rating. It will be understood that R and C are not limited to these particular values in this embodiment, and that in other embodiments, the values of R and C may vary.

Relay 164 as depicted is a solid state relay electrically connected to the output transformer T via full-wave rectifier FWR, resistor R, and capacitor C, at input terminals 170 and 172. Relay 164 also includes switch terminals 174 and 176. Switch terminal 174 is electrically connected to coil terminal 180 of relay 166, and switch terminal 176 is electrically connected to a terminal COOL and to coil terminal 192 of relay 142.

Relay 166 as depicted is a single-pole, double-throw relay, though in other embodiments, may be single-pole, single-throw, or double-pole double-throw, as needed. Relay 166 includes coil terminals 180 and 182, and switch terminals 184 and 186. In one embodiment, relay 166 is a normally closed relay, such that when no voltage potential is applied to coil terminals 180 and 182, switch terminals 184 and 186 are made, forming an electrical connection. When a voltage potential exists across coil terminals 180 and 182, relay 166 opens, such that terminals 184 and 186 are not electrically connected.

Coil terminal 180 is electrically connected to terminal 176 of relay 164; terminal 182 is electrically connected to terminal COMMON; switch terminal 184 is electrically connected to

coil terminal 190 of relay 142; and switch terminal 186 is electrically connected to terminal COOL.

Relay 142 as depicted is essentially the same relay as relay 166, a normally-closed, single-pole, double-throw relay having coil terminals 190 and 192, and switch terminals 194 and 196. When a voltage potential is at coil terminals 190 and 192, relay 142 opens such that switch terminals 194 and 196 are not electrically connected.

Coil terminal 190 is electrically connected to switch terminal 184 of relay 166; coil terminal 192 is electrically connected to terminal COOL and terminal 176 of relay 164; switch 194 is electrically connected to terminal FAN; and switch terminal 196 is electrically connected to terminal FAN'.

In operation, detection circuit 160 in conjunction with relay 142 operates generally as described above with reference to FIG. 3 and Table 1. Table 2 below shows additional details of the operation of circuit 162 as part of system 100, and will be used to describe the more detailed operation of circuit 162:

TABLE 2

System 100 State		Voltage V _{cool} Present?	Current I _{cool} Present?	Relay 164 Position	Relay 166 Position	Fan Relay 142 Position	Fan 114 On/Off
1	Calling for cool, load-management device 108 not activated (relay closed)	Yes	Yes	Closed	Open	Closed	On
2	Calling for cool, load-management device 108 activated (relay open)	Yes	No	Open	Closed	Open	Off
3	Not calling for cool, load-management device 108 not activated (relay	No	No	Open	Closed	Closed	Off

	closed)						
4	Not calling for cool, load-management device 108 activated (relay open)	No	No	Open	Closed	Closed	Off

Referring to Table 2, system state 1, system 100 is calling for cool and fan, and load-management device 108 is not activated (relay 132 is closed). In this system state, control voltage Vcool is present across terminals COOL and COMMON, and control current Icool flows, or is “present”.

Under these circumstances, and assuming the embodiment employing an AC control voltage, current Icool is an AC current, and diodes D1 and D2 alternately conduct such that transformer T receives an AC voltage signal at its input terminals, the AC voltage signal having a peak voltage substantially equal to the bias voltage of diodes D1 and D2.

Referring again to FIG. 4, transformer T steps up the received voltage signal with the output signal of transformer T being rectified by full-wave rectifier FWR, while capacitor C smoothes the rectified signal. Current-limiting resistor R reduces the current to relay 164, and a voltage potential exists across terminals 170 and 172 of relay 164.

In the depicted embodiment, relay 164 is a solid-state relay, and in one embodiment is an opto-isolator. In operation, a voltage potential across terminals 170 and 172 causes relay 164 to make, such that terminals 174 and 176 are electrically connected.

At the same time, a voltage potential occurs at terminals 180 and 182 of relay 166, such that it opens, and switch terminals 184 and 186 are not electrically connected. Further, current does not flow through coil terminals 190 and 192, and fan relay 142 maintains its closed position with switch terminals 194 and 196 in electrical contact.

With relay 142 closed, terminals FAN and FAN' are connected, and thermostat 104 turns on circulation fan 114.

Referring to Table 2, system state 2, system 100 is calling for cool and fan, and load-management device 108 is activated (relay 132 is open). In this state, control voltage Vcool exists across terminals COOL and COMMON, but control current Icool does not flow, or is not present, because load-management device 108 is activated and relay 132 open.

Under this system state, neither diodes D1 or D2 conduct, no potential across terminals 170 and 172 exists at relay 164, such that relay 164 is open. In turn, no current flows through coil terminals 180 and 182 such that relay 166 remains closed. With relay 166 closed, voltage Vcool is across terminals 190 and 192, causing relay 166 to open, thereby overriding the signal from thermostat 104 to turn on circulation fan 114.

Consequently, under system state 2, even though system 100 is calling for cool and thermostat 104 requests circulation fan 114 to run, relay 142 opens, preventing circulation fan 114 from circulating increasingly hot air throughout the building space.

Referring to Table 2, system state 3, system 100 is not calling for cool, and load-management device 108 is not activated. In this state, neither voltage Vcool nor current Icool are present. Diodes D1 and D2 don't conduct; relay 164 is open, relay 166 closed, and relay 142 is closed. Circulation fan 114 is not turned on because thermostat 104 is not calling for cool.

Referring to Table 2, system state 4, system 100 is not calling for cool, and load-management device 108 is activated. In this state, neither control voltage Vcool nor control current Icool are present, so circuit 162 operates the same as under system state 3. Diodes D1 and D2 don't conduct; relay 164 is open, relay 166 closed, and relay 142 is closed. Circulation fan 114 is not turned on because thermostat 104 is not calling for cool.

Referring to FIG. 5, in an alternate embodiment, system 200 includes multiple load-management devices 108 to prevent the accelerated heating situation caused by circulation fan 114 operating during the time that a load is being managed. System 200 includes FAU 102, thermostat 104, contactor 106, load 107, a first load-management device 108a enclosed in housing 202a, and a second load-management device 108b enclosed in housing 202b. In one embodiment, load-management device 108a may be located conveniently near contactor 106 and load 107, which is often outdoors.

Similar to the embodiments described above with respect to FIGS. 1-3, relay 132a of load-management device 108a is electrically connected between terminal COOL of thermostat 104 and terminal 124 of contactor 106. Terminal COOMON of FAU 102 is electrically connected to terminal 126 of contactor 106. When thermostat 104 calls for cool, voltage Vcool is applied across terminals COOL and COMMON. When load-management device 108a is not activated, current Icool flows, and cooling contact 106 maintains power to load 107.

Unlike the embodiments of FIGS. 1-3 described above, rather than including an LMA fan control device, system 200 includes second load-management device 108b to make or break the connection between FAN and FAN', thereby preventing circulation fan 114 from operating when system 200 calls for cool, but load-management device 108a is activated.

In the depicted embodiment, terminal 128b of load-management device 108b is electrically connected to terminal FAN of thermostat 104, and terminal 130b is electrically connected to terminal FAN' of FAU 102. Load-management device 108b may be located near load-management device 108a to facilitate optimal communications from a controller of load-management device 108a and load-management device 108b, but alternatively, may be located at a location separate from load-management device 108a for ease of wiring and accessibility.

Regardless of location, load-management device 108a and load-management device 108b operate in tandem, such that they both operate substantially at the same time. When relay 132a is open, relay 132b is open, and vice versa, load-management device 108a and load-management device 108b may be operated by a common controller and common control signal, such that when load-management device 108a is activated to remove power to load 107, LCR 108b is also activated to remove power to circulation fan 114. In other embodiments, load-management device 108a and 108b may operate in a master-slave relationship such that anytime load-management device 108a is activated, such activation causes load-management device 108b to also be activated.

Referring to FIG. 6, system 300 is substantially the same as system 200 of FIG. 5, with the exception that load-management device 108a and load-management device 108b are enclosed in the same housing 202. By enclosing both load-management device 108a and load-management device 108b into a single housing 202, the installation of the two LCRs 108 may be somewhat simplified as compared to the installation of the two separate LCRs 108 of the embodiment of FIG. 5.

Referring to FIG. 7, transmission of a load-management command to a plurality of buildings, some of which include cooling systems having above-ground ductwork, is depicted. A transmission network 220 transmits load-management command to buildings 10, 12, and 14. Reference letter "A" indicates a building with above-ground ductwork, and reference letter "B" indicates a building with below-ground ductwork. Buildings 10, as described above, include above-ground ductwork 30, and are enrolled in a load-management program administered by an electrical utility provider. Buildings 12 have below-ground ductwork and are also enrolled in a load-management program. Buildings 14 are not enrolled in a load-management program and may have either below-ground or above-ground ductwork.

Buildings 10, 12, and 14 may be grouped geographically such that all buildings in a particular geographic area include above-ground ductwork, such as buildings 10 and 14 in geographic area 222. Other geographic areas, such as geographic area 224, may include buildings 10 having above-ground and buildings 12 having below-ground ductwork.

Transmission network 220 as depicted is a wireless transmission network transmitting a wireless signal that includes load-management commands to buildings 10 and 12. In one embodiment, transmission network 220 broadcasts an RF signal, though other wireless signals, and a variety of protocols, may be employed. The wireless network may include a long-haul wireless network as is commonly used by utility providers, but may also include a short-haul, or local wireless network, such as a Zigbee, Bluetooth®, Z-Wave®, or other such local wireless network.

Although depicted as a wireless network in FIG. 7, transmission network 220 may also be a wired network, transmitting load-management commands over a power line communication network, a telephone service network, an internet service network, or another similar wired network.

A utility provider may offer one or more load-management programs to building owners, occupants, managers, and so on. When enrolled in such a program, a utility provider may provide load-management device 108, such as a load-control receiver, relay, or similar device, for installation at buildings 10 or 12. As described above, load-management device 108 receives load-management commands, some of which activate the load-management device 108, causing device 108 to interrupt or remove power to a load 107, which may be a compressor. Load-management device 108 may receive commands directly from transmission network 220, or through a controller of a local network.

For buildings 10 enrolled in the load-management program, frequently cycling the power to compressor 107 on and off as part of the load-management program may cause the accelerated heating effect described above. Shortening the length of time that load-management device 108 is activated, and increasing the frequency of on-off cycling, otherwise known as short-cycling the compressor, may alleviate the heating effect somewhat. However, continual short-cycling of compressors significantly decreases the life of the compressor such that short-cycling is generally undesirable.

Therefore, a utility provider may also provide a load-management aware fan control device 110 with instructions for use to one or more buildings 10 having above-ground ductwork 30 for the purposes of controlling a circulation fan 114 and avoiding the accelerated heating effect described above. In such an instance, the electrical utility provider may transmit a uniform set of load-management commands to be received at buildings 10 and 12 without concern that the commands received by buildings 10 will create the accelerated heating effect.

Although the present invention has been described with respect to the various embodiments, it will be understood that numerous insubstantial changes in configuration, arrangement or appearance of the elements of the present invention can be made without

departing from the intended scope of the present invention. Accordingly, it is intended that the scope of the present invention be determined by the claims as set forth.

For purposes of interpreting the claims for the present invention, it is expressly intended that the provisions of Section 112, sixth paragraph of 35 U.S.C. are not to be invoked unless the
5 specific terms “means for” or “step for” are recited in a claim.

WHAT IS CLAIMED IS:

1. A load-management-aware fan-control device for overriding normal operation of a circulation fan delivering conditioned air through ductwork that is normally controlled by a thermostat that includes a load management device, the load-management-aware fan-control
5 device comprising:
 - a detection circuit configured to detect a HVAC system control voltage and a HVAC system control current and to output a fan control override signal when the HVAC system control voltage is detected and the HVAC system control current is absent, the control voltage being detected by the detection circuit when the HVAC system requests that a load under control
10 of a load-management device be powered, and the control current being detected as absent when the HVAC system requests that the load be powered and the load-management device is activated such that the load is not powered; and
 - a fan relay configured to receive the fan control override signal from the detection circuit and to break an electrical connection between a thermostat of the HVAC system and the fan in
15 response to the fan control override signal, thereby overriding normal control of the fan by the thermostat and preventing operation of the fan and circulation of unconditioned air when the load-management device is activated.
2. The device of claim 1, wherein the detection circuit further includes a current-sensing
20 coil configured to detect the HVAC system control current.
3. The device of claim 2, wherein the current-sensing coil is a snap-on current transformer.
4. The device of claim 1, wherein the fan relay is a normally-closed relay.
25
5. The device of claim 1, wherein the detection circuit is further configured to detect the HVAC system control voltage at a terminal of a forced-air unit of the HVAC system and the thermostat.
- 30 6. The device of claim 1, wherein the HVAC system control voltage is a 24VAC control voltage.
7. The device of claim 1, further including a time delay device in electrical communication with the detection circuit and the fan relay, the time delay device configured to delay the break

of the electrical connection between the thermostat of the HVAC system and the fan for a predetermined time period after the detection of a HVAC system control voltage and the detection of the absence of the HVAC system control current.

8. The device of claim 7, wherein the predetermined time period is an amount of time required to force substantially all of a volume of conditioned air remaining in the ductwork after the detection circuit has detected the HVAC system control voltage and the absence of the HVAC system control current, and before the fan relay breaks the electrical connection between the thermostat of the HVAC system and the fan.

9. The device of claim 1, further including a timer device in electrical communication with the detection circuit and the fan relay, the timer device configured to signal the fan relay to make an electrical connection between the thermostat of the HVAC system and the fan after a predetermined time period, the predetermined time period measured from the break of the electrical connection between the thermostat and the fan.

10. The device of claim 1, wherein the detection circuit includes:
a first detection circuit relay configured to be in an open position in the absence of the HVAC system control current;

a second detection circuit relay in electrical communication with the first detection circuit relay and the fan relay, and configured to be in a closed position when the first circuit relay is in an open position, such that in the presence of the HVAC system control voltage, the HVAC system control voltage is applied to a coil of the fan relay, the fan relay thereby receiving the fan control override signal.

11. A method of controlling a circulation fan of an HVAC system having ductwork located in an unconditioned space and a load-management device controlling an electrical load, the method of controlling the circulation fan comprising:

detecting an HVAC system control voltage when the HVAC system requests an electrical load under control of a load-management device be powered;

detecting an absence of an HVAC system control current when the HVAC system requests the electrical load be powered and when the load-management device is activated such that the electrical load is not powered;

in response to detecting the HVAC system control voltage and detecting the absence of the HVAC system control current, generating a fan control override signal for overriding a fan control signal of a thermostat requesting operation of a circulation fan; and

5 breaking an electrical connection between the thermostat and the circulation fan by receiving the fan control override signal at the fan relay and causing the fan relay to open, thereby overriding the fan control signal of the thermostat and preventing operation of the circulation fan.

12. The method of claim 11, wherein the HVAC system is a cooling system and the electrical
10 load is a compressor, such that detecting an HVAC system control voltage when the HVAC system requests an electrical load under control of a load-management device be powered comprises:

 detecting a cooling system control voltage when the cooling system requests an electrical load under control of a load-management device be powered;

15 detecting an absence of an HVAC system control current when the HVAC system requests the electrical load be powered and when the load-management device is activated such that the electrical load is not powered comprises detecting an absence of a cooling system control current when the cooling system requests the compressor be powered and when the load-management device is activated such that the compressor is not powered; and

20 detecting the HVAC system control voltage and detecting the absence of the HVAC system control current comprises detecting the cooling system control voltage and detecting the absence of the cooling system control current.

13. The method of claim 11, further comprising activating the load-management device to
25 interrupt power to the electrical load.

14. The method of claim 13, wherein activating the load-management device to interrupt power to the electrical load comprises receiving a load-management command at the load-management device and activating a relay of the load-management device, thereby breaking a
30 power connection of the electrical load.

15. The method of claim 11, wherein detecting an HVAC system control voltage when the HVAC system requests an electrical load under control of a load-management device be powered comprises detecting a 24VAC HVAC system control voltage.

16. The method of claim 11, further comprising delaying the breaking of the electrical connection between the thermostat and the circulation fan for a predetermined time period after the detecting of the HVAC system control voltage and the detection of the absence of the HVAC system control current.

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17. A method of optimizing cooling efficiency when managing multiple electrical loads of cooling systems of buildings included in a load-management program, at least some of the cooling systems including above-ground ductwork, the method comprising:

10 providing a load-management device to each of a plurality of buildings having cooling systems, each of the load-management devices configured to cause power to a compressor of the cooling system to be interrupted in response to a load-management command, and at least one of the plurality of buildings including a cooling system having above-ground ductwork for distributing conditioned air;

15 providing a fan control device to the at least one of the plurality of buildings including the cooling system having above-ground ductwork, the fan control device configured to communicate with the load-management device provided to the building and to prevent operation of a circulation fan when power to the compressor is interrupted; and

20 transmitting a load-management command to the plurality of load-management devices, the command causing each of the load-management devices to interrupt power to the compressor, the interruption of power to the compressor of any building of the plurality of buildings having above-ground ductwork causing the fan control device to prevent operation of the circulation fan, thereby preventing unconditioned air from being distributed through the above-ground ductwork in that building.

25 18. The method of claim 17, wherein providing a load-management device to each of a plurality of buildings having cooling systems includes providing a load-management device to a plurality of residential home-owners as part of a load-management program for a specified geographic region.

30 19. The method of claim 17, wherein providing a load-management device to each of a plurality of buildings having cooling systems includes providing a load-control receiver having an internal relay configured to open a set of contacts when activated.

35 20. The method of claim 17, wherein providing a fan control device to the at least one of the plurality of buildings includes providing a fan control device having a detection circuit and a fan

relay, the detection circuit and the fan relay in electrical communication with a thermostat and the circulation fan.

21. The method of claim 20, further including:

the detection circuit being configured to detect the presence of a cooling system control voltage and the absence of a cooling system control current; and

the fan relay configured to break a connection between a thermostat and the circulation fan in response to the detection circuit detecting the presence of a cooling system control voltage and the absence of a cooling system control current.

22. The method of claim 17, wherein transmitting a load-management command to the plurality of load-management devices includes transmitting a load-management command over a wireless communication network.

23. The method of claim 22, wherein transmitting a load-management command over a wireless communication network includes transmitting a radio-frequency load-management command.

24. The method of claim 17, wherein transmitting a load-management command to the plurality of load-management devices includes transmitting a load-management command over a wired communication network.

25. The method of claim 24, wherein the wired communication network is selected from a group consisting of a power line communication network, a telephone service network and an internet service network.

26. A load-management-aware fan-control device for overriding normal operation of a circulation fan delivering conditioned air through an above-ground ductwork that is normally controlled by a thermostat of a cooling system that includes a load management device controlling a compressor of the system, the load-management-aware fan-control device comprising:

means for detecting a cooling system control voltage and a cooling system control current and to output a fan control override signal when the cooling system control voltage is detected and the cooling system control current is absent, the control voltage being detected when the cooling system requests that a compressor under control of a load-management device be

powered, and the control current being detected as absent when the cooling system requests that the compressor be powered and the load-management device is activated such that the compressor is not powered; and

means for receiving the fan control override signal and breaking an electrical connection between a thermostat of the cooling system and the fan in response to the fan control override signal, thereby overriding normal control of the fan by the thermostat and preventing operation of the fan and circulation of uncooled air when the load-management device is activated.

27. The device of claim 26, further comprising means for delaying the break of the electrical connection between the thermostat of the cooling system and the fan for a predetermined time period after the detection of a cooling system control voltage and the detection of the absence of the cooling system control current.

28. The device of claim 26, further comprising means for activating the load-management device such that the compressor is not powered.

29. A load-management-aware fan-control device for overriding normal operation of a circulation fan delivering conditioned air through ductwork in an unconditioned space, the circulation fan being normally controlled by a thermostat, the load-management-aware fan-control device comprising:

a detection circuit configured to detect a cooling system control voltage and a cooling system control current and to output a fan control override signal when the cooling system control voltage is detected and the cooling system control current is absent, the control voltage being detected by the detection circuit when the cooling system requests that a compressor under control of a load-management device be powered, and the control current being detected as absent when the cooling system requests that the compressor be powered and the load-management device is activated such that the compressor is not powered; and

a fan relay configured to receive the fan control override signal from the detection circuit and to break an electrical connection between a thermostat of the cooling system and the fan in response to the fan control override signal, thereby overriding normal control of the fan by the thermostat and preventing operation of the fan and circulation of unconditioned air when the load-management device is activated.

30. The load-management-aware fan-control device of claim 29, wherein the ductwork located in an unconditioned space comprises ductwork located above ground.

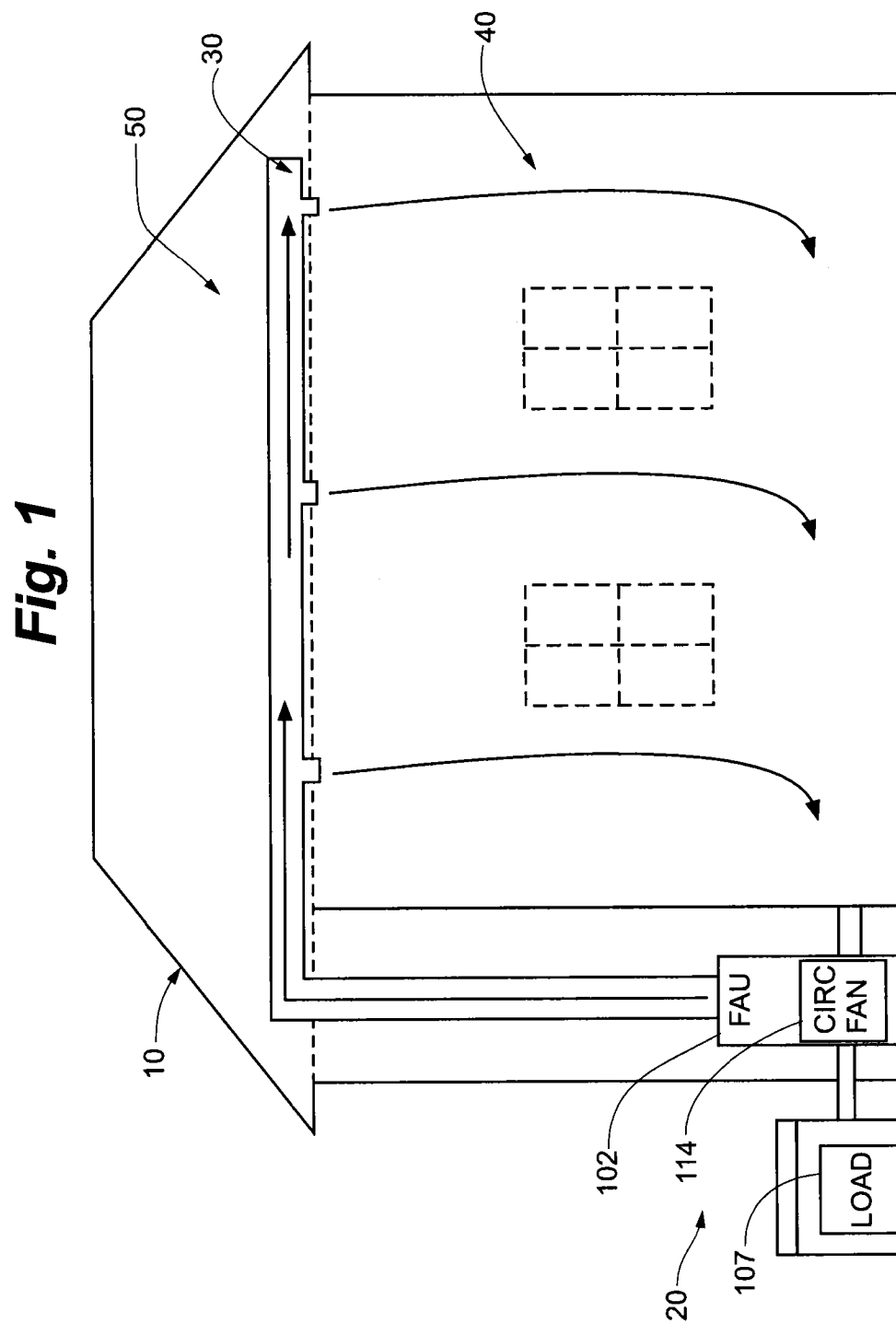
31. The load-management-aware fan-control device of claim 29, wherein the ductwork located above ground comprises ductwork located in an attic space.

5 32. The device of claim 29, wherein the detection circuit further includes an external current-sensing coil configured to detect the cooling system control current.

33. The device of claim 29, wherein the detection circuit further includes internal current-sensing circuitry.

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34. The device of claim 29, wherein the cooling system comprises a portion of an HVAC system that also includes a heating system.



**ANY REFERENCE TO FIGURE 4
SHOULD BE CONSIDERED
AS NON-EXISTENT**

Fig. 5