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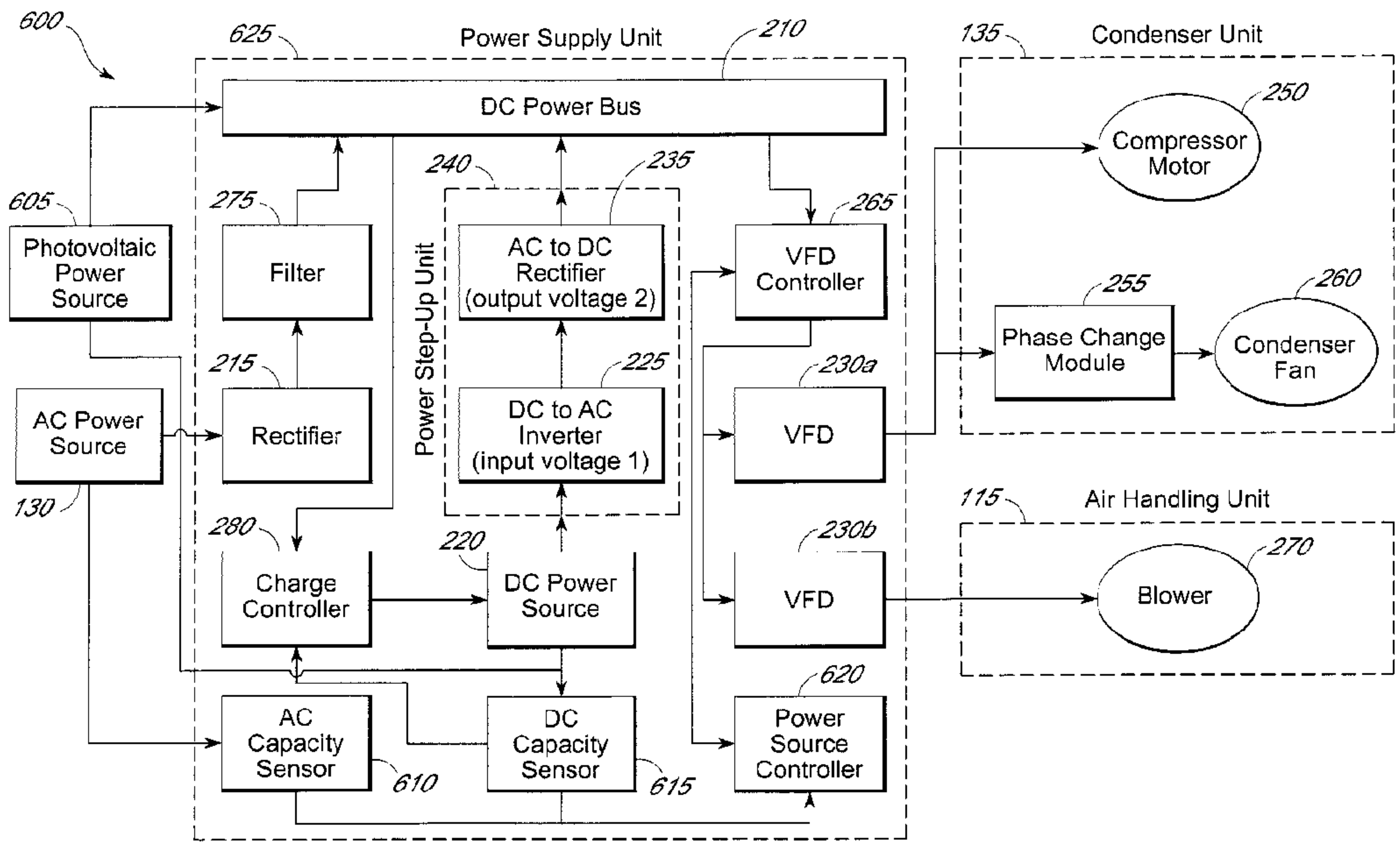

(57) Abrégé/Abstract:
An enclosure or shelter having an HVAC/R system is configured with a photovoltaic power source and a rechargeable DC power source for power back-up to maintain substantially uninterrupted power in the case of a main power failure. The system includes one or more variable frequency drives (VFD) controlled by a VFD controller and configured to provide three-phase power to one or more three-phase AC motors and single- phase power to one or more single-phase AC motors. The system also includes a power source controller configured to select power sources based on availability of one or more power sources and other logic.

ABSTRACT OF THE DISCLOSURE

An enclosure or shelter having an HVAC/R system is configured with a photovoltaic power source and a rechargeable DC power source for power back-up to maintain substantially uninterrupted power in the case of a main power failure. The system includes one or more variable frequency drives (VFD) controlled by a VFD controller and configured to provide three-phase power to one or more three-phase AC motors and single-phase power to one or more single-phase AC motors. The system also includes a power source controller configured to select power sources based on availability of one or more power sources and other logic.

HVAC/R SYSTEM HAVING POWER BACK-UP SYSTEM

BACKGROUND OF THE INVENTION

[0001] Heating, ventilation, air conditioning, and refrigeration (HVAC/R) systems, such as those used in residential and commercial buildings, are generally powered by alternating current (AC) power received from an AC utility power source, such as an AC grid power. In locations where AC grid power is expensive, unreliable, or unavailable, power may be provided by alternate power sources such as photovoltaic power sources and on-site electromechanical generators.

[0002] In some cases, the buildings or homes are located in remote areas with limited or no AC grid power available. For example, remote telecommunications shelters are typically cooled by on-site electrically powered HVAC/R systems, which maintain the interior temperature below that which would cause the telecommunication system to shut down or otherwise fail or compromise reliable operations. However, if grid or generated power is insufficient or lost completely, without adequate, immediate, power back-up, HVAC/R systems will not be able to operate properly. Loss of HVAC/R function can lead to discomfort, loss of perishable items, and damage to sensitive computer equipment, among other things, in remote, commercial and residential contexts. While, battery back-up systems are provided for many applications, such systems are typically insufficient for providing power to HVAC/R system because of limited battery power output.

SUMMARY OF THE INVENTION

[0003] An enclosure may include a heating, ventilation, air conditioning, and refrigeration (HVAC/R) system having a photovoltaic power source and a direct current (DC) power source, such as a back-up battery, and be configured to provide uninterrupted power to the HVAC/R system when a primary power source, such as alternating current (AC) grid power, is producing insufficient power or is unavailable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] In one embodiment, a DC powered electromechanical system includes: one or more three-phase motors, and a DC power supply for operating the system including:

a photovoltaic power source and a rechargeable DC power storage assembly connected thereto for generating a DC power input signal; a receiver for receiving DC power from the PV power source and the rechargeable DC power storage assembly; a variable frequency drive (VFD) electrically connected to the receiver and configured to provide three-phase alternating current (AC) power to operate the one or more three-phase motors; and a DC power step-up module connected to said VFD and configured to provide a DC output thereto having a higher voltage than said DC power input signal.

[0005] In another embodiment, a system comprising one or more three-phase motors, and a DC power bus includes: a photovoltaic power means for providing direct current (DC) power to a DC power bus; means for storing DC power, wherein the means for storing DC power is electrically connected to the DC power bus; means for electrically controlling a variable frequency drive, wherein the means for controlling the variable frequency drive is electrically connected to the DC power bus; and means for stepping-up the voltage of said means for storing DC power, wherein said means for stepping-up the voltage is connected to the DC power bus.

[0006] In a further embodiment, a method for controlling an HVAC/R power supply system, the method includes: receiving data indicating a capacity of an alternating current (AC) power source; receiving data indicating a capacity of a direct current (DC) power source; receiving data indicating a capacity of a photovoltaic power source; receiving data indicating an electric load of an HVAC/R system; instructing a Variable Frequency Drive (VFD) controller to draw power from the photovoltaic power source if the photovoltaic capacity is greater than or equal to the electric load of the HVAC/R system; instructing the VFD controller to draw supplemental power from one of the AC power source or DC power source if the photovoltaic capacity is less than the electric load; and instructing the VFD controller to reduce the load of the HVAC/R system if the load is greater than the combined capacity of the photovoltaic power source, AC power source, and DC power source.

[0007] Fig. 1 is a perspective illustration of a telecommunication shelter with the roof and some sidewalls removed to show the interior chamber and generally show the air conditioning and handling system;

[0008] Fig. 2 is a schematic block diagram illustrating an embodiment of an HVAC/R power supply system with a rechargeable DC power back-up;

[0009] Fig. 3 is a schematic diagram illustrating an embodiment of an integrated rectifier;

[0010] Fig. 4 is a schematic diagram illustrating an embodiment of a power step-up unit;

[0011] Fig. 5 is a schematic illustration of elements of an HVAC/R system, including a pulsed control valve;

[0012] Fig. 6 is a schematic block diagram illustrating an embodiment of an HVAC/R power supply system with a rechargeable DC power back-up, which utilizes a photovoltaic power source; and

[0013] Fig. 7 is a flowchart showing exemplary logic for a controller, such as power source controller.

DETAILED DESCRIPTION

[0014] Embodiments relate to heating, ventilation, air conditioning, and refrigeration (HVAC/R) systems which include a photovoltaic power source and a direct current (DC) power source, such as a back-up battery to cool a variety of enclosure types. Enclosures, for example, may be residential in nature, such as houses and apartments, commercial in nature, such as office buildings and factories, or remote installations, such as telecommunications shelters and remote military installations. Embodiments are configured to provide uninterrupted power to the HVAC/R system when a primary power source, such as alternating current (AC) grid power, is producing insufficient power or is unavailable. Embodiments of the present invention would be useful for applications such as those described in co-pending United States application number 13/012,072, filed on January 24, 2011.

[0015] One embodiment relates to systems for cooling an enclosure that houses sensitive electronic equipment, such as telecommunications equipment. An HVAC/R system controls the temperature within the enclosure so that the electronic equipment does not become damaged by exposure to high temperatures. In this embodiment, the HVAC/R system is powered by AC power from a power grid under normal conditions, but is also connected to a photovoltaic power source and a back-up power source. In this embodiment, the HVAC/R system is run using one or more three-phase motors and one or more single phase motors in order to be most efficient at providing cooling for the enclosure. In order to maintain efficiency, a variable frequency drive (VFD) that provides three phase power to the three phase motors and single phase power to the single phase motors is used within the HVAC/R system. In one embodiment, the AC power is first converted to DC power in order to power the VFD.

[0016] Three-phase motors, such as compressor motors within an HVAC/R system, may be operated much more efficiently and with less wear if the character of the power running them is controllable. For example, in one embodiment, when starting a three-phase electric motor, the frequency of the driving power can be modulated to avoid transient current spikes and unnecessary wear on the motor. VFDs are able to receive DC power and output modulated (i.e. frequency controlled) AC power to electric motors. By varying the frequency of the power to an electric motor, a VFD can more efficiently control the speed of that electric motor. The system described herein can utilize VFDs in an HVAC/R system to increase the efficiency of the system by providing control of the speed and output of the HVAC/R system components. For example, if a temperature controlled environment needs slight cooling, it is more efficient to run the HVAC/R system components, such as the compressor motor, at a reduced speed to meet the actual need, rather than to run it at full speed. Being able to modulate the speed of HVAC/R components such as those mentioned above also prevents unnecessary cycling of the system and allows for more fine control of the environment as a whole.

[0017] Because of the variety of different HVAC/R system components and their individual power requirements, it is often advantageous to provide more than one VFD in an HVAC/R system. Further, a VFD controller may be provided to provide overall control of the multiple VFDs to maximize HVAC/R system performance and efficiency.

[0018] Traditional AC power sources, such as AC grid power, can be unreliable depending on the location of the power supply need, the weather, and other variables. Thus, one embodiment is a shelter that uses an HVAC/R power supply system that can provide uninterrupted power to the HVAC/R system components regardless of the status of the AC power source. Embodiments include a photovoltaic power source and a back-up power source, such as a DC battery, which stores electrical power and may be utilized to control a VFD when AC power from the AC power source is not available. In another embodiment, the photovoltaic power source and the back-up power source may be used alone or in combination to supplement the power available to the HVAC/R system when, for example, the AC power source comes from a generator with limited output capacity. In such a system, the photovoltaic power source and the back-up power source may be utilized to provide supplemental power during periods of increased electrical load, or to provide power during periods where the AC power generator is not available.

[0019] Photovoltaic power sources generate electrical power by converting solar radiation into DC power using semiconductors that exhibit the photovoltaic effect i.e. the creation of a voltage (or a corresponding electrical current) in a material upon exposure to solar radiation. Photovoltaic power sources are often constructed as panels comprising a number of cells, which contain a photovoltaic material. Examples of materials presently used for photovoltaic power sources include: monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium selenide/sulfide. Photovoltaic power sources often include several components such as a panel comprising many individual photovoltaic cells, an inverter, which converts the generated DC current to AC current, batteries connected to the panels to store excess generated electricity, charge controllers which control the charge going to any connected batteries, and sensors which monitor the output of the photovoltaic power source.

[0020] Another embodiment relates to a system that uses a power source controller that allows an HVAC/R system to selectively draw power from one of a plurality of individual power sources, such as an AC grid power source, an AC generator power source, a photovoltaic power source, and a DC power source, such as a DC battery. A power source controller, which may be standalone or built into a VFD controller, can increase the overall system efficiency by precisely controlling the source of the power for the HVAC/R components when multiple sources are available.

[0021] Accordingly, one embodiment relates to providing power to an HVAC/R system, which may include AC and DC power sources with different electrical characteristics, and which is configured to supply uninterrupted power to the HVAC/R system components under a wide variety of circumstances. In this embodiment the system is able to reliably and efficiently maintain the internal environment of various types of enclosures, which may house sensitive electronic equipment, thereby ensuring optimal operation of the electronic equipment.

[0022] Fig. 1 is a perspective illustration of one type of enclosure that could benefit from the systems described herein. In Figure 1, a telecommunication shelter 100 is shown with the roof and some sidewalls removed to show the interior chamber and generally show the air conditioning and handling system. Within the telecommunications shelter 100 are vertical racks 150, which have shelves configured to support various types of electronic equipment, such as telecommunications equipment. The environment of the telecommunications shelter 100 is controlled by a heating, ventilation, air conditioning, and refrigeration (HVAC/R) system. The HVAC/R system may include components such as a condenser unit 135, refrigerant lines 120, air handling unit 115, primary air duct 110 and secondary air ducts 105. Additional HVAC/R components are discussed more completely with reference to Fig. 3. The components of the HAVC/R system work to control the environment within the shelter 100, including for example, the temperature and the humidity. Additional description of the air handling embodiment can be found in U.S. Patent Application No. 11/941,839, filed November 16, 2007.

Additionally, the shelter is provided with a connection to an AC power source 130, such as a connection to common AC grid power, and a connection to a photovoltaic power source 145, such as a photovoltaic panel.

[0023] To provide uninterrupted power to the HVAC/R system, power is supplied to the HVAC/R system by a power supply unit 125, which includes a Direct Current (DC) power source 140. The DC power source 140 may be, for example, one or more DC batteries. In other embodiments, the DC power source 140 is housed within power supply unit 125 enclosure. Preferably, the DC power source 140 is rechargeable. In the embodiment of Fig. 1, if the AC power source 130 becomes unavailable, the power supply unit 125 may instead provide power to the HVAC/R system from the photovoltaic power source 145, the stored capacity in the DC power source 140, or combinations thereof. Thus, the HVAC/R system is able to maintain the environment in the telecommunications shelter 100 regardless of the instant availability of the AC power source 130.

[0024] Of course one of ordinary skill in the art would recognize that a similar system could be used with a variety of enclosures, such as homes businesses, off site storage containers and the like. Thus, the invention is not limited to the particular type of enclosure illustrated in Figure 1.

[0025] Fig. 2 is a schematic block diagram illustrating an embodiment of an HVAC/R power supply system 200 with a rechargeable DC power back-up, as well as components of an HVAC/R system. The AC power source 130 provides AC power from, for example, AC grid power. The AC power source 130 is electrically connected to a rectifier 215. A rectifier is an electrical device that converts AC power, which periodically reverses direction, to DC power, where the current flows in only one direction. Rectifiers may be made of solid state diodes, vacuum tube diodes, mercury arc valves, and other components as are well known in the art. In some embodiments, the rectifier 215 includes an integral transformer capable of varying the AC input voltage from, for example, AC power source 130. A rectifier embodiment with integral transformer is described in more detail with respect to Fig. 3, below. In a preferred embodiment, a filter 275 (or smoothing circuit) is electrically connected to the output of the rectifier in order to produce steady DC current from the rectified AC power source 130. Many methods exist for smoothing the DC current including, for example, electrically connecting a reservoir capacitor or smoothing capacitor to the DC output of the rectifier 215. The filter 275 is also electrically connected with the DC power bus 210 to provide filtered DC power to other HVAC/R power supply system 200 components.

[0026] The DC power bus 210 electrically connects to components of the HVAC/R power supply system 200 to provide electric power to those components. The DC power bus 210 may include one or more conductors, such as wires or cables, capable of conducting and transmitting electric power. The DC power bus 210 may be a multi-wire loom with physical connectors so that the bus may be connected to components and expanded to meet the power needs of the HVAC/R power supply system 200. Certain embodiments of a DC power bus may comprise sub-buses that are at different voltages, such as a high-voltage DC sub-bus and a low-voltage DC sub-bus. In this way, a single DC power bus can provide DC power at different voltage levels in accordance with the needs of the components connected to the DC power bus 210 as well as the voltages of the various power sources connected to the system. In this embodiment, the DC power bus 210 electrically connects to the DC power source 220 so that it may be recharged. The DC power source 220 may be, for example, a battery, or a plurality of batteries electrically connected to each other. If multiple batteries are used, they may be connected in series or in parallel to produce resultant voltages different from the voltage of the individual battery units. To limit the amount of charge current flowing to the DC power source 220, a current limiting circuit or battery charge controller 280 may be placed between the power bus 210 and the DC power source 220. The charge controller 280 limits the current charging the DC power source 220 according to the specification of the DC power source 220 so that it is not damaged while being charged. Additionally, the battery charge controller 280 may condition the DC power source 220 for longer lasting operation.

[0027] The DC power source 220 may include one or more batteries, such as automobile batteries. Typically, such batteries have relatively low voltages, such as 12 volt or 24 volt. While it may be possible to increase the voltage by wiring the batteries in series, it may be preferable to have fewer batteries or a lower voltage DC power source 220. Accordingly, the DC power source 220 may be connected to a power step-up unit 240. Stepping-up voltage may be accomplished by a DC to DC conversion utilizing a DC to AC inverter. A DC to AC inverter is an electrical device that converts DC power to AC power. The converted AC current can be at any voltage and frequency with the use of appropriate transformers, switching, and control circuits, as is well known in the art. Inverters are commonly used to supply AC power from DC sources such as solar panels or batteries. In Fig. 2, DC power source 220 is a low voltage power source, such as a 12 volt automobile battery. The DC power source 220 is electrically connected to power step-up unit 240, which includes DC to AC inverter 225. The inverter 225 converts the low voltage current from the DC power source 220 to a higher voltage output AC current. Power step-up unit 240 also includes a rectifier 235. The inverter 225 is electrically connected to rectifier 235, which converts the high voltage AC current back to a DC current, but at a higher voltage than the original DC power source 220 voltage. For example, 12 volt current from a DC power source 220 may be converted to a 300 volt DC current using the power step-up unit 240. An embodiment of a power step-up unit is described further with reference to Fig. 4, below. The power step-up unit 240 is also connected to the DC power bus 210 to supply high voltage DC power to HVAC/R system components. The same process can also be used to step-down the voltage of the DC power source 220, where, for example, the DC power source is a high voltage source and low voltage DC is needed. The process for stepping-down the voltage would be the same, except the step of inverting the DC current to AC would lower rather than raise the voltage of the supplied current.

[0028] AC power may also be selectively stepped-up or down by use of a transformer, which is a device that transfers electrical energy from one circuit to another through inductively coupled conductors. A varying current in the first or primary conductor creates a varying magnetic flux in the transformer's core and thus a varying magnetic field through the secondary conductor. This varying magnetic field induces a voltage in the secondary conductor. If a load is connected to the secondary conductor, an electric current will flow in the secondary conductor and electrical energy will be transferred from the primary circuit through the transformer to the load. By appropriate selection of the ratio of turns in each conductor, a transformer my selectively step-up or step-down AC voltage.

[0029] The DC power bus 210 also electrically connects to a Variable Frequency Drive (VFD) controller 265. The VFD controller 265 is electrically connected to the VFDs 230 and comprises electronics which provide power and control signals to the VFDs 230 to, for example, turn them on or off, or to modulate their drive frequencies during operation. The VFD controller 265 may receive signals from sensors (not shown), such as temperature sensors, mounted within the telecommunications shelter 100 and may include logic for the control of the VFDs 230. In other embodiments, the VFD controller 265 may comprise a fixed control panel (not shown) mounted in a remote location, such as in the telecommunications shelter 100, operable to control the VFDs manually. The VFD controller 265 may also monitor the current load on the power bus 210 and vary the current draw of the VFDs (230a and 230b) to avoid any dangerous over-current condition. In alternative embodiments, the VFD controller 265 may require AC power, and so it may be electrically connected to an inverter (not shown) fed by the DC power bus 210 so as to receive AC operating power. In yet another embodiment, a VFD may provide AC power to a controller that requires AC operating power. In a further embodiment, the VFD controller may receive AC power directly from the AC power source 130. The VFD controller 265 may comprise a microprocessor or computing system including software and hardware configured to accomplish the aforesaid operations.

[0030] Each VFD controls the rotational speed of an AC electric motor, such as compressor motor 250 and blower 270. The VFD controls the speed of the motor by controlling the frequency of the electrical power supplied to the motor, as is well known in the art. Variable-frequency drives are sometimes alternatively referred to as adjustable-frequency drives (AFD), variable-speed drives (VSD), AC drives, microdrives or inverter drives. Since the voltage is varied along with frequency, these are sometimes also called VVVF (variable voltage variable frequency) drives. In the embodiment shown in Fig. 2, there are multiple VFDs (230a and 230b) electrically connected to separate components of the HVAC/R system. Because different elements of the HVAC/R system, such as the compressor motor 250 and the blower 270 may have different operational requirements, such as optimal speed and current draw, it is convenient to provide multiple VFDs based on the system needs; however, multiple VFDs are not necessary. Further, VFDs are preferred because they can vary the speed of different motor elements according to HVAC/R system needs. For example, when the HVAC/R system is in a cooling mode wherein the cooling requirements are minimal, the VFDs can lower the speed of the blower 270 as well as reducing the speed of the compressor motor 250 to accommodate for the reduced cooling needs. This not only reduces overall power consumption advantageously, but it reduces unnecessary wear on HVAC/R system components. A VFD, such as VFD 230a, may also be electrically connected to a phase change module 255 which is then electrically connected to another HVAC/R element, such as condenser fan 260. In this embodiment, the condenser fan 260 has a single-phase motor which is not compatible with the multi-phase output of VFD 230a, which is necessary for the compressor motor 250 on the same circuit. However, because the compressor motor 250 and condenser fan 260 typically operate at the same time, it is convenient to have current provided to both by VFD 230a. The phase change module 255 adapts the multi-phase VFD output current to a single-phase current to operate the condenser fan 260 efficiently. In certain embodiments, the phase change module 255 may comprise a plurality of capacitors in series and at least one capacitor in parallel with the plurality of capacitors in series. In other embodiments, the VFDs are electrically connected to the DC power bus 210 and are controlled individually by, for example, local control panels, without the need for a VFD controller 265.

[0031] Fig. 3 is a schematic diagram illustrating an embodiment of an integrated rectifier 300. The Rectifier 300 includes an integral transformer 305, rectifier circuit 310, and filter 315. In this embodiment, the rectifier 300 is capable of receiving both a 230 volt

AC signal and a 110 volt AC signal, and is configured to produce a 30 volt DC output signal. A low voltage DC signal may be used for charging a DC power source (not shown). Accordingly, in some embodiments, a rectifier such as rectifier 300 can be directly, electrically connected to a DC power source, such as a battery, such that the low voltage DC output can charge the DC power source. The transformer 305 includes three taps 320-322 on the input side. To produce a 110 volt AC signal, the top two taps, 320 and 321, are electrically connected to the transformer 305. Alternatively, to produce a 230 volt AC signal, the two outermost taps, 320 and 322, are electrically connected to the transformer 305. The transformer 305 steps down the input voltage to produce a lowered output voltage for the rectifier circuit 310. In this embodiment, the rectifier circuit 310 is a four diode bridge rectifier. Other rectifier configurations may be used. The filter 315 then smoothes the DC output signal from the rectifier circuit 310. As shown in Fig. 3, the filter 315 is a single capacitor. In other embodiments, alternative filters may be used as are known in the art.

[0032] Fig. 4 is a schematic diagram illustrating an embodiment of a power step-up unit, such as power step-up unit 240 of Fig. 2. Power step-up unit 400 includes two 12 volt DC to 120 volt AC inverters, 410 and 411, rectifiers 415 and 416, and filter 420. Power step-up unit 400 receives a 24 volt DC power signal from a DC power source 405, such as a battery, or series of batteries, and outputs 300 volt DC power. The two inverters 410 and 411 are each configured to receive a 12 volt DC input and output a 120 volt AC signal. The rectifiers 415 and 416 rectify the respective AC signals producing DC outputs of about 150 volts each. The rectifiers 415 and 416 are connected in serial, and therefore collectively produce a combined DC signal of about 300 volts. In the embodiment shown in Fig. 4, the rectifiers 415 and 416 are each a four diode bridge rectifier in parallel with a capacitor. Other rectifier configurations may be used. Additionally, a filter 420 is connected across the rectifier outputs. The filter 420 is configured to improve the quality of the DC output signal. As shown in Fig. 4, the filter 420 is a single capacitor. In other embodiments, alternative filters may be used.

[0033] Fig. 5 is a schematic illustration of elements of an HVAC/R system 500, including a pulsed control valve 510. Refrigerant is circulated in the system via the refrigerant lines 120. The compressor motor 250 compresses refrigerant circulated in the refrigerant lines 120 and then passes it to the condenser 505, where the compressed refrigerant is cooled and liquefied. The condenser fan 260 assists with the cooling of the compressed refrigerant by forcing air over cooling fins (not shown) attached to the condenser 505. The compressor motor 250 is electrically connected to a VFD 230, which provides three-phase AC power to it. The VFD 230 is additionally electrically connected to a phase change module 255, which converts the three-phase AC power to single-phase AC power for the condenser fan 260. Collectively, the compressor motor 250, the condenser 505, the condenser fan 260 and the phase change module 255 make up the condenser unit 135 of Fig. 1. After the refrigerant is cooled and condensed in the condenser unit 135, it is passed to the pulsed control valve 310.

[0034] The pulsed control valve 510 controls refrigerant flow from the condenser 505 to the evaporator 515. Conventional evaporators are designed to operate at full refrigerant flow and are inefficient at lower flows, and fluctuating flows. However, the VFD powered compressor motor 250 may result in variable refrigerant flows to the condenser and to the evaporator as the drive frequency is modulated according to system cooling needs. In order to achieve optimal system performance, the pulsed control valve 510 is used to produce an optimal refrigerant flow regardless of the action of the VFD 230. Such refrigerant control is especially important at lower refrigerant flow rates resulting from variable compressor speeds. The pulsed control valve 510 may be a mechanical valve such as described in U.S. Patents Nos. 5,675,982 and 6,843,064 or an electrically operated valve of the type described in U.S. Patent No. 5,718,125.

[0035] The evaporator 515 evaporates the compressed refrigerant thereby extracting heat from the air around it. The evaporator 515 may additionally have metal fins (not shown) to increase its heat exchanging efficiency.

[0036] Fig. 6 is a schematic block diagram illustrating an embodiment of an HVAC/R power supply system 600 with a rechargeable DC power back-up, which utilizes a photovoltaic power source 605. Fig. 6 is the system of Fig. 2 augmented with a photovoltaic power source 605, additional sensors 610 and 615 and an additional controller 620.

[0037] Photovoltaic power source 605 is an electric device that converts solar radiation such as ambient light to electrical energy. Photovoltaic power generators are typically one or more panels comprising photovoltaic cells that produce a voltage when exposed to solar radiation. Photovoltaic power sources may be portable (e.g. attached to a trailer) or may be permanently installed in the ground or permanently affixed to a shelter or enclosure. Photovoltaic power sources output DC power; however, in some embodiments the photovoltaic power source may be connected to an inverter, which converts the DC output to AC, or may have an integral inverter. Photovoltaic power sources that are connected to an inverter may output single phase or multi-phase AC power at a variety of voltages and wattages. Photovoltaic power sources may have power output (usually rated in wattage) that varies based on the size of the system (e.g. the number of panels) as well as the ambient conditions (e.g. direct versus indirect light). Embodiments of photovoltaic power sources are well known in the art. Photovoltaic power source 605 is electrically connected to the DC power bus 210. In alternative embodiments, the photovoltaic power source 605 may include an integral inverter and be connected instead to rectifier 215 instead. In yet other embodiments, where, for example, the photovoltaic power source 605 has very limited capacity, the photovoltaic power source 605 may be directly connected to charge controller 280 and only serve to provide charge to DC power source 220.

[0038] AC capacity sensor 610 is electrically connected to the AC power source 130. The AC capacity sensor may be either the active sensing type, which works by sensing the instant power available at the connection point, or of the passive type, whereby a signal is sent to the AC capacity sensor corresponding to the power output capacity. Additionally, other sensing methods, as are known in the art, may be used. Useful switching and sensing components and circuits are described in U.S. Patent No. 7,227,749.

The AC capacity sensor 610 is also electrically connected to a power source controller 620, which is described in more detail below.

[0039] DC capacity sensor 615 is electrically connected to the DC power source 220 and to photovoltaic power source 605. The DC capacity sensor may be either the active sensing type, which works by sensing the instant capacity of the DC power source as well as the instant output of the photovoltaic power source 605, or of the passive type, whereby the DC power source 220 and photovoltaic power source 605 each sends a signal to the DC capacity sensor 615 corresponding to its power output capacity. With DC power sources, such as batteries, the capacity of the power source is generally based on the instant voltage of the power source. For example, as the measured voltage across the battery's terminals decreases, so too does the calculated DC power source capacity. However, other sensing methods, as are known in the art, may be used. Additionally, the DC capacity sensor 615 is electrically connected to the power source controller 620, which is described in more detail below.

[0040] The power source controller 620 is electrically connected to one or more power capacity sensors, such as AC capacity sensor 610 and DC capacity sensor 615. In this embodiment, the power source controller 620 is also electrically connected to the VFD controller 265. The power source controller 620 receives power output capacity data from the sensors connected to it, as well as power load data from the VFD controller and calculates a power source distribution. In simple embodiments, the power source controller 620 might instruct the VFD controller 265 to choose either the AC power source 130, the photovoltaic power source 605, or the DC power source 220 as a power source for operation of the HVAC/R components. In a preferred embodiment, the power source controller 620 senses the load required from the VFD controller and instructs the VFD controller to selectively draw power from each power source in an optimal fashion. For example, if the photovoltaic power source 605 is sufficient to meet the instant needs of the HVAC/R components, it would be most efficient and economical to draw power from only that source. However, if the load exceeds the photovoltaic power source's 605 total output, the power source controller 620 could supplement the power with either the AC power source 130 or the DC power source 220, so as to not overload the photovoltaic power source 605. For example, during periods of start-up of the HVAC/R components, power needs may temporarily exceed the total power output of the photovoltaic power source 605, or the instant power capacity of the same. In such a case, the power source controller 620 would direct the VFD controller 265 to utilize stored capacity in the DC power source 220 or available capacity from the AC power source 130 to avoid overload of the photovoltaic power source 605 and potential HVAC/R component damage. Likewise, the power source controller 620 may instruct the VFD controller 265 to reduce its power draw given the combined capacity of the DC power source 220 and photovoltaic power source 605 when AC power source 130 is unavailable. In preferred embodiments, the power source controller 620 can cause the VFD controller to draw power in any increment (e.g. 0% - 100%) from any available power source, such as the photovoltaic power source 605, the AC power source 130 and the DC power source 220. Notably, in other embodiments, there may be additional power sources.

[0041] In other embodiments, the power source controller 620 may be incorporated into the VFD controller 265. In such embodiments, the VFD controller is capable of receiving data from the AC capacity sensor 610 and the DC capacity sensor 615 so that it may regulate the power drawn from each power source in accordance with the load required by the HVAC/R system and other logic.

[0042] The power source controller 620 may comprise a microprocessor or computing system including software and hardware configured to accomplish the aforesaid operations. Examples of controller features and functions are described in U.S. Patent No. 7,630,856.

[0043] Fig. 7 is a flowchart showing exemplary logic for a controller, such as power source controller 620 in Fig. 6. In the embodiment of Fig. 7, the power source controller is photovoltaic power biased; that is, the controller will prefer to always draw from a photovoltaic power source, such as the photovoltaic power source 605 of Fig. 6, rather than other power sources. This strategy is not required, but may be preferable where it is desirable to keep the DC power source at max capacity as often as possible and to minimize draw from a traditional AC power source. Further, it may be desirable to reduce the cycling (i.e. charge-discharge-charge) of the DC power source to extend the lifetime of the DC power source.

[0044] At state 705 the power source controller 620 receives capacity data from an AC capacity sensor, such as sensor 610 in Fig. 6. Next, at state 710 the power source controller 620 receives capacity data from a DC capacity sensor, such as sensor 615 in Fig. 6. Then at state 715, the power source controller receives load data from the VFD controller, such as controller 265 in Fig. 6.

[0045] At decision state 720, the power source controller 620 compares the current load to the available photovoltaic power capacity. If the load is less than or equal to the photovoltaic capacity, then at decision state 740 the power source controller 620 determines whether the DC power source is being drawn from. If the DC power source is being drawn from, the power source controller 620 instructs the VFD to draw power from the photovoltaic power source only at state 750, since there is ample photovoltaic capacity. Then the power source controller 620 loops back into data gathering at step 705. If no power is being drawn from the DC power source, then the power source controller determines whether the AC power source is being drawn from at decision state 745. If the AC power source is being drawn from, the power source controller 620 instructs the VFDs to draw power from the photovoltaic power source only at state 750. If no power is being drawn from the AC power source, then the power source controller loops back into a data gathering step at state 705.

[0046] If, at decision state 720, the load is greater than the photovoltaic power source alone can provide, the power source controller then determines whether the load is greater than the combined capacity of the photovoltaic power source and the AC power source at decision state 725.

[0047] If, at decision state 725, the combined power capacity of the photovoltaic power source and AC power source are adequate to cover the load, the power source controller 620 instructs the VFD controller to draw the supplemental power from the AC power source at state 755. Then the power source controller 620 loops back into data gathering at step 705. If, on the other hand, the load is greater than the combined power capacity of the photovoltaic power source and AC power sources, then the power source controller 620 determines if the load is greater than the combined power capacity of the photovoltaic power source, AC power source and DC power source at decision state 730.

[0048] If, at decision state 730, the load is less than or equal to the combined power capacity of the photovoltaic power source, AC power source and DC power source, the power source controller 620 instructs the VFD controller to draw supplemental power from the DC power source at state 760. Then the power source controller loops back into a data gathering step at state 705. If, on the other hand, the load is greater than the combined power capacity of the photovoltaic power source, AC power source and DC power source, the power source controller instructs the VFD controller to reduce power draw at state 735. For example, at state 735, the power source controller could instruct the VFD power controller to lower the speed of all motors attached to the VFDs to reduce overall power draw. Then the power source controller loops back into a data gathering step at state 705. Fig. 7 is merely one exemplary embodiment of programming logic that may be used with the power source controller 620.

[0049] While the above detailed description has shown, described, and pointed out novel features as applied to various embodiments, it will be understood that various omissions, substitutions, and changes in the form and details of the devices and processes illustrated may be made by those skilled in the art without departing from the spirit of the invention. As will be recognized, the present invention may be embodied within a form that does not provide all of the features and benefits set forth herein, as some features may be used or practiced separately from others.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A heating, ventilation, air conditioning, and refrigeration (HVAC/R) system, comprising:

a rectifier electrically connected to a first AC power source;

a first DC power source;

a step up module electrically connected to the first DC power source;

a first power supply electrically connected to the rectifier and the step up module and configured to output three-phase AC power at variable frequencies;

a three-phase AC compressor motor electrically connected to the first power supply;

a phase change module electrically connected to the first power supply and configured to receive three-phase AC power from the first power supply and output single-phase AC power;

a single-phase AC evaporator fan motor electrically connected to the phase change module and configured to receive single-phase AC power from the phase change module;

a control module electrically connected to the first power supply and configured to provide control signals to the first power supply; a condenser; an evaporator; and

a pulsed operation control valve configured to control the flow of refrigerant between the condenser and the evaporator.

2. The HVAC/R system of claim 1, further comprising:

a second power supply electrically connected to the rectifier and the step up module and configured to output three-phase AC power at variable frequencies;

a three-phase AC blower motor electrically connected to the second power supply; and

wherein the second power supply is electrically connected to the control module and configured to receive control signals from the control module.

3. The HVAC/R system of claim 1 wherein the first DC power source is at least one DC battery.

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4. The HVAC/R system of claim 2, wherein the first power supply is a variable frequency drive and the second power supply is a variable frequency drive.

5. The HVAC/R system of claim 3, wherein the control module is electrically connected to a user control panel.

6. The HVAC/R system of claim 3, wherein the control module is electrically connected to a thermostat.

7. The HVAC/R system of claim 4, wherein the pulsed operation control valve is a mechanical valve.

8. The HVAC/R system of claim 1, wherein the pulsed operation control valve is an electronic valve.

9. A method of controlling a heating, ventilation, air conditioning, and refrigeration (HVAC/R) system, the method comprising:

providing DC power to a first power supply from a first power source;

providing DC power to a step up module from a second power source;

providing DC power to the first power supply from the step up module;

providing three-phase AC power at a first frequency from the first power supply to a first three-phase AC motor;

providing single-phase AC power at the first frequency from a phase change module to a single-phase AC motor;

changing the speed of the first three-phase AC motor by providing a first control signal from a control module to the first power supply so that the first power supply provides AC power to the first three-phase AC motor at a second frequency; and

providing a pulsed operation control valve to control the flow of refrigerant to an evaporator.

10. The method of claim 9, further comprising:

providing DC power to a second power supply from the first power source;

providing DC power to the second power supply from the step up module;

providing three-phase AC power at a third frequency from the second power supply to a second three-phase AC motor; and

changing the speed of the second three-phase AC motor by providing a second control signal from the control module to the second power supply so that the second power supply provides AC power to the second three-phase AC motor at a fourth frequency.

11. The method of claim 9 wherein the second power source is at least one DC battery.

12. The method of claim 11 wherein the first power source is a rectifier electrically connected to an AC power source.

13. The method of claim 9, wherein the pulsed operation control valve is a mechanical valve.

14. The method of claim 9, wherein the pulsed operation control valve is an electronic valve.

15. The method of claim 10, wherein the first power supply is a variable frequency drive and the second power supply is a variable frequency drive.

16. The method of claim 15, wherein the first three-phase AC motor is a compressor motor.

17. The method of claim 16, wherein the second three-phase AC motor is a blower motor.

18. The method of claim 17, wherein providing the three-phase AC power at the first frequency causes the compressor motor to operate at a first compressor speed and providing the three-phase AC power at the second frequency causes the compressor motor to operate at a second compressor speed, different from the first compressor speed.

19. The method of claim 18, wherein the first compressor speed causes a first refrigerant flow to the pulsed operation control valve and the second compressor speed causes a second refrigerant flow to the pulsed operation control valve, different from the first refrigerant flow.

20. The method of claim 19, wherein the flow of refrigerant to the evaporator is substantially the same at the first compressor speed and at the second compressor speed.

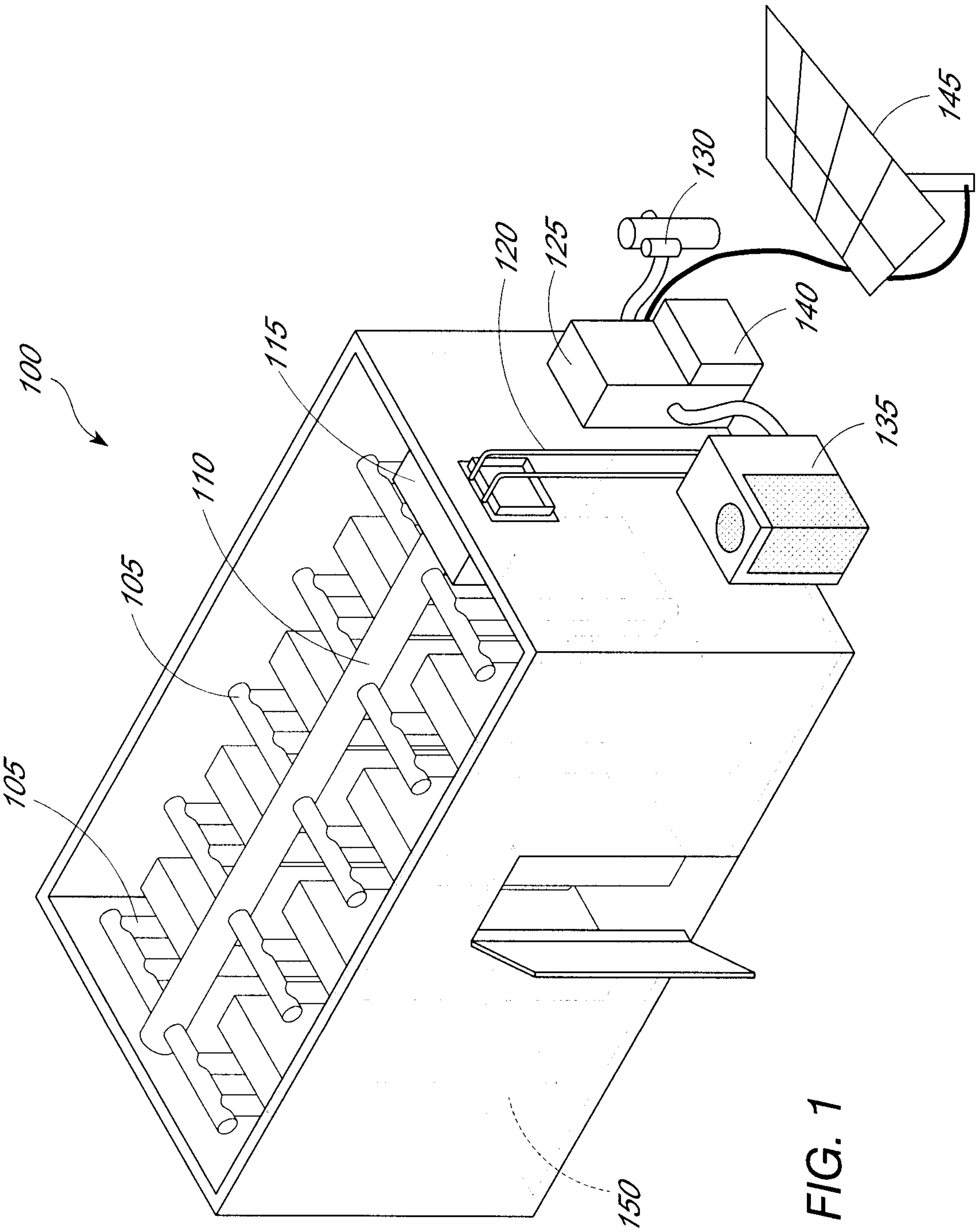


FIG. 1

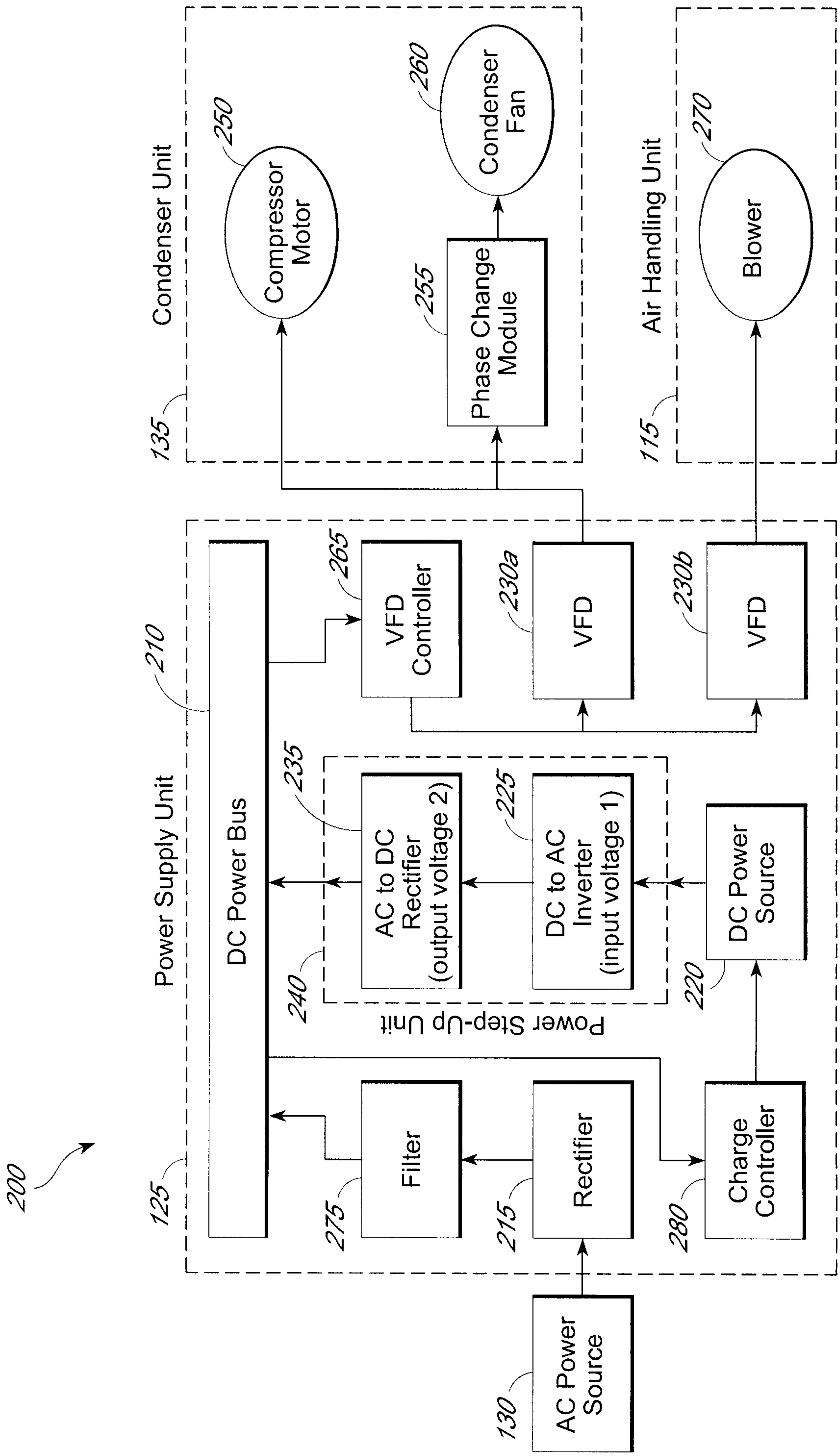

200
125
Power Supply Unit
210
DC Power Bus
275
Filter
215
Rectifier
280
Charge Controller
240
Power Step-Up Unit
235
AC to DC Rectifier (output voltage 2)
225
DC to AC Inverter (input voltage 1)
220
DC Power Source
265
VFD Controller
230a
VFD
230b
VFD
130
AC Power Source
135
Condenser Unit
250
Compressor Motor
255
Phase Change Module
260
Condenser Fan
115
Air Handling Unit
270
Blower

FIG. 2

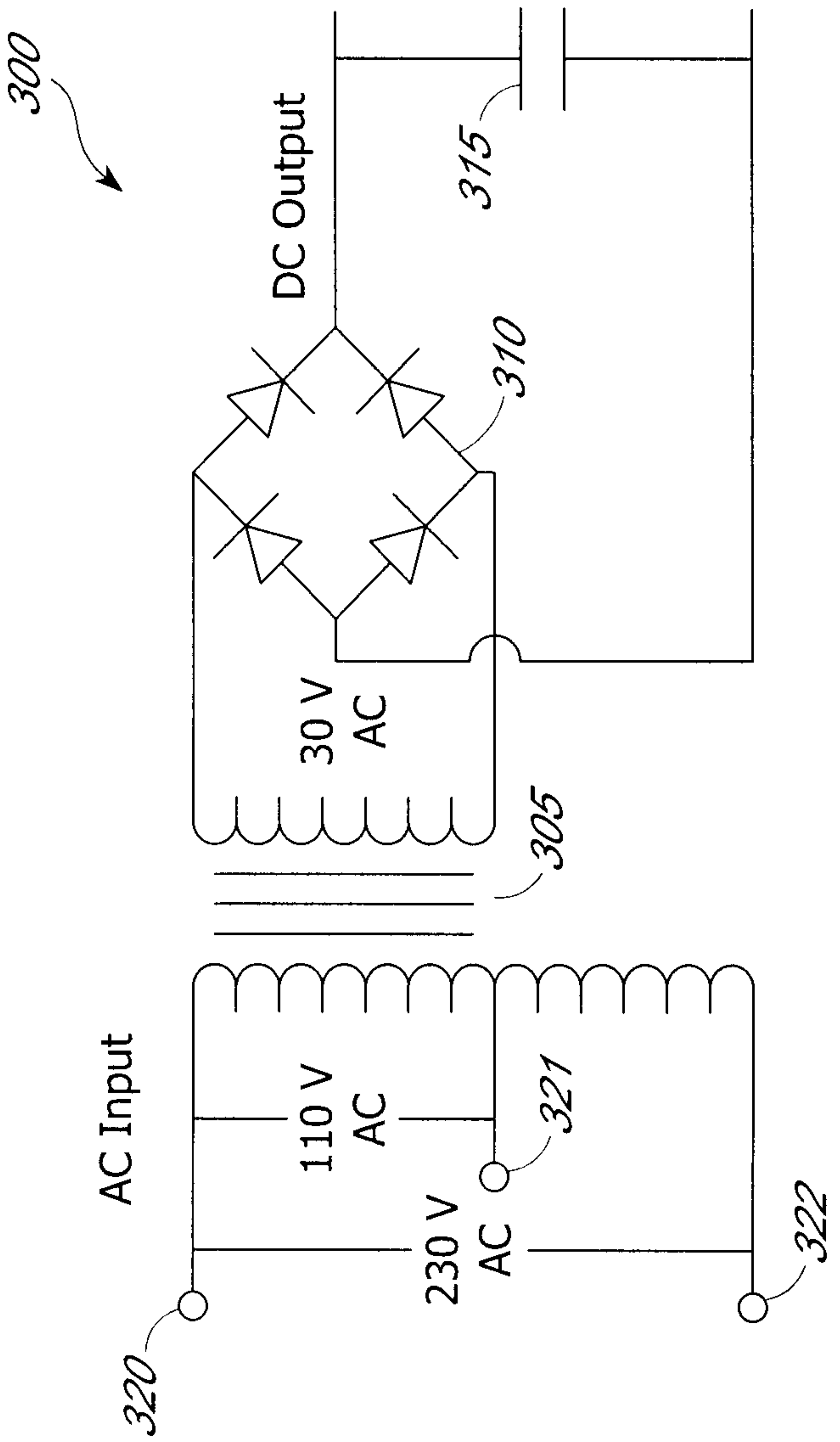

300
DC Output
315
310
30 V AC
305
AC Input
110 V AC
321
230 V AC
322
320

FIG. 3

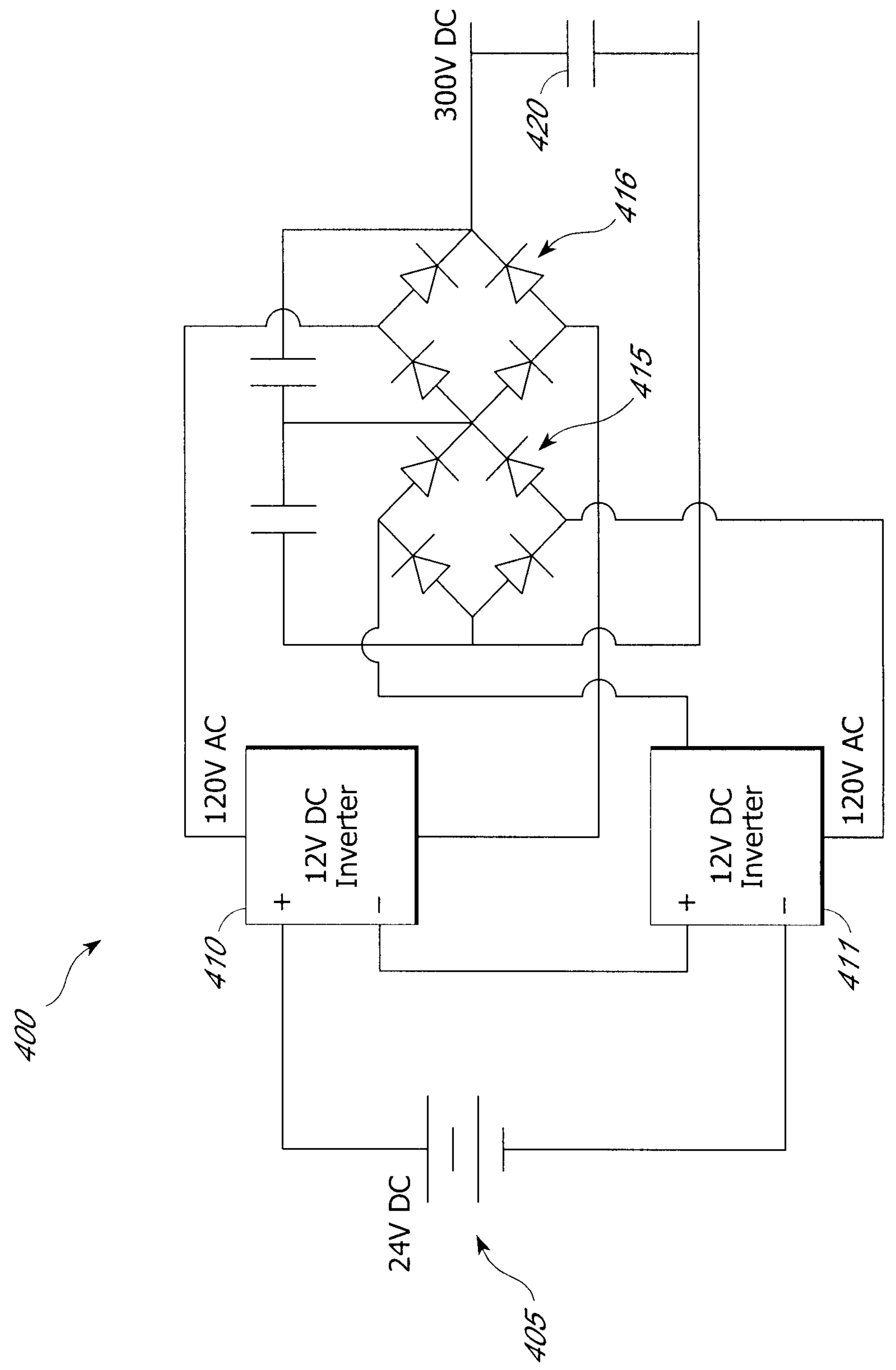

300V DC
420
416
415
120V AC
12V DC Inverter
+
-
120V AC
12V DC Inverter
+
-
400
410
411
24V DC
405

FIG. 4

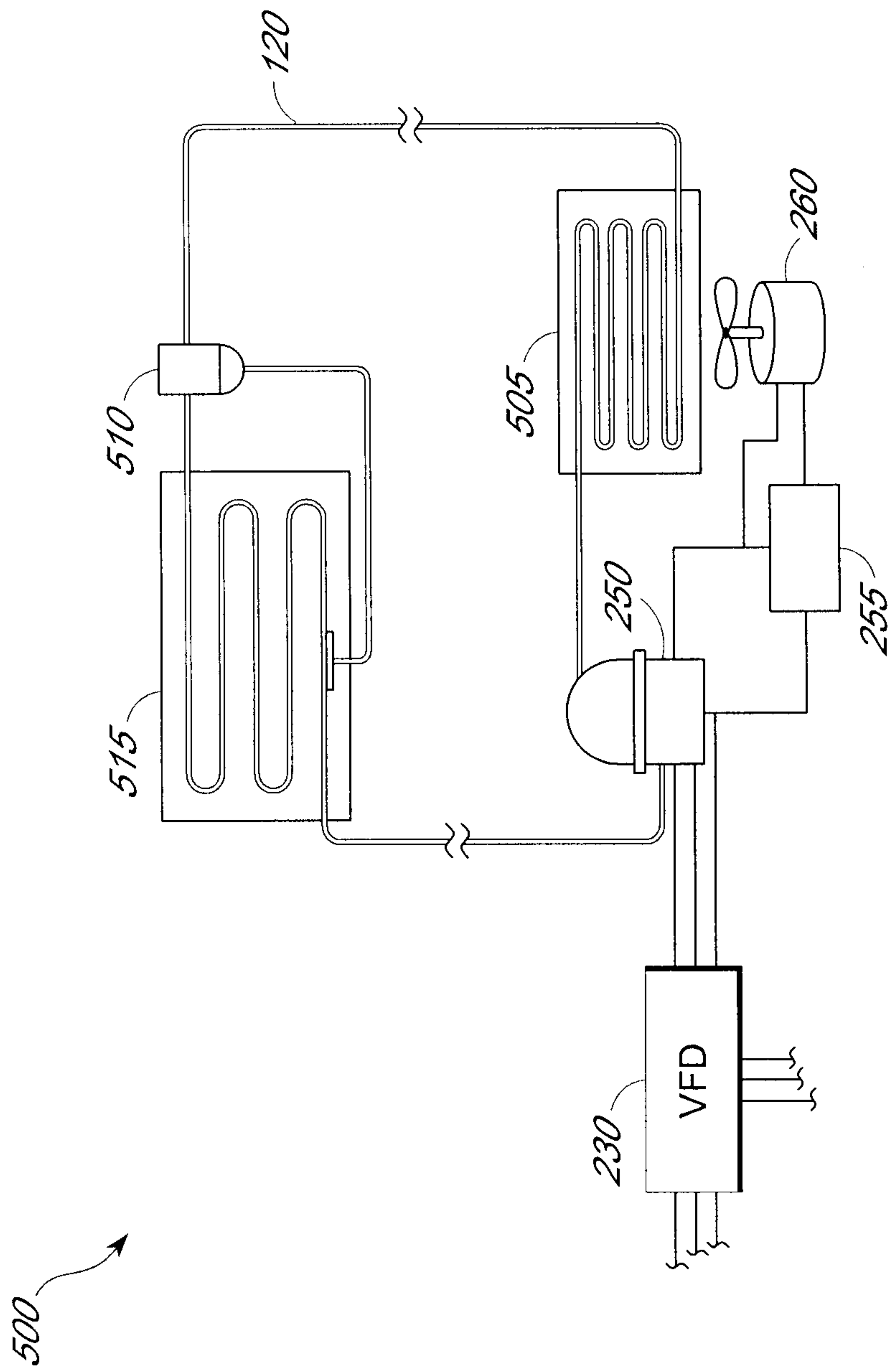


FIG. 5

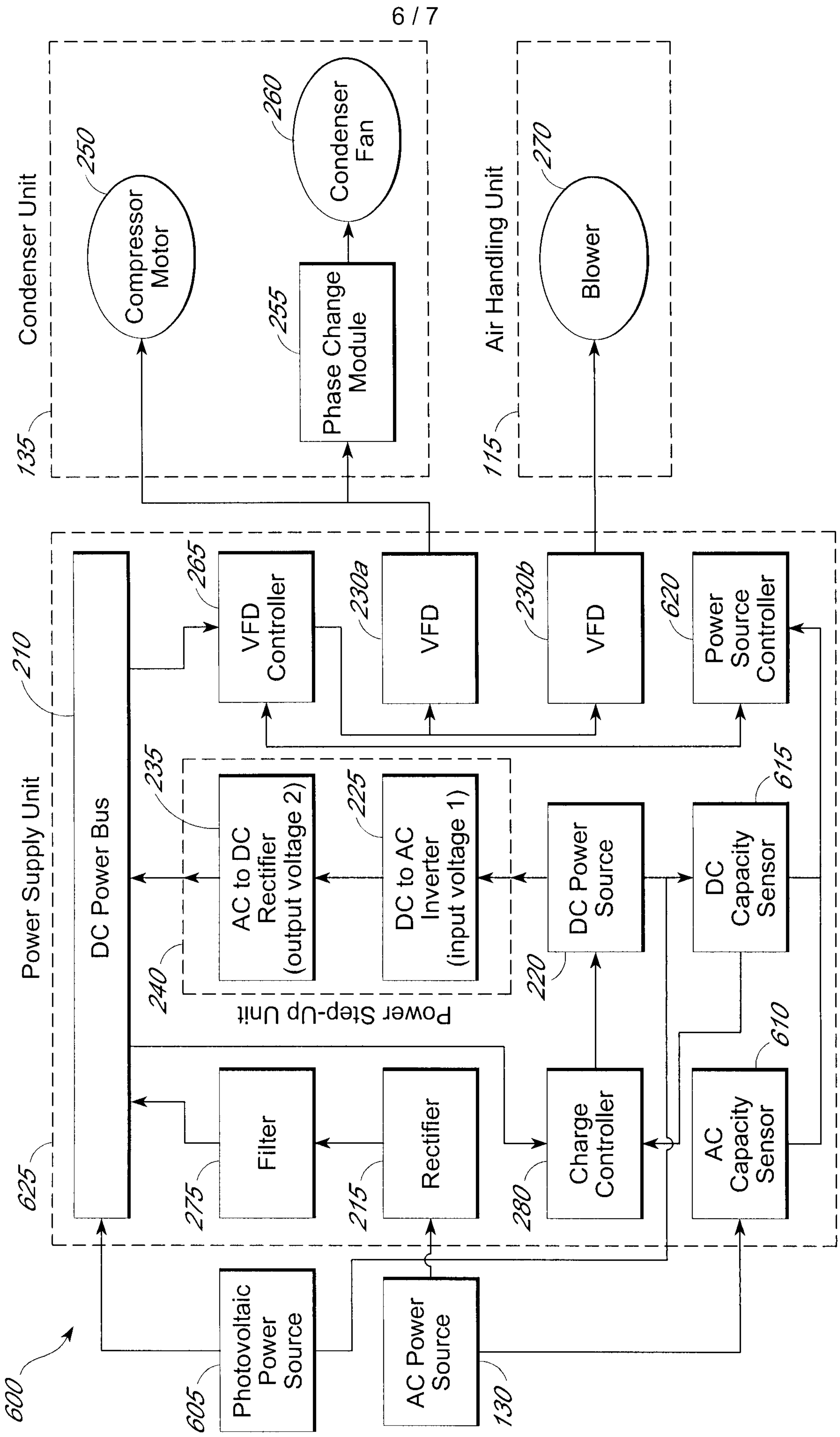

Condenser Unit
135
Compressor Motor
250
Phase Change Module
255
Condenser Fan
260
Air Handling Unit
115
Blower
270
Power Supply Unit
625
DC Power Bus
210
VFD Controller
265
VFD
230a
VFD
230b
Power Source Controller
620
AC to DC Rectifier (output voltage 2)
235
DC to AC Inverter (input voltage 1)
225
Power Step-Up Unit
240
DC Power Source
220
DC Capacity Sensor
615
Filter
275
Rectifier
215
Charge Controller
280
AC Capacity Sensor
610
Photovoltaic Power Source
605
AC Power Source
130
600

FIG. 6

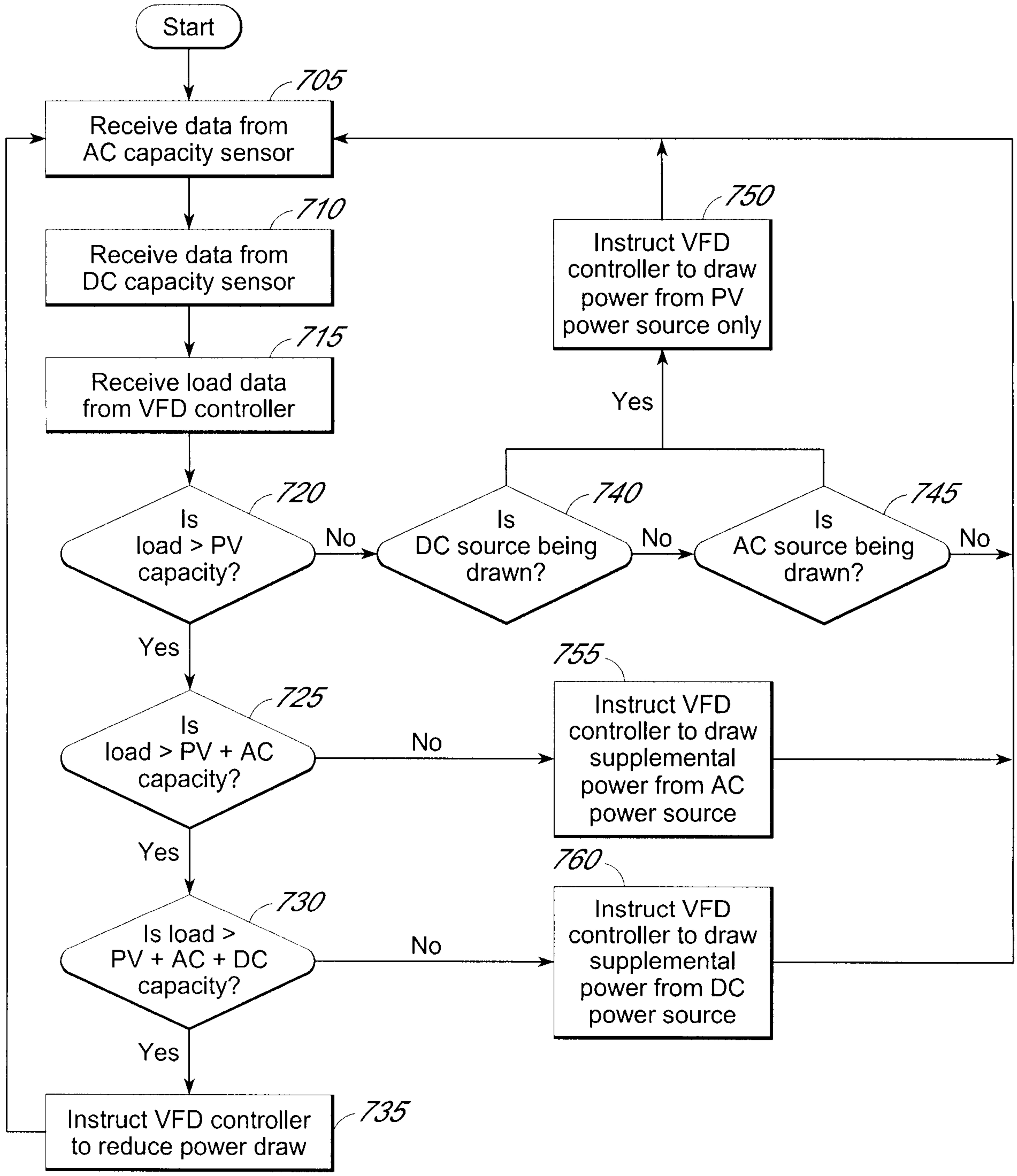
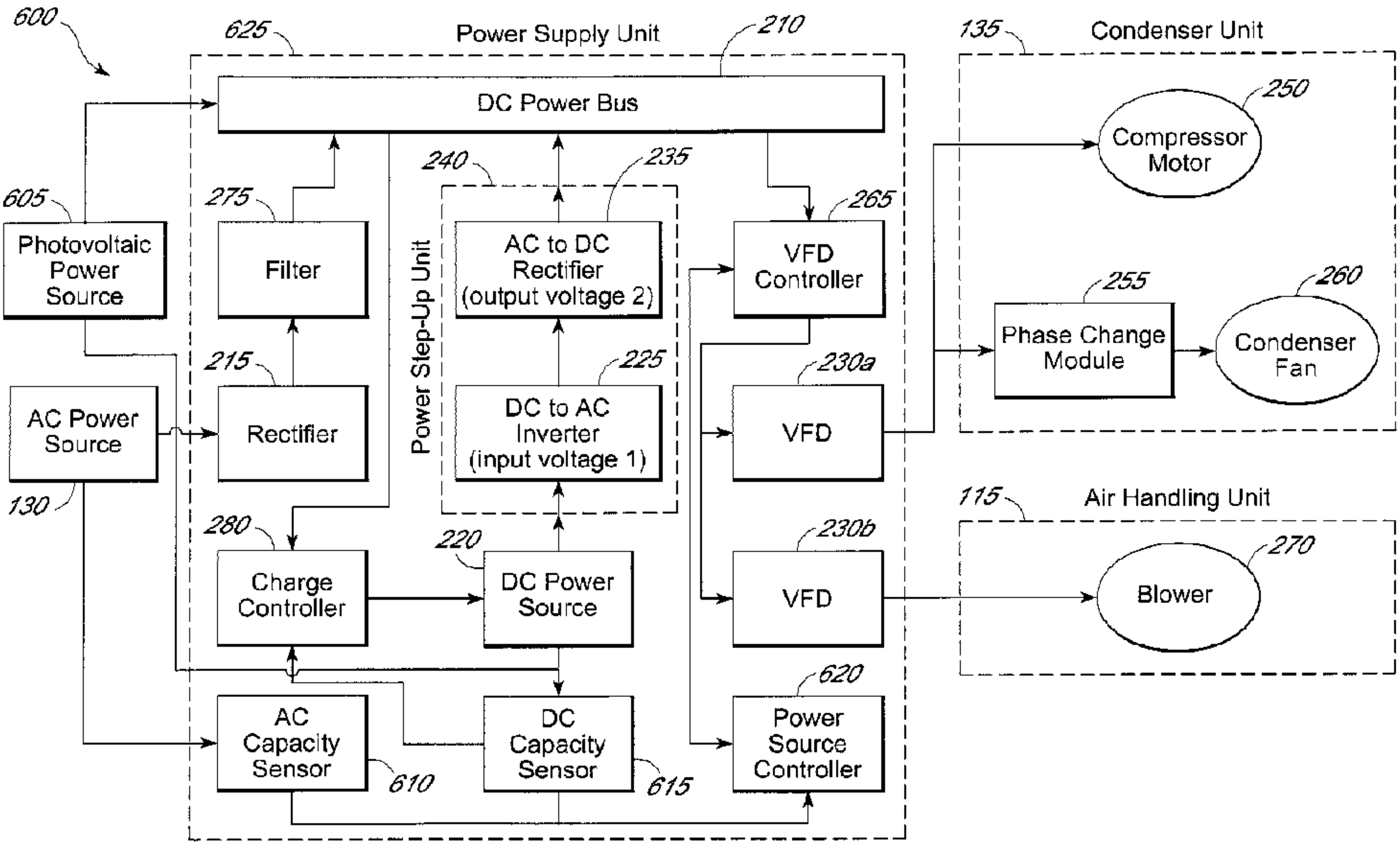

Start
705
Receive data from AC capacity sensor
710
Receive data from DC capacity sensor
715
Receive load data from VFD controller
720
Is load > PV capacity?
No
740
Is DC source being drawn?
No
745
Is AC source being drawn?
No
Yes
750
Instruct VFD controller to draw power from PV power source only
Yes
725
Is load > PV + AC capacity?
No
755
Instruct VFD controller to draw supplemental power from AC power source
Yes
730
Is load > PV + AC + DC capacity?
No
760
Instruct VFD controller to draw supplemental power from DC power source
Yes
735
Instruct VFD controller to reduce power draw

FIG. 7



600
625
Power Supply Unit
210
DC Power Bus
605
Photovoltaic Power Source
275
Filter
240
235
AC to DC Rectifier (output voltage 2)
Power Step-Up Unit
225
DC to AC Inverter (input voltage 1)
265
VFD Controller
215
Rectifier
AC Power Source
130
230a
VFD
230b
VFD
280
Charge Controller
220
DC Power Source
AC Capacity Sensor
610
DC Capacity Sensor
615
620
Power Source Controller
135
Condenser Unit
250
Compressor Motor
255
Phase Change Module
260
Condenser Fan
115
Air Handling Unit
270
Blower