



(51) International Patent Classification:
G05F 1/10 (2006.01) **G05F 1/00** (2006.01)

(21) International Application Number:
PCT/US2010/023307

(22) International Filing Date:
5 February 2010 (05.02.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/206,891 5 February 2009 (05.02.2009) US

(71) Applicant (for all designated States except US): **EN-PHASE ENERGY, INC.** [US/US]; 201 1st Street, Suite 300, Petaluma, California 94952 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **FORNAGE, Martin** [FR/US]; 25 Halsey Avenue, Petaluma, California 94952 (US). **DARGATZ, Marv** [US/US]; 4760 Howe Lane, Auburn, California 95602 (US).

(74) Agent: **MOSER, Raymond, R., Jr.**; Moser IP Law Group, 1030 Broad Street, Suite 203, Shrewsbury, NJ 07702 (US).

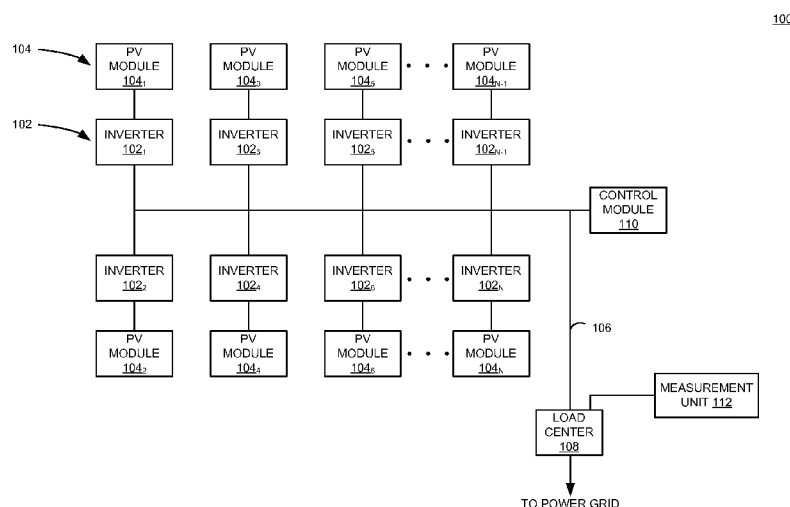
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished upon receipt of that report (Rule 48.2(g))

(54) Title: METHOD AND APPARATUS FOR DETERMINING A CORRECTED MONITORING VOLTAGE



(57) Abstract: A method and apparatus for determining a corrected monitoring voltage, at least a portion of the method being performed by a computing system comprising at least one processor. The method comprises generating power at a first location; monitoring the generated power by measuring a first voltage proximate the first location; measuring a second voltage proximate a second location, the first and the second locations electrically coupled; and determining, based on the measured second voltage, a corrected monitoring voltage to compensate the measured first voltage for a distance between the first and the second locations.

METHOD AND APPARATUS FOR DETERMINING A CORRECTED MONITORING VOLTAGE

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] Embodiments of the present disclosure generally relate to power systems and, more particularly, to a method and apparatus for determining a corrected monitoring voltage.

Description of the Related Art

[0002] Solar panels have historically been deployed in mostly remote applications, such as remote cabins in the wilderness or satellites, where commercial power was not available. Due to the high cost of installation, solar panels were not an economical choice for generating power unless no other power options were available. However, the worldwide growth of energy demand is leading to a durable increase in energy cost. In addition, it is now well established that the fossil energy reserves currently being used to generate electricity are rapidly being depleted. These growing impediments to conventional commercial power generation make solar panels a more attractive option to pursue.

[0003] Solar panels, or photovoltaic (PV) modules, convert energy from sunlight received into direct current (DC). The PV modules cannot store the electrical energy they produce, so the energy must either be dispersed to an energy storage system, such as a battery or pumped hydroelectricity storage, or dispersed by a load. One option to use the energy produced is to employ one or more inverters to convert the DC current into an alternating current (AC) and couple the AC current to the commercial power grid. The power produced by such a distributed generation (DG) system can then be sold to the commercial power company.

[0004] In order to mitigate potential safety hazards, a DG coupled to a commercial power grid must be operated in accordance with relevant regulatory requirements, such as IEEE-1547. As part of meeting the IEEE-1547 requirements, an inverter within a DG must be deactivated under certain circumstances, including

line frequency or line voltage operating outside of pre-defined limits. The IEEE-1547 standard specifies that such voltage requirements must be met at a Point of Common Coupling (PCC) between the commercial power system and the DG (i.e., a point of demarcation between the public utility service and the DG).

[0005] For installations where an inverter within a DG is located a significant distance from the PCC, an output voltage measured at the inverter may be higher than a voltage measured at the PCC due a voltage drop along the line from the inverter to the PCC. In some circumstances, the measured voltage at the inverter may exceed the required voltage range although the voltage at the PCC remains within the required range, resulting in the inverter unnecessarily shutting down and thereby reducing energy production. Additionally, as the inverter ceases power production and the voltage at the inverter is reduced to acceptable levels, the inverter once again activates and begins producing power, resulting in a continued oscillation that negatively impacts power production.

[0006] Therefore, there is a need for a method and apparatus for correcting a monitoring voltage measured at an inverter.

SUMMARY OF THE INVENTION

[0007] Embodiments of the present invention generally relate to a method and apparatus for determining a corrected monitoring voltage, at least a portion of the method being performed by a computing system comprising at least one processor. The method comprises generating power at a first location; monitoring the generated power by measuring a first voltage proximate the first location; measuring a second voltage proximate a second location, the first and the second locations electrically coupled; and determining, based on the measured second voltage, a corrected monitoring voltage to compensate the measured first voltage for a distance between the first and the second locations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention,

briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0009] Figure 1 is a block diagram of a system for distributed generation (DG) in accordance with one or more embodiments of the present invention;

[0010] Figure 2 is a block diagram of a control module in accordance with one or more embodiments of the present invention;

[0011] Figure 3 is a block diagram of an inverter in accordance with one or more embodiments of the present invention; and

[0012] Figure 4 is a flow diagram of a method for determining a corrected monitoring voltage in accordance with one or more embodiments of the present invention.

DETAILED DESCRIPTION

[0013] Figure 1 is a block diagram of a system 100 for distributed generation (DG) in accordance with one or more embodiments of the present invention. This diagram only portrays one variation of the myriad of possible system configurations. The present invention can function in a variety of distributed power generation environments and systems.

[0014] The system 100 comprises a plurality of inverters $102_1, 102_2 \dots 102_n$, collectively referred to as inverters 102, a plurality of PV modules $104_1, 104_2 \dots 104_n$, collectively referred to as PV modules 104, an AC bus 106, and a load center 108.

[0015] Each inverter $102_1, 102_2 \dots 102_n$ is coupled to a PV module $104_1, 104_2 \dots 104_n$, respectively. In some embodiments, a DC-DC converter may be coupled between each PV module 104 and each inverter 102 (e.g., one converter per PV

module 104). Alternatively, multiple PV modules 104 may be coupled to a single inverter 102 (i.e., a centralized inverter); in some such embodiments, a DC-DC converter may be coupled between the PV modules 104 and the centralized inverter.

[0016] The inverters 102 are coupled to the AC bus 106, which in turn is coupled to the load center 108. The load center 108 houses connections between incoming power lines from a commercial power grid distribution system and the AC bus 106, and represents a Point of Common Coupling (PCC) between the system 100 and the commercial power grid. The inverters 102 convert DC power generated by the PV modules 104 into AC power, and meter out AC current that is in-phase with the AC commercial power grid voltage. The system 100 couples the generated AC power to the commercial power grid via the load center 108. Additionally or alternatively, the generated power may be coupled to appliances, and/or energy generated may be stored for later use; for example, the generated energy may be stored utilizing batteries, heated water, hydro pumping, H₂O-to-hydrogen conversion, or the like. In some alternative embodiments, the system 100 may comprise other types of renewable energy generators in addition to or in place of the inverters 102, such as wind turbines, hydroelectric systems, or the like.

[0017] The system 100 further comprises a control module 110 coupled to the AC bus 106. The control module 110 is capable of issuing command and control signals to the inverters 102 in order to control the functionality of the inverters 102.

[0018] In accordance with one or more embodiments of the present invention, each of the inverters 102 applies voltage compensation to locally measured voltages (i.e., voltages measured at the inverter 102) when determining a monitored voltage for comparison to relevant voltage regulatory requirements. Such voltage compensation corrects for a voltage drop that occurs along the AC bus 106 between the inverters 102 and the PCC and allows the inverters 102 to determine monitoring voltage levels with respect to the PCC (i.e., corrected monitoring voltage levels) for ensuring compliance with the relevant voltage regulatory requirements. In the event that a corrected monitoring voltage exceeds required limits, the corresponding

inverter 102 may be deactivated or, alternatively, AC voltage regulation may be performed.

[0019] In some embodiments, the control module 110 may receive one or more voltage samples (i.e., measurements) indicating a voltage proximate (i.e., at or near) the PCC. The control module 110 may then broadcast these PCC voltage samples V_{pcc} to one or more inverters 102 for determining the corresponding corrected monitoring voltage as described further below. The PCC voltage samples V_{pcc} may be obtained by a measurement unit 112 deployed at or near the load center 108; in some embodiments, the measurement unit 112 and the control module 110 may be a single integrated unit. The measurement unit 112 may sample the voltage proximate the PCC, for example, utilizing an analog to digital (A/D) converter, and communicate the PCC voltage samples V_{pcc} to the control module 110 for broadcast to the inverters 102. The measurement unit 112 may convert the voltage samples to a root mean square (RMS) value prior to transmission to the controller 110; alternatively, the controller 110 or the inverters 102 may perform such conversion. One example of such a measurement unit may be found in commonly assigned U.S. patent application Serial No. 12/657,447 entitled "Method and Apparatus for Characterizing a Circuit Coupled to an AC Line" and filed January 21, 2010, which is herein incorporated in its entirety by reference.

[0020] In some embodiments, the measurement unit 112 may communicate the PCC voltage samples V_{pcc} to the control module 110 utilizing power line communication (PLC), and the control module 110 may then broadcast the PCC voltage samples V_{pcc} to the inverters 102 utilizing PLC; alternatively, other wired and/or wireless communication techniques may be utilized. In one or more alternative embodiments, the PCC voltage samples V_{pcc} may be obtained by the measurement unit 112 and communicated directly (i.e., without the use of the controller 110) to one or more inverters 102 utilizing any of the communications techniques previously mentioned.

[0021] In some alternative embodiments, the control module 110 may determine the corrected monitoring voltage for one or more of the inverters 102, determine

whether each corrected monitoring voltage is within required limits, and/or initiate deactivation of one or more inverters 102 for which the corrected monitoring voltage levels exceed required limits.

[0022] Figure 2 is a block diagram of a control module 110 in accordance with one or more embodiments of the present invention. The control module 110 comprises a communications transceiver 202 coupled to at least one central processing unit (CPU) 204. The CPU 204 is additionally coupled to support circuits 206, and a memory 208. The CPU 204 may comprise one or more conventionally available microprocessors. Alternatively, the CPU 204 may include one or more application specific integrated circuits (ASIC). The support circuits 206 are well known circuits used to promote functionality of the central processing unit. Such circuits include, but are not limited to, a cache, power supplies, clock circuits, buses, network cards, input/output (I/O) circuits, and the like.

[0023] The memory 208 may comprise random access memory, read only memory, removable disk memory, flash memory, and various combinations of these types of memory. The memory 208 is sometimes referred to as main memory and may, in part, be used as cache memory or buffer memory. The memory 208 generally stores the operating system 214 of the control module 110. The operating system 214 may be one of a number of commercially available operating systems such as, but not limited to, SOLARIS from SUN Microsystems, Inc., AIX from IBM Inc., HP-UX from Hewlett Packard Corporation, LINUX from Red Hat Software, Windows 2000 from Microsoft Corporation, and the like.

[0024] The memory 208 may store various forms of application software, such as inverter control software 210 for operably controlling the inverters 102. The communications transceiver 202 communicably couples the control module 110 to the inverters 102 to facilitate command and control of the inverters 102. The communications transceiver 202 may utilize wireless or wired communication techniques for such communication.

[0025] Figure 3 is a block diagram of an inverter 102 in accordance with one or more embodiments of the present invention. The inverter 102 comprises a power

conversion module 302, a conversion control module 304, a voltage monitoring module 306, an AC current sampler 308, and an AC voltage sampler 310.

[0026] The power conversion module 302 is coupled to the PV module 104 and acts to convert DC current from the PV module 104 to AC output current. The conversion control module 304 is coupled to the AC voltage sampler 310 for receiving an AC voltage reference signal from the commercial power grid, and to the power conversion module 302 for providing operative control and driving the power conversion module 302 to inject the generated AC output current in phase with the grid as required by the relevant standards.

[0027] The voltage monitoring module 306 is coupled to the conversion control module 304, the AC current sampler 308, and the AC voltage sampler 310. The AC current sampler 308 is coupled to an output terminal of the power conversion module 302, and the AC voltage sampler 310 is coupled across both output terminals of the power conversion module 302. The AC current sampler 308 and the AC voltage sampler 310 obtain samples (i.e., measurements) of the AC inverter current and AC inverter voltage, respectively, at the output of the power conversion module 302 and provide such inverter output current and voltage samples to the voltage monitoring module 306. The AC current sampler 308 and the AC voltage sampler 310 may each comprise an A/D converter for obtaining the inverter output current and voltage samples, respectively. In some other embodiments, rather than being directly measured, the inverter output current may be estimated based on DC input voltage and current to the inverter 102 and the AC voltage output from the inverter 102.

[0028] The voltage monitoring module 306 may be comprised of hardware, software, or a combination thereof, and comprises at least one CPU 314 coupled to support circuits 316, memory 318, and a communications transceiver 324. The communications transceiver 324 is further coupled to at least one of the output lines from the power conversion module 302 for communicating via PLC, for example, with the control module 110 and/or the measurement unit 112. In alternative

embodiments, the communications transceiver 324 may utilize wireless and/or other wired communications techniques for such communication.

[0029] The CPU 314 may comprise one or more conventionally available microprocessors. Alternatively, the CPU 314 may include one or more application specific integrated circuits (ASIC). The support circuits 316 are well known circuits used to promote functionality of the central processing unit. Such circuits include, but are not limited to, a cache, power supplies, clock circuits, buses, network cards, input/output (I/O) circuits, and the like.

[0030] The memory 318 may comprise random access memory, read only memory, removable disk memory, flash memory, and various combinations of these types of memory. The memory 318 is sometimes referred to as main memory and may, in part, be used as cache memory or buffer memory. The memory 318 generally stores the operating system (OS) 320 of the voltage monitoring module 306. The OS 320 may be one of a number of commercially available OSs such as, but not limited to, Linux, Real-Time Operating System (RTOS), and the like.

[0031] The memory 318 may store various forms of application software, such as voltage monitoring module (VMM) software 322 for determining a corrected monitoring voltage corresponding to the inverter 102.

[0032] To determine the corrected monitoring voltage, the voltage monitoring module 306 determines a correction coefficient K_v based on an inverter output voltage sample (i.e., a measurement of the inverter output voltage) received from the AC voltage sampler 310, and a PCC voltage sample that indicates a measurement of a voltage proximate the PCC. In some embodiments, the PCC voltage sample is an RMS value obtained by the measurement unit 112 and communicated from the control module 110 as previously described. The voltage monitoring module 306 determines the correction coefficient, K_v , as follows:

$$[0033] \quad K_v = V_{pcc} / V_{meas} \quad (i)$$

[0034] where V_{pcc} is the PCC voltage sample and V_{meas} is the inverter output voltage sample.

[0035] Additionally, when K_v is computed, the voltage monitoring module 306 computes an output power of the inverter, P_{meas} . In some embodiments, the voltage monitoring module 306 utilizes the inverter output voltage sample V_{meas} and an inverter output current sample received from the AC current sampler 308, as well as phase angle, to determine the output power of the inverter, P_{meas} . Alternatively, the voltage monitoring module 306 may calculate P_{meas} based on DC voltage and DC current pertaining to the inverter 102 (for example, DC voltage and DC current samples obtained by the conversion control module 304) and a conversion efficiency of the inverter 102.

[0036] In some embodiments, the inverter 102 is pre-set with an initial $K_v = 1$ and determines a new K_v upon receiving a valid V_{pcc} measurement message. Such a message may be validated utilizing conventional communication techniques, such as addressing and checksums (e.g., cyclic redundancy check, or CRC). If the new K_v is within an acceptable correction coefficient range, the voltage monitoring module 306 utilizes the new K_v to determine a corrected monitoring voltage; if the new K_v is not within the acceptable correction coefficient range, K_v remains at its pre-set value until a next V_{pcc} is obtained. In some embodiments, the acceptable correction coefficient range is $0.95 < K_v < 1.05$.

[0037] The voltage monitoring module 306 utilizes K_v for computing the corrected monitoring voltage V_{corr} upon obtaining inverter output current and voltage samples I_{inv} and V_{inv} , respectively (e.g., inverter output current and voltage samples obtained subsequent to the samples utilized to compute K_v). The voltage monitoring module 306 determines the corrected monitoring voltage V_{corr} as follows:

$$[0038] \quad V_{corr} = V_{inv} * (1 - ((P_{inv} * (1 - K_v)) / P_{meas})) \quad (ii)$$

[0039] where K_v is the correction coefficient, V_{inv} and P_{inv} are the inverter output voltage and power, respectively, and P_{meas} is the inverter output power determined at the time K_v was computed. P_{inv} is computed based on inverter output current and

voltage samples obtained by the AC current sampler 308 and the AC voltage sampler 310, respectively.

[0040] The voltage monitoring module 306 periodically computes V_{corr} based on one or more of an updated inverter output power measurement P_{inv} , an updated inverter output voltage measurement V_{inv} , or an updated K_v (e.g., K_v may be updated upon receiving a new valid V_{PCC} measurement message). In some embodiments, V_{corr} as well as all corresponding voltage, current, power, and control parameters are determined at least once every line cycle (e.g., every 16.6667 milliseconds). If a new valid V_{pcc} measurement message is not received within an aging time window, K_v is reset to “1” until a valid V_{pcc} message is received. In some embodiments, a linear aging function may be utilized; alternatively, a nonlinear aging function, or a combination of a linear and a nonlinear aging functions may be utilized.

[0041] In the event that the inverter output power P_{inv} moves outside of a valid output power range for the current K_v , K_v is reset to “1” until a new valid V_{pcc} measurement message is received and a new K_v determined. The valid output power range may be some percentage of the rated total inverter power, for example, within the range of 5% to 20% of the inverter power rating. In some embodiments, K_v may be reset to “1” in the event that the inverter output power P_{inv} exceeds a maximum power deviation.

[0042] The corrected monitoring voltage V_{corr} provides a more accurate estimate of the voltage at the PCC than the inverter output voltage alone for determining compliance with regulatory requirements pertaining to voltage levels at the PCC. In some embodiments, the voltage monitoring module 306 determines whether the corrected monitoring voltage V_{corr} is within a required voltage range with respect to the regulatory requirements; in the event the corrected monitoring voltage V_{corr} exceeds the required voltage range, the voltage monitoring module 306 provides a deactivation signal to the conversion control module 304 to deactivate the power conversion module 302 or, alternatively, AC voltage regulation may be performed. In some alternative embodiments, one or more of determining the corrected monitoring voltage V_{corr} , determining compliance with regulatory requirements,

and/or deactivation of one or more inverters as a result of one or more corrected monitoring voltage levels exceeding a required voltage range may be performed by the control module 110.

[0043] Figure 4 is a flow diagram of a method 400 for determining a corrected monitoring voltage in accordance with one or more embodiments of the present invention. In some embodiments, such as the embodiment described below, AC current from a DG system comprising at least one DC-AC inverter is coupled to a commercial power grid at a PCC. Although the embodiment below is described with respect to a single inverter, each inverter of the DG system may utilize the method 400. In alternative embodiments, a controller for the DG system may utilize the method 400 for determining one or more corrected monitoring voltages and/or driving the corresponding inverters accordingly.

[0044] The method 400 begins at step 402 and proceeds to step 404. At step 404, a correction coefficient K_v of an inverter has an initial value of "1". In some embodiments, the inverter may be preset with $K_v = 1$, for example, at a factory during manufacturing. The method 400 proceeds to step 406, where a voltage sample (i.e., measurement) indicating a voltage proximate the PCC (" V_{pcc} "), is obtained. The PCC voltage sample V_{pcc} may be received by the inverter as part of a validated message transmitted to the inverter; for example, the message may be broadcasted from a control module coupled to the DG system and validated utilizing conventional communication techniques, such as addressing and checksums (e.g., cyclic redundancy check, or CRC). In some embodiments, a data logger (e.g., the measurement unit 112 previously described) may be coupled proximate the PCC, for example, at a load center coupling the DG system to the commercial power grid. The data logger may sample (i.e., measure) the voltage proximate the PCC, convert the voltage sample to an RMS value, and communicate the resulting PCC voltage sample V_{pcc} to the controller for broadcast to the one or more inverters of the DG system. In some alternative embodiments, the PCC voltage sample V_{pcc} may be converted to an RMS value at the controller or the inverter. In some other alternative embodiments, the data logger may directly communicate the PCC

voltage sample V_{pcc} to the inverters utilizing wireless and/or wired communications techniques.

[0045] The method 400 proceeds to step 407, where a voltage sample of an AC output voltage of the inverter (V_{meas}) is obtained, for example, by an AC voltage sampler of the inverter. At step 408, a new K_v is determined as follows:

$$[0046] \quad K_v = V_{pcc} / V_{meas} \quad (iii)$$

[0047] Additionally, at the time K_v is computed, an output power of the inverter (P_{meas}) is determined based on V_{meas} and a sample of the AC output current from the inverter obtained, for example, by an AC current sampler of the inverter.

[0048] At step 410, a determination is made whether K_v is within an acceptable correction coefficient range; in some embodiments, the acceptable correction coefficient range is $0.95 < K_v < 1.05$. If it is determined that K_v is not within the acceptable correction coefficient range, the method 400 returns to step 404. If it is determined that K_v is within the acceptable correction coefficient range, the method 400 proceeds to step 411.

[0049] At step 411, inverter output current and voltage samples are obtained (V_{inv} and I_{inv} , respectively) and utilized to determine the inverter output power (P_{inv}). At step 412, a corrected monitoring voltage is determined as follows:

$$[0050] \quad V_{corr} = V_{inv} * (1 - ((P_{inv} * (1 - K_v)) / P_{meas})) \quad (iv)$$

[0051] At step 414, a determination is made whether the corrected monitoring voltage is within required regulatory limits. In some embodiments, the inverter may compare the corrected monitoring voltage to the regulatory limits to make the determination; alternatively, the corrected monitoring voltage may be communicated, for example to the controller or the measurement unit, for determining compliance with the regulatory limits. If the result of such determination is no, the method 400 proceeds to step 422, where the inverter is deactivated; alternatively, AC voltage regulation may be performed. In some embodiments where the inverter is deactivated, upon determining that the corrected monitoring voltage exceeds

required limits, the inverter may cease power production; alternatively, the inverter may receive a control signal from the controller or the measurement unit causing the inverter to cease power product. The method 400 then proceeds to step 424 where it ends. If the result of the determination at step 414 is yes, the method 400 proceeds to step 416.

[0052] At step 416, a determination is made whether a new valid V_{pcc} measurement message has been received. In some embodiments, V_{pcc} may be determined and communicated to the inverter at least once every line cycle (e.g., every 16.6667 milliseconds). If a new valid V_{pcc} measurement message has been received, the method 400 returns to step 407. If a new valid V_{pcc} measurement has not been received, the method 400 proceeds to step 418. At step 418, a determination is made whether an aging time window for K_v has been exceeded. In some embodiments, a linear aging function may be applied to K_v such that K_v reaches a value of 1 at the end of the aging time window; alternatively, a nonlinear aging function, or a combination of linear and nonlinear aging functions, may be utilized. If the aging time window has been exceeded, the method 400 returns to step 404. If the aging time window has not been exceeded, the method 400 proceeds to step 419.

[0053] At step 419, inverter output current and voltage samples (V_{inv} and I_{inv} , respectively) are obtained and utilized to determine a new inverter output power P_{inv} . At step 420, a determination is made whether the inverter output power P_{inv} is within a valid output power range for the current K_v . The valid output power range may be some percentage of the rated total inverter power, for example, within the range of 5% to 20% of the inverter power rating. If the inverter output power P_{inv} is within the valid output power range, the method 400 returns to step 412. If the inverter output power exceeds the output power range, K_v is reset to 1 and the method 400 returns to step 404.

[0054] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing

from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS:

1. A method for determining a corrected monitoring voltage, at least a portion of the method being performed by a computing system comprising at least one processor, the method comprising:

generating power at a first location;

monitoring the generated power by measuring a first voltage proximate the first location;

measuring a second voltage proximate a second location, the first and the second locations electrically coupled; and

determining, based on the measured second voltage, a corrected monitoring voltage to compensate the measured first voltage for a distance between the first and the second locations.

2. The method of claim 1, wherein measuring the first voltage comprises obtaining a first and a third voltage measurement of the first voltage, wherein measuring the second voltage comprises obtaining a second voltage measurement of the second voltage, and wherein determining the corrected monitoring voltage comprises:

obtaining a first power measurement proximate the first location;

computing a correction coefficient based on the first and the second voltage measurements;

obtaining a second power measurement proximate the first location; and

computing the corrected monitoring voltage based on the first and the second power measurements, the third voltage measurement, and the correction coefficient.

3. The method of claim 2, further comprising:

determining that the corrected monitoring voltage is not within an operating range; and

disabling a device generating the power at the first location or performing AC voltage regulation.

4. The method of claim 2, further comprising determining, subsequent to computing the correction coefficient and prior to computing the corrected monitoring voltage, that the correction coefficient is within a correction coefficient range.

5. The method of claim 2, further comprising:

determining that the correction coefficient has exceeded a time window;

and

setting the correction coefficient to a value of one.

6. The method of claim 2, further comprising:

determining that the correction coefficient has not exceeded a time window;

obtaining a third power measurement proximate the first location;

determining whether the third power measurement is within an output power range; and

resultant from determining whether the third power measurement is within the output power range, (i) setting the correction coefficient to a value of one, or (ii) recomputing the correction coefficient based on the third power measurement.

7. The method of claim 2, wherein the corrected monitoring voltage is computed as $V_{corr} = V_3 * (1 - (P_2 * (1 - (V_2 / V_1)) / P_1))$, wherein P_1 = the first power measurement, P_2 = the second power measurement, V_1 = the first voltage measurement, V_2 = the second voltage measurement, and V_3 = the third voltage measurement.

8. An apparatus for determining a corrected monitoring voltage, comprising:

a voltage monitoring module adapted for:

monitoring power at a first location by measuring a first voltage proximate the first location;

receiving a second voltage measurement of a second voltage proximate a second location, the second location electrically coupled to the first location; and

determining, based on the second voltage measurement, a corrected monitoring voltage to compensate the measured first voltage for a distance between the first and the second locations.

9. The apparatus of claim 8, wherein the voltage monitoring module determines the corrected voltage by (i) obtaining a first and a third voltage measurement of the first voltage, (ii) obtaining a first power measurement proximate the first location, (iv) computing a correction coefficient based on the first and the second voltage measurements, (v) obtaining a second power measurement proximate the first location, and (v) computing the corrected monitoring voltage based on the first and the second power measurements, the third voltage measurement, and the correction coefficient.

10. The apparatus of claim 9, wherein the voltage monitoring module is further adapted for:

determining that the corrected monitoring voltage is not within an operating range; and

disabling the power generating device or performing AC voltage regulation.

11. The apparatus of claim 9, wherein the voltage monitoring module is further adapted for determining, subsequent to computing the correction coefficient and prior to computing the corrected monitoring voltage, that the correction coefficient is within a correction coefficient range.

12. The apparatus of claim 9, wherein the voltage monitoring module is further adapted for:

determining that the correction coefficient has exceeded a time window; and

setting the correction coefficient to a value of one.

13. The apparatus of claim 9, wherein the voltage monitoring module is further adapted for:

determining that the correction coefficient has not exceeded a time window;

obtaining a third power measurement, the third power measurement measuring the output power from the power generating device;

determining whether the third power measurement is within an output power range; and

resultant from determining whether the third power measurement is within the output range, (i) setting the correction coefficient to a value of one, or (ii) recomputing the correction coefficient based on the third power measurement.

14. A system for determining a corrected monitoring voltage, the system comprising:

an inverter, adapted for generating power at a first location and monitoring the generated power by measuring a first voltage proximate the first location; and

a measurement unit, adapted for measuring a second voltage proximate a second location, the first and the second locations electrically coupled; wherein the inverter is further adapted for determining, based on the measured second voltage, a corrected monitoring voltage to compensate the measured first voltage for a distance between the first and the second locations.

15. The system of claim 14, wherein the inverter determines the corrected voltage by (i) obtaining a first and a third voltage measurement of the first voltage, (ii) receiving a second voltage measurement, obtained by the measurement unit, of the second voltage, (iii) obtaining a first power measurement proximate the first location, (iv) computing a correction coefficient based on the first and the second voltage measurements, (v) obtaining a second power measurement proximate the first location, and (vi) computing the corrected monitoring voltage based on the first and the second power measurements, the third voltage measurement, and the correction coefficient.

16. The system of claim 15, wherein the inverter is further adapted for:

determining that the corrected monitoring voltage is not within an operating range; and

disabling power production or performing AC voltage regulation.

17. The system of claim 15, wherein the inverter is further adapted for determining, subsequent to computing the correction coefficient and prior to computing the corrected monitoring voltage, that the correction coefficient is within a correction coefficient range.

18. The system of claim 15, wherein the inverter is further adapted for:

determining that the correction coefficient has exceeded a time window; and

setting the correction coefficient to a value of one.

19. The system of claim 15, wherein the inverter is further adapted for:

determining that the correction coefficient has not exceeded a time window;

obtaining a third power measurement proximate the first location;

determining whether the third power measurement is within an output power range; and

resultant from determining whether the third power measurement is within the output power range, (i) setting the correction coefficient to a value of one, or (ii) recomputing the correction coefficient based on the third power measurement.

20. The system of claim 15, wherein the corrected monitoring voltage is computed as $V_{corr} = V_3 * (1 - (P_2 * (1 - (V_2 / V_1)) / P_1))$, wherein P_1 = the first power measurement, P_2 = the second power measurement, V_1 = the first voltage measurement, V_2 = the second voltage measurement, and V_3 = the third voltage measurement.

100

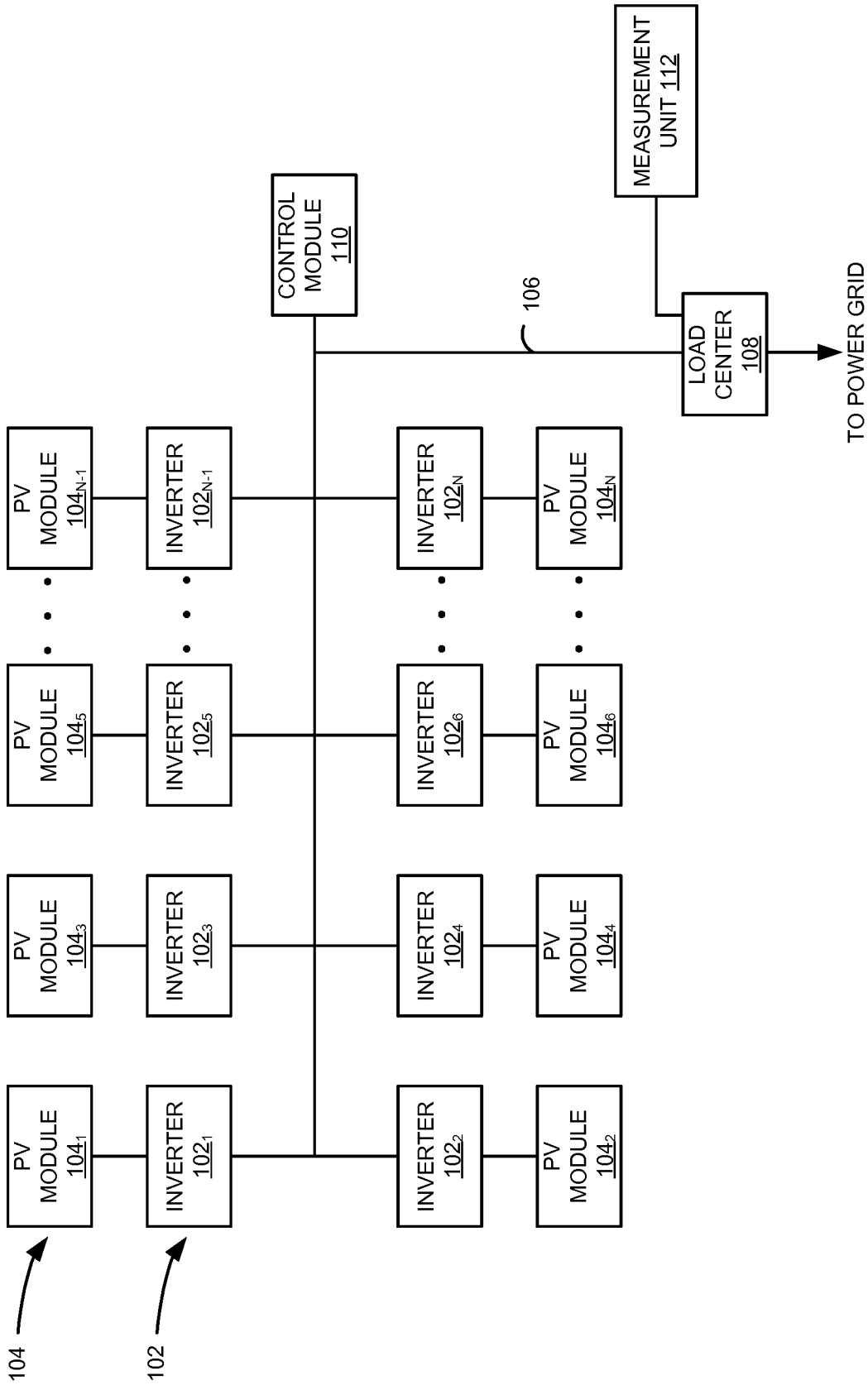


FIG. 1

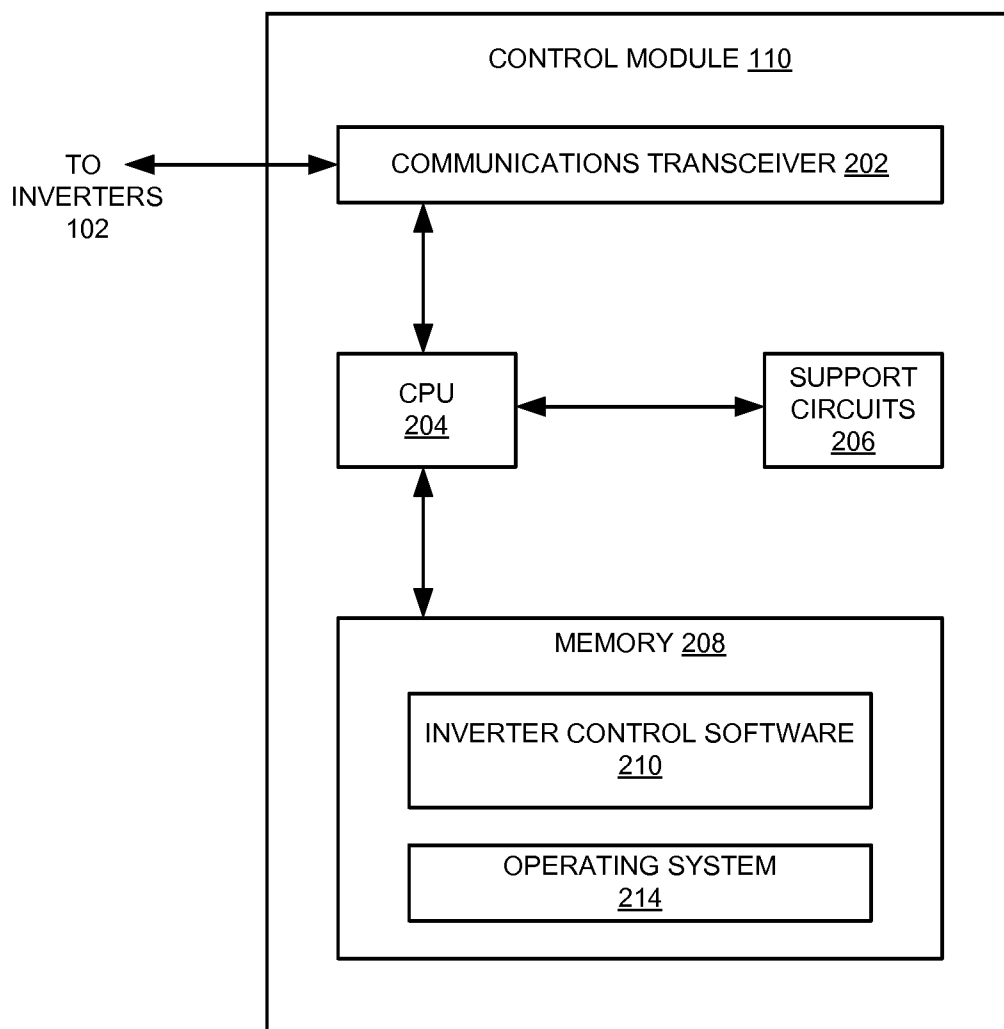


FIG. 2

300

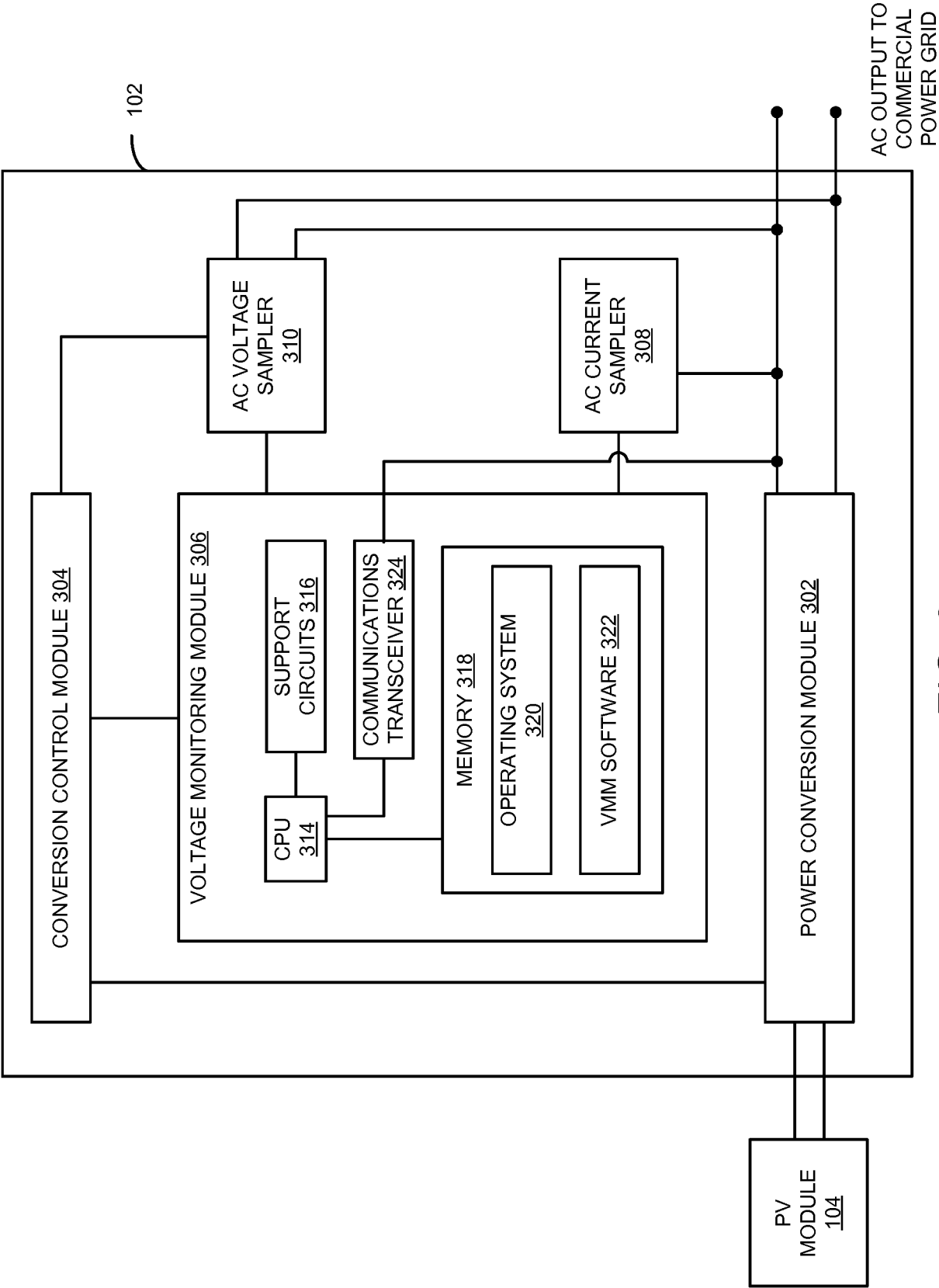


FIG. 3

400

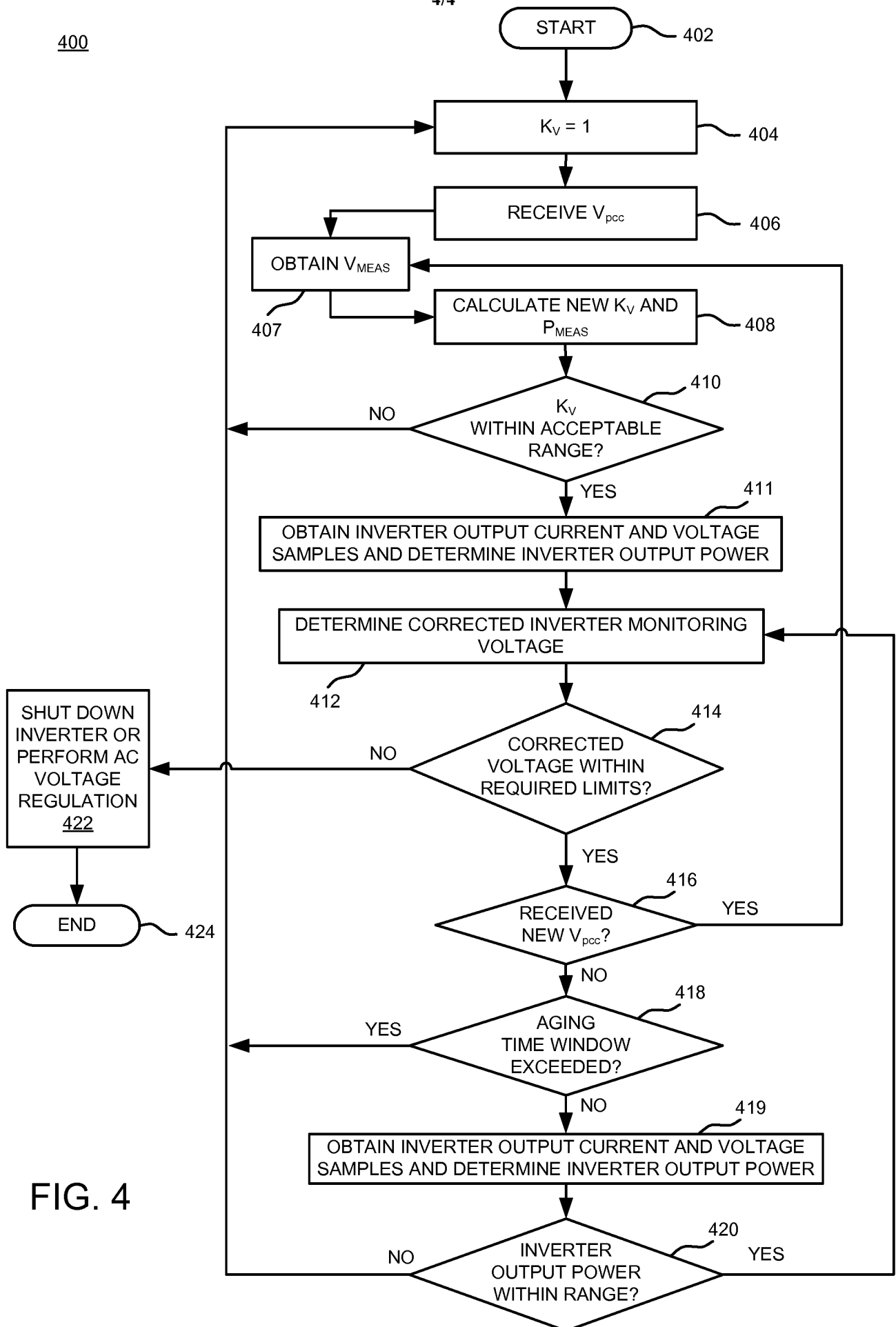


FIG. 4