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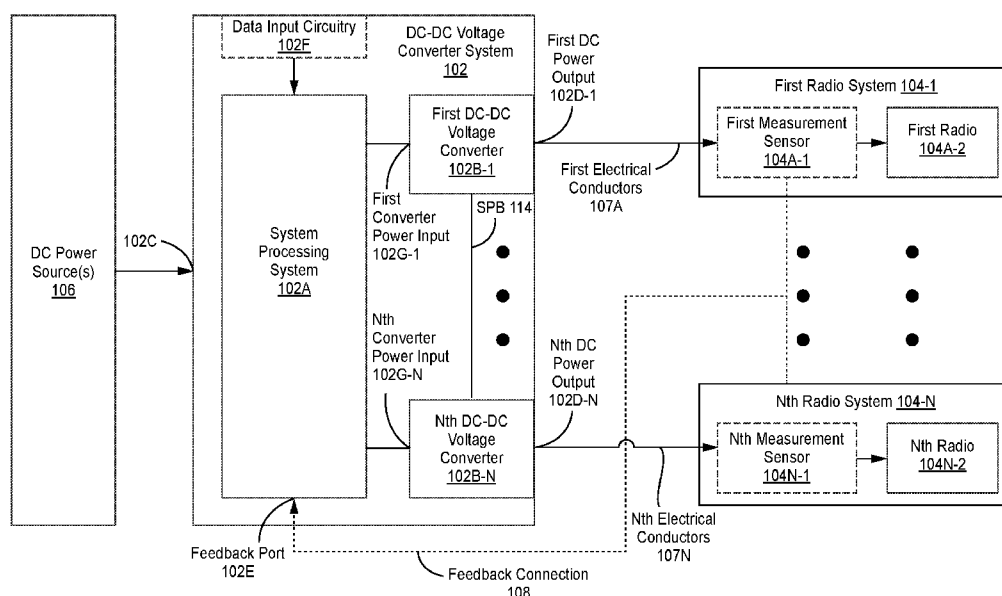


FIG. 1A

(57) Abstract: Techniques are provided for whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of the DC-DC voltage converter modules are electrically connected.

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SYSTEM AND METHOD FOR DETECTING ELECTRICALLY CONNECTED OUTPUTS OF DIFFERENT VOLTAGE CONVERTERS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims benefit of Italian Patent Application Serial No. 102023000012564 filed June 19, 2023; the entire contents of the aforementioned patent application are incorporated herein by reference as if set forth in its entirety.

BACKGROUND

[0002] A direct current (DC)-DC voltage converter may be used to boost its output voltage to diminish power dissipation in electrical conductors coupling an output of the DC-DC voltage converter to a DC power input of a radio. The DC-DC voltage converter provides DC electrical power to the radio through the electrical conductors. U.S. Patent No. 9,448,576 (hereinafter the '576 Patent) describes different embodiments of voltage converter systems configured to accomplish this. The '576 Patent is incorporated by reference herein in its entirety.

[0003] First ends of the electrical conductors are configured to be electrically coupled to the DC-DC voltage converter. Radio ends of the electrical conductors are configured to be electrically coupled to the radio.

[0004] A typical cellular base station includes multiple radios, and thus may utilize multiple DC-DC voltage converters. One DC-DC voltage converter provides power to a unique set of one or more radios. However, more than one DC-DC voltage converter may provide power to such a set.

SUMMARY

[0005] A method is provided and which determines whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected. The method comprises: setting each DC-DC voltage converter of a DC-DC voltage

converter module to provide a DC voltage level, at a DC power output of a DC-DC voltage converter, at or below a second DC voltage threshold level; determining whether a system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module; determining that the system parallel signal has not been received by each DC-DC voltage converter of the DC-DC voltage converter module, then receiving a DC voltage measurement of each DC power output of the DC-DC voltage converter module; determining whether a magnitude of each DC voltage measurement is greater than a first DC voltage threshold level; determining that the magnitude of each DC voltage measurement is not greater than the first DC voltage threshold level, then providing a constant DC voltage at a single DC power output of the DC-DC voltage converter module; receiving a DC voltage measurement at each of other DC power output of the DC-DC voltage converter module; determining that the magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level, then determining whether each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal; determining that each DC-DC voltage converter of the DC-DC voltage converter module has not received the system parallel signal, then transmitting a module parallel signal to all DC-DC voltage converters in the DC-DC voltage converter module; and either (a) determining that each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal, (b) determining that the magnitude of each DC voltage measurement is greater than the first DC voltage threshold level, or (c) determining that the system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module, then transmitting the system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system.

[0006] A non-transitory computer readable medium is provided and stores a program causing at least one processor to execute a process configured to determine whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected. The process comprises: setting each DC-DC voltage converter of a DC-DC voltage converter module to provide a DC voltage level, at a DC power output of a DC-DC voltage converter, at or below a second DC voltage threshold level; determining whether a system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module; determining that the system parallel signal has not been received by each DC-DC voltage converter of the DC-DC voltage converter module, then receiving a DC voltage measurement of each DC power output of the DC-DC voltage converter module; determining whether a magnitude of each DC voltage measurement is greater than a first DC voltage

threshold level; determining that the magnitude of each DC voltage measurement is not greater than the first DC voltage threshold level, then providing a constant DC voltage at a single DC power output of the DC-DC voltage converter module; receiving a DC voltage measurement at each of other DC power output of the DC-DC voltage converter module; determining whether a magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level; determining that a magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level, then determining whether each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal; determining that each DC-DC voltage converter of the DC-DC voltage converter module has not received the system parallel signal, then transmitting a module parallel signal to all DC-DC voltage converters in the DC-DC voltage converter module; and either (a) determining that each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal, (b) determining that the magnitude of each DC voltage measurement is greater than the first DC voltage threshold level, or (c) determining that the system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module, then transmitting the system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system.

[0007] An apparatus is provided and is configured to determine whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected. The apparatus comprises: processing circuitry configured to: set each DC-DC voltage converter of a DC-DC voltage converter module to provide a DC voltage level, at a DC power output of a DC-DC voltage converter, at or below a second DC voltage threshold level; determine whether a system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module; determine that the system parallel signal has not been received by each DC-DC voltage converter of the DC-DC voltage converter module, then receiving a DC voltage measurement of each DC power output of the DC-DC voltage converter module; determine whether a magnitude of each DC voltage measurement is greater than a first DC voltage threshold level; determine that the magnitude of each DC voltage measurement is not greater than the first DC voltage threshold level, then providing a constant DC voltage at a single DC power output of the DC-DC voltage converter module; receive a DC voltage measurement at each of other DC power output of the DC-DC voltage converter module; determine whether a magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level; determine that a magnitude of each received DC voltage

measurement is greater than the first DC voltage threshold level, then determining whether each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal; determine that each DC-DC voltage converter of the DC-DC voltage converter module has not received the system parallel signal, then transmitting a module parallel signal to all DC-DC voltage converters in the DC-DC voltage converter module; and either (a) determine that each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal, (b) determine that the magnitude of each DC voltage measurement is greater than the first DC voltage threshold level, or (c) determine that the system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module, then transmitting the system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system; and at least two DC-DC voltage converters which are communicatively coupled to the processing circuitry.

[0008] A method is provided which determines whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected. The method comprises: at a first time, providing a constant DC voltage to be provided a single DC power output of a first DC-DC voltage converter module; receiving DC voltage measurements at other DC power outputs of the DC-DC voltage converter system; determining whether a magnitude of (a) each of the DC voltage measurements or (b) at least one DC voltage measurement of a DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level; determining that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level, then providing a system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system; determining that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of the different DC-DC voltage converter module is not greater than a first DC voltage threshold level, then determining whether each of the DC voltage measurements at the other DC power outputs of a same DC-DC voltage converter module is greater than the first DC voltage threshold level; determining that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is greater than the first DC voltage threshold level, then providing a module parallel signal to all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage; (i) determining that each of the DC voltage measurements at

the other DC power outputs of the same DC-DC voltage converter module is not greater than the first DC voltage threshold level or (ii) upon providing the module parallel signal to the all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage, then determining whether the constant DC voltage at a single DC power output was provided by a last DC-DC voltage converter module of the DC-DC voltage converter system; and determining that the constant DC voltage at a single DC power output was not provided by a last DC-DC voltage converter module of the DC-DC voltage converter system, then at a subsequent time, providing the constant DC voltage at a single DC power output of a next DC-DC voltage converter module.

[0009] A non-transitory computer readable medium is provided and stores a program causing at least one processor to execute a process configured to determine whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected. The process comprises: at a first time, providing a constant DC voltage to be provided a single DC power output of a first DC-DC voltage converter module; receiving DC voltage measurements at other DC power outputs of the DC-DC voltage converter system; determining whether a magnitude of (a) each of the DC voltage measurements or (b) at least one DC voltage measurement of a DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level; determining that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level, then providing a system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system; determining that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of the different DC-DC voltage converter module is not greater than a first DC voltage threshold level, then determining whether each of the DC voltage measurements at the other DC power outputs of a same DC-DC voltage converter module is greater than the first DC voltage threshold level; determining that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is greater than the first DC voltage threshold level, then providing a module parallel signal to all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage; (i) determining that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is not greater than the first DC voltage threshold level or (ii) upon providing the module parallel signal to the all

DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage, then determining whether a constant DC voltage at a single DC power output was provided by a last DC-DC voltage converter module of the DC-DC voltage converter system; and determining that the constant DC voltage at a single DC power output was not provided by a last DC-DC voltage converter module of the DC-DC voltage converter system, then at a subsequent time, providing the constant DC voltage at a single DC power output of a next DC-DC voltage converter module.

[0010] An apparatus is provided and which is configured to determine whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected. The apparatus comprises: processing circuitry configured to: at a first time, provide a constant DC voltage to be provided a single DC power output of a first DC-DC voltage converter module; receive DC voltage measurements at other DC power outputs of the DC-DC voltage converter system; determine whether a magnitude of (a) each of the DC voltage measurements or (b) at least one DC voltage measurement of a DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level; determine that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level, then providing a system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system; determine that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of the different DC-DC voltage converter module is not greater than a first DC voltage threshold level, then determining whether each of the DC voltage measurements at the other DC power outputs of a same DC-DC voltage converter module is greater than the first DC voltage threshold level; determine that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is greater than the first DC voltage threshold level, then providing a module parallel signal to all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage; (i) determine that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is not greater than the first DC voltage threshold level or (ii) upon providing the module parallel signal to the all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage, then determining whether the constant DC voltage at a single DC power output was provided by a last DC-DC voltage converter module of the DC-DC

voltage converter system; and determine that the constant DC voltage at a single DC power output was not provided by a last DC-DC voltage converter module of the DC-DC voltage converter system, then at a subsequent time, providing the constant DC voltage at a single DC power output of a next DC-DC voltage converter module; and at least two DC-DC voltage converters communicatively coupled to the processing circuitry.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Understanding that the drawings depict only exemplary embodiments and are not therefore to be considered limiting in scope, the exemplary embodiments will be described with additional specificity and detail through the use of the accompanying drawings, in which:

[0012] FIG. 1A illustrates a block diagram of one embodiment of a DC-DC voltage converter system;

[0013] FIG. 1B illustrates a block diagram of one embodiment of a DC-DC voltage converter module;

[0014] FIG. 1C illustrates a block diagram of one embodiment of a DC-DC voltage converter;

[0015] FIG. 1D illustrates a diagram of one embodiment of a DC-DC voltage converter system including three DC-DC voltage converter modules;

[0016] FIG. 1E illustrates a block diagram of one embodiment of a DC-DC voltage converter system with electrically shorted outputs;

[0017] FIG. 1F illustrates a diagram of bus bars with holes configured to be mounted over all positive or negative terminals of a DC-DC voltage converter system;

[0018] FIG. 1G illustrates a diagram of bus bars with holes configured to be mounted over all positive or negative terminals of a DC-DC voltage converter module of a DC-DC voltage converter system;

[0019] FIG. 1H illustrates a diagram of a first shorting conductor mounted over and electrically shorting positive terminals of all DC power outputs of a DC-DC voltage converter system and of a second shorting conductor mounted over and electrically shorting negative terminals of all DC power outputs of the DC-DC voltage converter system;

[0020] FIG. 1I illustrates a diagram of a first shorting conductor mounted over and electrically shorting positive terminals of all DC power outputs of a DC-DC voltage converter module and

of a second shorting conductor mounted over and electrically shorting negative terminals of all DC power outputs of a DC-DC voltage converter module;

[0021] FIG. 2 illustrates a flow diagram of one embodiment of a method for determining whether all DC power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of the DC-DC voltage converter modules are electrically connected; and

[0022] FIG. 3 illustrates a flow diagram of one embodiment of a method for determining whether all DC power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of the DC-DC voltage converter modules are electrically connected.

In accordance with common practice, the various described features are not drawn to scale but are drawn to emphasize specific features relevant to the exemplary embodiments.

DETAILED DESCRIPTION

[0023] In the following detailed description, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of specific illustrative embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that logical, mechanical, and electrical changes may be made without departing from the scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense.

[0024] Installers may be able to program a DC-DC voltage converter system with identities of DC power outputs of DC-DC voltage converters (of such a system) which are electrically shorted. However, such programming may be subject to human error. Such an error may cause improper operation of DC-DC voltage converter(s) and damage the DC-DC voltage converter system (or components thereof) and/or radio(s) which are electrically powered by the DC-DC voltage converter system.

[0025] Therefore, techniques are provided for automatically determining when any two or more DC power outputs of DC-DC voltage converters of a DC-DC voltage converter system are electrically connected (or shorted) with a low resistance electrical conductor (*i.e.*, “ganged” outputs). For pedagogical purposes, such determination is made for all DC power outputs of

the DC-DC voltage converter system or all DC power outputs of each DC-DC voltage converter module of the DC-DC voltage converter system.

[0026] When determining or being provisioned with information that its output is ganged with output(s) of other DC-DC voltage converter(s), a DC-DC voltage converter can be operated in a manner that is harmonious with those other DC-DC voltage converter(s) with whose outputs the output of the DC-DC voltage converter is ganged. Optionally, all DC-DC voltage converters whose outputs are ganged may be configured to provide a same DC voltage at their output. When determining or being provisioned with information that its output is not ganged with output(s) of other DC-DC voltage converter(s), a DC-DC voltage converter can be operated independently of other DC-DC voltage converter(s). Automatic detection eliminates human error arising from manual inputting of corresponding information about such ganging of outputs.

[0027] Techniques are provided to ascertain ganged outputs when a DC-DC voltage converter system including one or more DC-DC voltage converters is turned on and when a new DC-DC voltage converter(s) are added to the DC-DC voltage converter system (while that system is powered on). The new DC-DC voltage converter(s) may be “hot swap” replacement(s) for DC-DC voltage converter(s) removed from the DC-DC voltage converter system, *e.g.*, due to failure, and electrically connected to the DC-DC voltage converter system while it is powered on.

[0028] FIG. 1A illustrates a block diagram of one embodiment of a DC-DC voltage converter system 102. The DC-DC voltage converter system 102 includes a converter system processing system (or converter system processing circuitry, system processing system or system processing circuitry) 102A, N DC-DC voltage converters 102B-1, 102B-N, a DC power input 102C, N DC power outputs 102D-1, 102D-N, and a system parallel bus (SPB) 114. Optionally, the DC-DC voltage converter system 102 includes an optional feedback port 102E, which, for example, may be configured to receive serial or parallel data.

[0029] N is an integer greater than one. Each of the N DC power outputs 102D-1, 102D-N is a DC power output of a unique DC-DC voltage converter, and thus of the DC-DC voltage converter system 102. Each DC-DC voltage converter 102B-1, 102B-N is configured to establish the DC voltage at a corresponding DC power output 102D-1, 102D-N. Optionally, each DC-DC voltage converter 102B-1, 102B-N includes a DC-DC voltage boost converter or a

DC-DC voltage buck-boost converter. The DC power input 102C is configured to be electrically coupled to a DC power source 106.

[0030] The system parallel bus 114 is an electrical bus configured to identify to each DC-DC voltage converter whether all of the DC power outputs 102D-1, 102D-N of all of the DC-DC voltage converters 102B-1, 102B-N of the DC-DC voltage converter system 102 have been determined to be electrically connected in parallel. The signal on the bus indicating this may be a voltage level, *e.g.*, a logic level for example high or low.

[0031] The DC power source 106 is configured to provide DC electrical power to the DC-DC voltage converter system 102, through the DC power input 102C. The DC electrical power, provided by the DC power source 106, has a DC power source voltage level, *e.g.*, -54 volts DC (VDC), which is also provided to the DC power input 102C of the DC-DC voltage converter system 102. Optionally, the DC power source voltage level is provided to an input of each DC-DC voltage converter 102B-1, 102B-N of the DC-DC voltage converter system 102. Optionally, the DC power source 106 includes an alternating current (AC) to direct current (DC) (AC/DC) power supply, at least one battery, at least one solar cell, and/or any other type of DC power source.

[0032] Each DC-DC voltage converter 102B-1, 102B-N and the optional feedback port 102E are electrically coupled to the system processing system 102A. An output of each *i*th DC-DC voltage converter 102B-1, 102B-N is electrically connected to an *i*th DC power output. Each *j*th DC power output is configured to be coupled through *j*th electrical conductors to a *j*th radio system.

[0033] Each radio system 104-1, 104-N includes a radio 104A-2, 104N-2 and an optional measurement sensor 104A-1. Optionally, a radio system includes an enclosure that encloses an optional measurement sensor and a radio.

[0034] Each optional measurement sensor is configured to measure a DC parameter value, *e.g.*, a DC voltage level or a direct current level; thus, an optional measurement sensor may be a voltage sensor or a current sensor. The optional measurement sensor may also be referred herein as measurement circuitry. For pedagogical reasons, each optional measurement sensor 104A-1, 104N-1 may be electrically coupled between electrical conductors 107A, 107N and a radio 104A-2, 104N-2; however, alternatively, if the optional measurement sensor is a magnetically coupled current sensor, such as a Hall effect sensor, the optional measurement

sensor is magnetically coupled, *e.g.*, to the electrical conductors 107A, 107N and is not serially electrically coupled as illustrated.

[0035] An optional feedback port 102E is configured to be communicatively coupled through an optional feedback connection (or a feedback communications link) 108 to each optional measurement sensor 104A-1, 104A-N. The optional feedback connection 108 may be a wired or a wireless connection. Optionally, the wired connection may be a parallel or serial wired connection using a wired communications protocol, *e.g.*, compliant with an RS-485 standard. Optionally, the wireless connection may use a wireless communications protocol, *e.g.*, used for local area networks (for example, an IEEE compliant 802.11 protocol) or personal area networks (for example, a Bluetooth protocol). Thus, each optional measurement sensor includes a transmitter (or a transceiver) corresponding to the communications protocol employed; each optional feedback port includes a receiver (or a transceiver) configured for the communications protocol employed. Although an optional single feedback port and an optional single feedback connection 108 are illustrated as being electrically coupled to each optional measurement sensor, other configurations may be used, *e.g.*, an optional single feedback port and an optional single feedback connection electrically connected to a unique, single optional measurement sensor.

[0036] The DC-DC voltage converter system 102 optionally includes data input circuitry 102F electrically coupled to the system processing system 102A. Optionally, the data input circuitry 102F includes an input / output interface (*e.g.*, a touch screen) and/or a receiver (or transceiver) (*e.g.*, configured for a wide area network, a local area network, and/or a personal area network) configured to receive externally provided data from an external computing system, *e.g.*, a mobile telephone, a tablet, or any remote computing system. The data input circuitry 102F is optionally configured to receive, *e.g.*, from the installer and/or the network operator (as described elsewhere herein, a resistance of each of the electrical conductors.

[0037] The system processing system 102A may be any type of computational system, *e.g.*, a state machine, neural network, and/or another type of computational system. In one embodiment, the system processing system 102A comprises a processor circuitry electrically coupled to memory circuitry. The system processing system 102A may be utilized to store and/or execute all or some of the methods and processes described herein. Optionally, the system processing system 102A is configured to be electrically coupled to the module parallel bus and/or the system parallel bus 114. Optionally, the system processing system 102A is configured to provide a signal, *e.g.*, a voltage level, for example a logical signal level, on one of

the module parallel bus or the system parallel bus 114 if the system processing system 102A determines respectively that all DC power outputs, of a DC-DC voltage converter module are electrically connected in parallel or that all DC power outputs, of the DC-DC voltage converter system 102 including the DC-DC voltage converter 102B, are electrically connected in parallel.

[0038] FIG. 1B illustrates a block diagram of one embodiment of a DC-DC voltage converter module 118. Thus, optionally a set of the DC-DC voltage converters described with respect to FIG. 1A may be consolidated in a DC-DC voltage converter module 118 which is a part of the DC-DC voltage converter system 102; the DC-DC voltage converter system 102 may include more than one module. Optionally, each DC-DC voltage converter module 118 includes two or more, *e.g.*, three, DC-DC voltage converters 102B.

[0039] The DC-DC voltage converter module 118 includes two or more DC-DC voltage converters and a converter power input and a DC power output for each DC-DC voltage converter. Each converter power input 102G-1, 102G-2, 102G-3 is electrically coupled to an input of a unique DC-DC voltage converter 102B-1, 102B-2, 102B-3. Each DC power output 102D-1, 102D-2, 102D-3 is electrically coupled to an output of a unique DC-DC voltage converter 102B-1, 102B-2, 102B-3. The DC-DC voltage converter module 118 includes a module parallel bus (MPB) 115. The module parallel bus 115 is an electrical bus configured to identify to each DC-DC voltage converter whether all of the DC power outputs 102D-1, 102D-N of all of the DC-DC voltage converters 102B-1, 102B-2, 102B-3 in the module have been determined to be electrically connected in parallel. Optionally, the signal on a bus indicating that all outputs of a DC-DC voltage converter module or all outputs of a DC-DC voltage converter system are electrically connected may be a voltage level, *e.g.*, a logic level for example high or low. At least one DC-DC voltage converter of such DC-DC voltage converter module or DC-DC voltage converter system whose outputs are electrically connected in parallel detects such electrical connection and causes the signal on a bus (*e.g.*, the MPB 115 or the system parallel bus 114)) which indicates such electrical connection and is detected by the other or all DC-DC voltage converters (respectively of the module or system) over the bus. Each bus may be implemented with a serial bus, a bus using ORing circuitry, open collector circuitry, and/or any other bus.

[0040] For pedagogical purposes, FIG. 1B illustrates a DC-DC voltage converter including a first DC-DC voltage converter, 102B-1, a second DC-DC voltage converter, 102B-2, and a third DC-DC voltage converter, 102B-3. Optionally, DC-DC voltage converter module 118 includes a complete or partial enclosure which completely or partially encloses the at least two DC-DC

voltage converters 102B-1, 102B-2, 102B-3. The DC-DC voltage converter system 102 may optionally include one or more openings or slots into each of which a DC-DC voltage converter module 118 can be inserted. Optionally, each slot has a unique identifier which may be electrically conveyed to a corresponding module, *e.g.*, using a unique numerical code, *e.g.*, in binary format, for each slot or a resistor of a unique value (mounted in the enclosure by a corresponding slot) which conveys a unique voltage level to a DC-DC voltage converter module 118 inserted into the slot.

[0041] FIG. 1C illustrates a block diagram of one embodiment of a DC-DC voltage converter 102B. The DC-DC voltage converter 102B includes DC-DC voltage converter circuitry 102B-a, a converter processing system 102B-c, and a voltage sensor 102B-b. An output of the DC-DC voltage converter circuitry 102B-a is electrically coupled to a voltage sensor 102B-b and to a DC power output. The DC-DC voltage converter circuitry 102B-a may be DC-DC boost or a buck-boost voltage converter circuitry. An input of the DC-DC voltage converter circuitry is electrically coupled to a converter power input 102G.

[0042] The converter processing system 102B-c may be any type of computational system, *e.g.*, a state machine, neural network, and/or another type of computational system. In one embodiment, the converter processing system 102B-c comprises a processor circuitry electrically coupled to memory circuitry. The converter processing system 102B-d may be utilized to store and/or execute all or some of the methods and processes described herein. Optionally, the converter processing system 102B-c is configured to be electrically coupled to the module parallel bus 115 and/or the system parallel bus 114. Optionally, the converter processing system 102B-c is configured to provide a signal, *e.g.*, a voltage level, for example a logical signal level, on one of the MPB 115 or the SPB 114 if the converter processing system 102B-c determines respectively that all DC power outputs, of a DC-DC voltage converter module 118 including the DC-DC voltage converter 102B, are electrically connected in parallel or that all DC power outputs, of the DC-DC voltage converter system 102 including the DC-DC voltage converter 102B, are electrically connected in parallel. The converter processing systems in other DC-DC voltage converters (whose DC power outputs are electrically connected in parallel) are configured to detect such a signal.

[0043] Optionally, the DC-DC voltage converter 102B includes a bypass path 102B-d and an ORing circuit 102B-e. When the bypass path is enabled 102B-d and a magnitude of the DC voltage received at the converter power input 102G from the DC power source(s) 106 is greater than a magnitude of a DC voltage generated by the DC-DC voltage converter, then a voltage

provided by the DC power source(s) 106 is provided at the DC power output 102D of the DC-DC voltage converter 102B and operation of the DC-DC voltage converter 102B is disabled. For purposes of clarity, when the ORing circuit 102B-e5 is utilized in the DC-DC voltage converter 102B, the voltage sensor 102B-b may be located between the ORing circuit 102B-e and the DC power output 102D. Optionally, an additional voltage sensor may be coupled between an output of the DC-DC voltage converter circuitry 102B-a and the ORing circuit 102B-e.

[0044] FIG. 1D illustrates a diagram of one embodiment of a DC-DC voltage converter system 102 including three DC-DC voltage converter modules 118A, 118B, 118C. For pedagogical purposes, the DC-DC voltage converter system 102 includes three DC-DC voltage converter modules 118A, 118B, 118C each of which comprises three DC-DC voltage converters. Only the DC power outputs 102D-1, 102D-2, 102D-3, 102D-4, 102D-5, 102D-6, 102D-7, 102D-8, 102D-9 of each DC-DC voltage converter module (and thus each DC-DC voltage converter) are illustrated. For pedagogical purposes, each DC power output 102D-1, 102D-2, 102D-3, 102D-4, 102D-5, 102D-6, 102D-7, 102D-8, 102D-9 comprises a pair of positive terminals 119P and a pair of negative terminals 119N.

[0045] Two or more DC power outputs of a DC-DC voltage converter system 102 may be electrically shorted, *e.g.*, to provide more DC electrical power, to one or more radios. In an extreme, all DC power outputs 102D of all DC-DC voltage converters 102B of a DC-DC voltage converter system 102, may be electrically shorted when providing DC electrical power to all radio(s) electrically powered by the DC-DC voltage converter system 102. Optionally, when DC power outputs 102D, of one or more DC-DC voltage converters 102B of a DC-DC voltage converter system 102, are electrically shorted, the DC-DC voltage converters 102B, whose DC power outputs 102D are electrically shorted, may be configured to each provide static boosting, *i.e.*, each provide a same fixed DC voltage level at the electrically shorted DC power outputs. Optionally, a DC-DC voltage converter, whose DC power output is not electrically shorted with another DC power output of another DC-DC voltage converter, may be configured to provide static or dynamic boosting. Static boosting means providing a constant DC voltage level at a DC power output. Dynamic boosting means providing a non-constant DC voltage level at the DC power output. The non-constant DC voltage level may be a function of the direct current drawn from the DC power output and a resistance of electrical conductors through which DC power is supplied to a load, *e.g.*, radio(s). Dynamic boosting compensates in whole or in part for a voltage drop in the electrical conductors. Optionally, dynamic boosting is

implemented by varying the DC voltage level at the DC power output so as to provide a constant (or substantially constant) DC voltage at a DC input of the load with respect to the direct current drawn from the DC power output.

[0046] FIG. 1E illustrates a block diagram of one embodiment of a DC-DC voltage converter system 102 with electrically shorted outputs. In the illustrated embodiment, three sets of DC power outputs are electrically shorted by shorting conductors (or shorting electrical conductors) 113A, 113B, 113C. Optionally, each three sets of shorted DC power outputs may be part of a unique or different DC-DC voltage converter module 118. A first set of DC power outputs 102D-1, 102D-2, 102D-3 are electrically coupled by first shorting conductors 113A and electrically coupled through first electrical conductors 107A to a first radio 104A-2. A second set of DC power outputs 102D-4, 102D-5, 102D-6 are electrically coupled by second shorting conductors 113B and electrically coupled through second electrical conductors 107B to a second radio 104B-2. A third set of DC power outputs 102D-7, 102D-8, 102D-9 are electrically coupled by third shorting conductors 113C and electrically coupled through third electrical conductors 107C to a third radio 104B-2. For pedagogical purposes, single radios are each shown as being fed DC electrical power from a set of multiple DC power outputs. However, alternatively one or more sets of multiple DC power outputs may each feed a group of two or more radios instead of only a single radio.

[0047] The shorting conductor includes an electrical conductor, such as copper, gold, aluminum, and/or an alloy thereof. The shorting conductors may be formed with bus bar, wires, and/or any other electrical conductor implementation. For pedagogical purposes, the shorting conductors will be subsequently described in a context of providing electrical shorting of all DC power outputs of (a) a DC-DC voltage converter system 102 or (b) a DC-DC voltage converter module 118 of the DC-DC voltage converter system 102. FIG. 1F illustrates a diagram of a system bus bar 116A with holes 111 configured to be mounted over all positive or negative terminals of a DC-DC voltage converter system 102. FIG. 1G illustrates a diagram of a module bus bar 116B with holes 111 configured to be mounted over all positive or negative terminals of a DC-DC voltage converter module 118 of a DC-DC voltage converter system 102. FIG. 1H illustrates a diagram of a first shorting conductor mounted over and electrically shorting positive terminals 119P of all DC power outputs of a DC-DC voltage converter system 102 and of a second shorting conductor 116A-2 mounted over and electrically shorting negative terminals 119N of all DC power outputs of the DC-DC voltage converter system 102. The positive and negative terminals of the DC power outputs of each DC-DC voltage converter

module 118 of the DC-DC voltage converter system 102 are electrically shorted in this manner. FIG. 1I illustrates a diagram of a first, second, and third shorting conductors 116B-1, 116B-2, 116B-3 mounted over and electrically shorting positive terminals 119P of all DC power outputs of respectively a first, a second, and a third DC-DC voltage converter module 118A, 118B, 118C and of a third, fourth, and fifth shorting conductors 116B-4, 116B-5, 116B-6 mounted over and electrically shorting negative terminals 119N of all DC power outputs of respectively a first, a second, and a third DC-DC voltage converter module 118A, 118B, 118C. The positive terminals and negative terminals of the DC power outputs, of one or more DC-DC voltage converter modules 118 of the DC-DC voltage converter system 102, may respectively be electrically shorted in this manner.

[0048] To ensure that the DC-DC voltage converters 102B whose outputs are electrically shorted operate in a coherent manner, *e.g.*, by having each such DC-DC voltage converter 102B provide a same constant DC voltage its DC power output 102D, the DC-DC voltage converter system 102 or each DC-DC voltage converter module 118 must ascertain which, if any, of the DC power outputs 102D, of its constituent DC-DC voltage converters 102B, are electrically shorted, or each DC-DC voltage converter 102B must ascertain if its DC power output 102D is electrically shorted to at least one (or to at least two or to all) other DC power outputs 102D of other DC-DC voltage converters 102B of the DC-DC voltage converter system 102.

[0049] FIG. 2 illustrates a flow diagram of one embodiment of a method 220 for determining whether all DC power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of the DC-DC voltage converter modules are electrically connected. Method 220 is performed at startup of the DC-DC voltage converter system. The methods illustrated herein may be implemented with, *e.g.*, the system processing system 102A and/or one or more of the converter processing systems 102B-c described elsewhere herein but may be implemented with other processing systems as well. For pedagogical purposes, implementation of the methods may be described with respect to Figures 1A-1I. The blocks of the flow diagrams have been arranged in a generally sequential manner for ease of explanation; however, it is to be understood that this arrangement is merely exemplary, and it should be recognized that the processing associated with the methods described herein (and the blocks shown in the Figures) may occur in a different order (for example, where at least some of the processing associated with the blocks is performed in parallel and/or in an event-driven manner).

[0050] In optional block 220A, at a first time, a constant DC voltage is commanded to be provided at a single DC power output of a first DC-DC voltage converter module. Optionally, the constant DC voltage is provided at such single DC power output of the first DC-DC voltage converter module.

[0051] In block 220B, DC voltage measurements, at other DC power outputs of the DC-DC voltage converter system, are received. Optionally, such DC voltage measurements are made by a voltage sensor 102B-b in each DC-DC voltage converter 102B.

[0052] In block 220C, whether a magnitude of (a) each of the DC voltage measurements of the other DC power outputs of the DC-DC voltage converter system or (b) at least one DC voltage measurement of a DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level is determined. The first DC voltage threshold is a positive number substantially equal to or less, *e.g.*, by 0.5V-1V, than the constant voltage. If the magnitude of (a) each of the DC voltage measurements of the other DC power outputs of the DC-DC voltage converter system or (b) at least one DC voltage measurement of a DC power output of a different DC-DC voltage converter module is greater than the first DC voltage threshold level, then in block 220D a system parallel signal is provided, *e.g.*, on the system parallel bus 114, to all DC-DC voltage converters of the DC-DC voltage converter system. Optionally, this may be accomplished by, *e.g.*, the system processing system 102A or a converter processing system 102B-c, changing a voltage level on the bus, *e.g.*, by affecting an open collector circuit or wired OR circuit. If the magnitude of (a) each of the DC voltage measurements of the other DC power outputs of the DC-DC voltage converter system or (b) at least one DC voltage measurement of a DC power output of a different DC-DC voltage converter module is not greater than the first DC voltage threshold level, then in block 220E whether a magnitude of each of the DC voltage measurements at other DC power outputs, *e.g.*, at least one or all other DC power outputs, of the same DC-DC voltage converter module is greater than the first DC voltage threshold level is determined. If the magnitude of each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is greater than the first DC voltage threshold level, then in block 220F a module parallel signal is provided, *e.g.*, on the module parallel bus 115, to all DC-DC voltage converters of the DC-DC voltage converter module whose DC-DC voltage converter provided the constant DC voltage level. Optionally, this may be accomplished by, *e.g.*, the system processing system 102A or a converter processing system 102B-c, changing a voltage level on the bus, *e.g.*, by affecting an open collector circuit or wired OR circuit.

[0053] After block 220F, proceed to block 220G. If the magnitude of each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is not greater than the first DC voltage threshold level, then also proceed to block 220G. In block 220G, whether a command to provide a constant DC voltage at a single DC power output was performed by a last, *e.g.*, the third, DC-DC voltage converter module of the DC-DC voltage converter system is determined. When such activity was performed by the last DC-DC voltage converter module, then method 220 has been performed for each DC-DC voltage converter module of the DC-DC voltage converter system. If the command to provide a constant DC voltage at a single DC power output was not performed by the last DC-DC voltage converter module of the DC-DC voltage converter system, then in block 220H, at a subsequent time, a constant DC voltage is commanded to be provided at a single DC power output of a next DC-DC voltage converter module. Optionally, the constant DC voltage is provided at such single DC power output of the next DC-DC voltage converter module. Then proceed to block 220E.

[0054] After block 220D or if it determined that a command to provide a constant DC voltage at a single DC power output was performed by the last DC-DC voltage converter module of the DC-DC voltage converter system, then optionally proceed to optional block 220I. In optional block 220I each DC-DC voltage converter of the DC-DC voltage converter system determines whether a system parallel signal has been received or generated.

[0055] If a system parallel signal has been received or generated by each DC-DC voltage converter of the DC-DC voltage converter system, then in optional block 220J at an output of each DC-DC voltage converter of the DC-DC voltage converter system provide a same DC voltage. If a system parallel signal has not been received or generated by each DC-DC voltage converter of the DC-DC voltage converter system, then in optional block 220K for each DC-DC voltage converter module whether a module parallel signal has been received or generated by each DC-DC voltage converter in a DC-DC voltage converter module is determined.

[0056] In optional block 220L, for each DC-DC voltage converter module all of whose DC-DC voltage converters have received or generated a module parallel signal, a same DC voltage is provided at a DC power outputs of a DC-DC voltage converter module. In optional block 220M, at each DC power output of a DC-DC voltage converter which has not received or generated either a system or a module parallel signal, an independent DC voltage is provided.

[0057] FIG. 3 illustrates a flow diagram of one embodiment of a method 330 for determining whether all DC power outputs of a DC-DC voltage converter system are electrically connected

or whether all DC power outputs of all of one or more of the DC-DC voltage converter modules are electrically connected. Method 330 is performed at startup of the DC-DC voltage converter system or when a new DC-DC voltage converter module is inserted into a slot of the DC-DC voltage converter system. Optionally, the new DC-DC voltage converter module may be a replacement for a previously removed DC-DC voltage converter module. Such a replacement, when made in a powered on DC-DC voltage converter system, may be referred to as hot swapping.

[0058] The methods illustrated herein may be implemented with, *e.g.*, the system processing system 102A and/or one or more of the converter processing systems 102B-c3 described elsewhere herein but may be implemented with other processing systems as well. For pedagogical purposes, implementation of the methods may be described with respect to Figures 1A-1I. The blocks of the flow diagrams have been arranged in a generally sequential manner for ease of explanation; however, it is to be understood that this arrangement is merely exemplary, and it should be recognized that the processing associated with the methods described herein (and the blocks shown in the Figures) may occur in a different order (for example, where at least some of the processing associated with the blocks is performed in parallel and/or in an event-driven manner).

[0059] In block 330A, each DC-DC voltage converter of a DC-DC voltage converter module is set to provide a DC voltage level, at a DC power output of the DC-DC voltage converter, that is set at or below a second DC voltage threshold level, *e.g.*, zero volts. The DC-DC voltage converter module may be a new DC-DC voltage converter module inserted into a slot of a DC-DC voltage converter system which is powered on. Alternatively, the DC-DC voltage converter module is a first DC-DC voltage converter module (or a next or subsequent DC-DC voltage converter module when optional block 330O is performed) of the DC-DC voltage converter module system when such system is being powered on. Blocks 330A-330I and 330K are configured to be performed for each DC-DC voltage converter module of the DC-DC voltage converter system being started up.

[0060] In block 330B, whether a system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module is determined. If a system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module, then proceed to block 330K. If a system parallel signal has not been received by each DC-DC voltage converter of the DC-DC voltage converter module, then in block 330C a DC voltage measurement of each DC power output of the DC-DC voltage converter module is

received. In block 330D, whether a magnitude of each DC voltage measurement of each DC voltage measurement is greater than the first DC voltage threshold level is determined. If the magnitude of each DC voltage measurement is greater than the first DC voltage threshold level, then proceed to block 330K. If the magnitude of each DC voltage measurement is not greater than the first DC voltage threshold level, then in block 330E a constant DC voltage is commanded to be provided at a single DC power output of the DC-DC voltage converter module. Optionally, the constant DC voltage is provided at the single DC power output. In block 330F, a DC voltage measurement at each other DC power output of the DC-DC voltage converter module is received.

[0061] In block 330G, whether a magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level is determined. If the magnitude of each received DC voltage measurement is not greater than the first DC voltage threshold level, then proceed to block 330M or stop. If the magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level, then in block 330H whether each DC-DC voltage converter of the DC-DC voltage converter module has been received a system parallel signal is determined.

[0062] If each DC-DC voltage converter of the DC-DC voltage converter module has been received a system parallel signal, then in block 330K a system parallel signal is transmitted to all DC-DC voltage converters of the DC-DC voltage converter system. After block 330K, proceed to optional block 330L or stop. If each DC-DC voltage converter of the DC-DC voltage converter module has not been received a system parallel signal, then in block 330I a module parallel signal is transmitted to all DC-DC voltage converters in the DC-DC voltage converter module. After block 330I proceed to block 330J or stop.

[0063] In optional block 330M, at an DC power output of each DC-DC voltage converter of the DC-DC voltage converter module provide an independent DC voltage. Independent DC voltage means a DC voltage at a DC power output that is generated by a DC-DC voltage converter whose output provides the DC voltage level at an output and without coordination with any other DC-DC voltage converter in the same DC-DC voltage converter system.

[0064] In optional block 330J, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter module provide a same DC voltage. In optional block 330L, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter system provide a same DC voltage.

[0065] If the DC-DC voltage converter system is undergoing power startup, then in optional block 330N whether the DC-DC voltage converter module is a last DC-DC voltage converter module, of the DC-DC voltage converter system, whose DC power outputs are evaluated to determine whether they are electrically connected, *e.g.*, with blocks 330A-330J, is determined. If it is determined that the DC-DC voltage converter module is the last DC-DC voltage converter module to be analyzed, then stop. If it is determined that the DC-DC voltage converter module is not the last DC-DC voltage converter module to be analyzed, then in optional block 330O, select the next DC-DC voltage converter module and proceed to block 330A.

[0066] Each processing system (or processing circuitry) disclosed herein may comprise state machine(s), neural network(s), and/or other types of computing systems. Such processing system may comprise processing circuitry coupled to memory circuitry. The processing circuitry may include one or more microprocessors, microcontrollers, digital signal processing (DSP) elements, application-specific integrated circuits (ASICs), and/or field programmable gate arrays (FPGAs). The processor system may include or function with software programs, firmware, or other computer readable instructions, *e.g.*, stored in the memory circuitry, for carrying out various process tasks, calculations, and control functions, used in the methods described herein. These instructions are typically tangibly embodied on any storage media (or computer readable medium) used for storage of computer readable instructions or data structures.

[0067] The memory circuitry can be implemented with any available storage media (or computer readable medium) that can be accessed by a general purpose or special purpose computer or processor, or any programmable logic device. Suitable computer readable medium may include storage or memory media such as semiconductor, magnetic, and/or optical media. For example, computer readable media may include conventional hard disks, volatile or non-volatile media such as Random Access Memory (RAM) (including, but not limited to, Dynamic Random Access Memory (DRAM)), Read Only Memory (ROM), Electrically Erasable Programmable ROM (EEPROM), and/or flash memory.

[0068] Methods of the invention can be implemented in computer readable instructions, such as program modules or applications, which may be stored in the computer readable medium and executed by the processing circuitry. Generally, program modules or applications include routines, programs, objects, data components, data structures, algorithms, and the like, which perform particular tasks or implement particular abstract data types.

EXAMPLE EMBODIMENTS

[0069] Example 1 includes a method for determining whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected, the method comprising: setting each DC-DC voltage converter of a DC-DC voltage converter module to provide a DC voltage level, at a DC power output of a DC-DC voltage converter, at or below a second DC voltage threshold level; determining whether a system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module; determining that the system parallel signal has not been received by each DC-DC voltage converter of the DC-DC voltage converter module, then receiving a DC voltage measurement of each DC power output of the DC-DC voltage converter module; determining whether a magnitude of each DC voltage measurement is greater than a first DC voltage threshold level; determining that the magnitude of each DC voltage measurement is not greater than the first DC voltage threshold level, then providing a constant DC voltage at a single DC power output of the DC-DC voltage converter module; receiving a DC voltage measurement at each of other DC power output of the DC-DC voltage converter module; determining that the magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level, then determining whether each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal; determining that each DC-DC voltage converter of the DC-DC voltage converter module has not received the system parallel signal, then transmitting a module parallel signal to all DC-DC voltage converters in the DC-DC voltage converter module; and either (a) determining that each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal, (b) determining that the magnitude of each DC voltage measurement is greater than the first DC voltage threshold level, or (c) determining that the system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module, then transmitting the system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system.

[0070] Example 2 includes the method of Example 1, wherein the second DC voltage threshold level is zero volts.

[0071] Example 3 includes the method of any of Examples 1-2, further comprising: upon transmitting the system parallel signal to the all DC-DC voltage converters of the DC-DC

voltage converter system, then providing, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter system, a same DC voltage; upon transmitting the module parallel signal to the all DC-DC voltage converters of the DC-DC voltage converter module, then providing, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter module, the same DC voltage; and determining that a magnitude of each received DC voltage measurement is not greater than the first DC voltage threshold level, then providing, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter module, an independently derived DC voltage.

[0072] Example 4 includes the method of Example 3, further comprising: determining whether the DC-DC voltage converter module is a last DC-DC voltage converter module. of the DC-DC voltage converter system, whose DC power outputs are evaluated to determine whether they are electrically connected; and determining that the DC-DC voltage converter module is not a last DC-DC voltage converter module. of the DC-DC voltage converter system, whose DC power outputs are so evaluated, then selecting a next DC-DC voltage converter module.

[0073] Example 5 includes the method of any of Examples 3-4, wherein the same DC voltage is a fixed DC voltage.

[0074] Example 6 includes the method of any of Examples 1-5, wherein the first DC voltage threshold level is equal to or less than the constant DC voltage.

[0075] Example 7 includes a non-transitory computer readable medium storing a program causing at least one processor to execute a process configured to determine whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected, the process comprising: setting each DC-DC voltage converter of a DC-DC voltage converter module to provide a DC voltage level, at a DC power output of a DC-DC voltage converter, at or below a second DC voltage threshold level; determining whether a system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module; determining that the system parallel signal has not been received by each DC-DC voltage converter of the DC-DC voltage converter module, then receiving a DC voltage measurement of each DC power output of the DC-DC voltage converter module; determining whether a magnitude of each DC voltage measurement is greater than a first DC voltage threshold level; determining that the magnitude of each DC voltage measurement is not greater than the first DC voltage threshold level, then providing a constant DC voltage at a

single DC power output of the DC-DC voltage converter module; receiving a DC voltage measurement at each of other DC power output of the DC-DC voltage converter module; determining whether a magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level; determining that a magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level, then determining whether each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal; determining that each DC-DC voltage converter of the DC-DC voltage converter module has not received the system parallel signal, then transmitting a module parallel signal to all DC-DC voltage converters in the DC-DC voltage converter module; and either (a) determining that each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal, (b) determining that the magnitude of each DC voltage measurement is greater than the first DC voltage threshold level, or (c) determining that the system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module, then transmitting the system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system.

[0076] Example 8 includes the non-transitory computer readable medium of Example 7, wherein the second DC voltage threshold level is zero volts.

[0077] Example 9 includes the non-transitory computer readable medium of any of Examples 7-8, wherein the process further comprises: upon transmitting the system parallel signal to the all DC-DC voltage converters of the DC-DC voltage converter system, then providing, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter system, a same DC voltage; upon transmitting the module parallel signal to the all DC-DC voltage converters of the DC-DC voltage converter module, then providing, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter module, the same DC voltage; and determining that a magnitude of each received DC voltage measurement is not greater than the first DC voltage threshold level, then providing, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter module, an independently derived DC voltage.

[0078] Example 10 includes the non-transitory computer readable medium of Example 9, wherein the process further comprises: determining whether the DC-DC voltage converter module is a last DC-DC voltage converter module. of the DC-DC voltage converter system, whose DC power outputs are evaluated to determine whether they are electrically connected; and determining that the DC-DC voltage converter module is not a last DC-DC voltage

converter module. of the DC-DC voltage converter system, whose DC power outputs are so evaluated, then selecting a next DC-DC voltage converter module.

[0079] Example 11 includes the non-transitory computer readable medium of any of Examples 9-10, wherein the same DC voltage is a fixed DC voltage.

[0080] Example 12 includes the non-transitory computer readable medium of any of Examples 7-11, wherein the first DC voltage threshold level is equal to or less than the constant DC voltage.

[0081] Example 13 includes an apparatus configured to determine whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected, the apparatus comprising: processing circuitry configured to: set each DC-DC voltage converter of a DC-DC voltage converter module to provide a DC voltage level, at a DC power output of a DC-DC voltage converter, at or below a second DC voltage threshold level; determine whether a system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module; determine that the system parallel signal has not been received by each DC-DC voltage converter of the DC-DC voltage converter module, then receiving a DC voltage measurement of each DC power output of the DC-DC voltage converter module; determine whether a magnitude of each DC voltage measurement is greater than a first DC voltage threshold level; determine that the magnitude of each DC voltage measurement is not greater than the first DC voltage threshold level, then providing a constant DC voltage at a single DC power output of the DC-DC voltage converter module; receive a DC voltage measurement at each of other DC power output of the DC-DC voltage converter module; determine whether a magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level; determine that a magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level, then determining whether each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal; determine that each DC-DC voltage converter of the DC-DC voltage converter module has not received the system parallel signal, then transmitting a module parallel signal to all DC-DC voltage converters in the DC-DC voltage converter module; and either (a) determine that each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal, (b) determine that the magnitude of each DC voltage measurement is greater than the first DC voltage threshold level, or (c) determine that the system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module,

then transmitting the system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system; and at least two DC-DC voltage converters which are communicatively coupled to the processing circuitry.

[0082] Example 14 includes the apparatus of Example 13, wherein the second DC voltage threshold level is zero volts.

[0083] Example 15 includes the apparatus of any of Examples 13-14, wherein the processing circuitry is further configured to: upon transmitting the system parallel signal to the all DC-DC voltage converters of the DC-DC voltage converter system, then provide, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter system, a same DC voltage; upon transmitting the module parallel signal to the all DC-DC voltage converters of the DC-DC voltage converter module, then provide, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter module, the same DC voltage; and determine that a magnitude of each received DC voltage measurement is not greater than the first DC voltage threshold level, then providing, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter module, an independently derived DC voltage.

[0084] Example 16 includes the apparatus of Example 15, wherein the processing circuitry is further configured to: determine whether the DC-DC voltage converter module is a last DC-DC voltage converter module. of the DC-DC voltage converter system, whose DC power outputs are evaluated to determine whether they are electrically connected; and determine that the DC-DC voltage converter module is not a last DC-DC voltage converter module. of the DC-DC voltage converter system, whose DC power outputs are so evaluated, then selecting a next DC-DC voltage converter module.

[0085] Example 17 includes the apparatus of any of Examples 15-16, wherein the same DC voltage is a fixed DC voltage.

[0086] Example 18 includes the apparatus of any of Examples 13-17, wherein the first DC voltage threshold level is equal to or less than the constant DC voltage.

[0087] Example 19 includes a method for determining whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected, the method comprising: at a first time, providing a constant DC voltage to be provided a single DC power output of a first DC-DC voltage converter module; receiving DC voltage measurements at other DC power outputs of the DC-DC voltage converter system;

determining whether a magnitude of (a) each of the DC voltage measurements or (b) at least one DC voltage measurement of a DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level; determining that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level, then providing a system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system; determining that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of the different DC-DC voltage converter module is not greater than a first DC voltage threshold level, then determining whether each of the DC voltage measurements at the other DC power outputs of a same DC-DC voltage converter module is greater than the first DC voltage threshold level; determining that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is greater than the first DC voltage threshold level, then providing a module parallel signal to all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage; (i) determining that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is not greater than the first DC voltage threshold level or (ii) upon providing the module parallel signal to the all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage, then determining whether the constant DC voltage at a single DC power output was provided by a last DC-DC voltage converter module of the DC-DC voltage converter system; and determining that the constant DC voltage at a single DC power output was not provided by a last DC-DC voltage converter module of the DC-DC voltage converter system, then at a subsequent time, providing the constant DC voltage at a single DC power output of a next DC-DC voltage converter module.

[0088] Example 20 includes the method of Example 19, further comprising: either (p) upon providing the system parallel signal to the all DC-DC voltage converters or (q) determining that the constant DC voltage at a single DC power output was provided by a last DC-DC voltage converter module of the DC-DC voltage converter system, then determining whether, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has been received or generated; upon determining that, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has been received or generated, then providing, at an output of each DC-DC voltage converter of the DC-DC voltage converter

system, a same DC voltage; and upon determining that, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has not been received or generated, then: (x) determining, for each DC-DC voltage converter module, whether a module parallel signal has been received or generated by each DC-DC voltage converter in the DC-DC voltage converter module; (y) providing, at a DC power output of each DC-DC voltage converter of a DC-DC voltage converter module which has received or obtained the module parallel signal, the same DC voltage; and (z) providing, at each DC power output of each DC-DC voltage converter which has not received or generated the system or the module parallel signal, a DC voltage which has been derived independently of other DC-DC voltage converters.

[0089] Example 21 includes the method of any of Examples 19-20, wherein the first DC voltage threshold level is equal to or less than the constant DC voltage.

[0090] Example 22 includes the method of any of Examples 19-21, wherein the same DC voltage is a fixed DC voltage.

[0091] Example 23 includes a non-transitory computer readable medium storing a program causing at least one processor to execute a process configured to determine whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected, the process comprising: at a first time, providing a constant DC voltage to be provided a single DC power output of a first DC-DC voltage converter module; receiving DC voltage measurements at other DC power outputs of the DC-DC voltage converter system; determining whether a magnitude of (a) each of the DC voltage measurements or (b) at least one DC voltage measurement of a DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level; determining that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level, then providing a system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system; determining that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of the different DC-DC voltage converter module is not greater than a first DC voltage threshold level, then determining whether each of the DC voltage measurements at the other DC power outputs of a same DC-DC voltage converter module is greater than the first DC voltage threshold level; determining that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage

converter module is greater than the first DC voltage threshold level, then providing a module parallel signal to all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage; (i) determining that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is not greater than the first DC voltage threshold level or (ii) upon providing the module parallel signal to the all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage, then determining whether a constant DC voltage at a single DC power output was provided by a last DC-DC voltage converter module of the DC-DC voltage converter system; and determining that the constant DC voltage at a single DC power output was not provided by a last DC-DC voltage converter module of the DC-DC voltage converter system, then at a subsequent time, providing the constant DC voltage at a single DC power output of a next DC-DC voltage converter module.

[0092] Example 24 includes the non-transitory computer readable medium of Example 23, wherein the process further comprises: either (p) upon providing the system parallel signal to the all DC-DC voltage converters or (q) determining that the constant DC voltage at a single DC power output was provided by a last DC-DC voltage converter module of the DC-DC voltage converter system, then determining whether, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has been received or generated; upon determining that, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has been received or generated, then providing, at an output of each DC-DC voltage converter of the DC-DC voltage converter system, a same DC voltage; and upon determining that, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has not been received or generated, then: (x) determining, for each DC-DC voltage converter module, whether the module parallel signal has been received or generated by each DC-DC voltage converter in the DC-DC voltage converter module; (y) providing, at a DC power output of each DC-DC voltage converter of a DC-DC voltage converter module which has received or obtained the module parallel signal, the same DC voltage; and (z) providing, at each DC power output of each DC-DC voltage converter which has not received or generated the system or the module parallel signal, a DC voltage which has been derived independently of other DC-DC voltage converters.

[0093] Example 25 includes the non-transitory computer readable medium of any of Examples 23-24, wherein the first DC voltage threshold level is equal to or less than the constant DC voltage.

[0094] Example 26 includes the non-transitory computer readable medium of any of Examples 23-25, wherein the same DC voltage is a fixed DC voltage.

[0095] Example 27 includes an apparatus configured to determine whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected, the apparatus comprising: processing circuitry configured to: at a first time, provide a constant DC voltage to be provided a single DC power output of a first DC-DC voltage converter module; receive DC voltage measurements at other DC power outputs of the DC-DC voltage converter system; determine whether a magnitude of (a) each of the DC voltage measurements or (b) at least one DC voltage measurement of a DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level; determine that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level, then providing a system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system; determine that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of the different DC-DC voltage converter module is not greater than a first DC voltage threshold level, then determining whether each of the DC voltage measurements at the other DC power outputs of a same DC-DC voltage converter module is greater than the first DC voltage threshold level; determine that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is greater than the first DC voltage threshold level, then providing a module parallel signal to all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage; (i) determine that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is not greater than the first DC voltage threshold level or (ii) upon providing the module parallel signal to the all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage, then determining whether the constant DC voltage at a single DC power output was provided by a last DC-DC voltage converter module of the DC-DC voltage converter system; and determine that the constant DC voltage at a single DC power output was not provided by a last DC-DC voltage converter module of the DC-DC voltage converter system, then at a subsequent time, providing the constant DC voltage at a single DC

power output of a next DC-DC voltage converter module; and at least two DC-DC voltage converters communicatively coupled to the processing circuitry.

[0096] Example 28 includes the apparatus of Example 27, wherein the processing circuitry is further configured to: either (p) upon providing the system parallel signal to the all DC-DC voltage converters or (q) determining that the constant DC voltage at a single DC power output was provided by a last DC-DC voltage converter module of the DC-DC voltage converter system, then determine whether, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has been received or generated; upon determining that, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has been received or generated, then provide, at an output of each DC-DC voltage converter of the DC-DC voltage converter system, a same DC voltage; and upon determining that, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has not been received or generated, then: (x) determine, for each DC-DC voltage converter module, whether the module parallel signal has been received or generated by each DC-DC voltage converter in the DC-DC voltage converter module; (y) provide, at a DC power output of each DC-DC voltage converter of a DC-DC voltage converter module which has received or obtained the module parallel signal, the same DC voltage; and (z) provide, at each DC power output of each DC-DC voltage converter which has not received or generated the system or the module parallel signal, a DC voltage which has been derived independently of other DC-DC voltage converters.

[0097] Example 29 includes the apparatus of any of Examples 27-28, wherein the first DC voltage threshold level is equal to or less than the constant DC voltage.

[0098] Example 30 includes the apparatus of any of Examples 27-29, wherein the same DC voltage is a fixed DC voltage.

[0099] A number of embodiments of the invention defined by the following claims have been described. Nevertheless, it will be understood that various modifications to the described embodiments may be made without departing from the spirit and scope of the claimed invention. Accordingly, other embodiments are within the scope of the following claims.

CLAIMS

What is claimed is:

1. A method for determining whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected, the method comprising:
 - setting each DC-DC voltage converter of a DC-DC voltage converter module to provide a DC voltage level, at a DC power output of a DC-DC voltage converter, at or below a second DC voltage threshold level;
 - determining whether a system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module;
 - determining that the system parallel signal has not been received by each DC-DC voltage converter of the DC-DC voltage converter module, then receiving a DC voltage measurement of each DC power output of the DC-DC voltage converter module;
 - determining whether a magnitude of each DC voltage measurement is greater than a first DC voltage threshold level;
 - determining that the magnitude of each DC voltage measurement is not greater than the first DC voltage threshold level, then providing a constant DC voltage at a single DC power output of the DC-DC voltage converter module;
 - receiving a DC voltage measurement at each of other DC power output of the DC-DC voltage converter module;
 - determining that the magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level, then determining whether each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal;
 - determining that each DC-DC voltage converter of the DC-DC voltage converter module has not received the system parallel signal, then transmitting a module parallel signal to all DC-DC voltage converters in the DC-DC voltage converter module; and
 - either (a) determining that each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal, (b) determining that the magnitude of each DC voltage measurement is greater than the first DC voltage threshold level, or (c) determining that the system parallel signal has been received by each DC-DC voltage converter

of the DC-DC voltage converter module, then transmitting the system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system.

2. The method of claim 1, wherein the second DC voltage threshold level is zero volts.

3. The method of claim 1, further comprising:

upon transmitting the system parallel signal to the all DC-DC voltage converters of the DC-DC voltage converter system, then providing, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter system, a same DC voltage;

upon transmitting the module parallel signal to the all DC-DC voltage converters of the DC-DC voltage converter module, then providing, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter module, the same DC voltage; and

determining that a magnitude of each received DC voltage measurement is not greater than the first DC voltage threshold level, then providing, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter module, an independently derived DC voltage.

4. The method of claim 3, further comprising:

determining whether the DC-DC voltage converter module is a last DC-DC voltage converter module. of the DC-DC voltage converter system, whose DC power outputs are evaluated to determine whether they are electrically connected; and

determining that the DC-DC voltage converter module is not a last DC-DC voltage converter module. of the DC-DC voltage converter system, whose DC power outputs are so evaluated, then selecting a next DC-DC voltage converter module.

5. The method of claim 3, wherein the same DC voltage is a fixed DC voltage.

6. The method of claim 1, wherein the first DC voltage threshold level is equal to or less than the constant DC voltage.

7. A non-transitory computer readable medium storing a program causing at least one processor to execute a process configured to determine whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected, the process comprising:

- setting each DC-DC voltage converter of a DC-DC voltage converter module to provide a DC voltage level, at a DC power output of a DC-DC voltage converter, at or below a second DC voltage threshold level;

- determining whether a system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module;

- determining that the system parallel signal has not been received by each DC-DC voltage converter of the DC-DC voltage converter module, then receiving a DC voltage measurement of each DC power output of the DC-DC voltage converter module;

- determining whether a magnitude of each DC voltage measurement is greater than a first DC voltage threshold level;

- determining that the magnitude of each DC voltage measurement is not greater than the first DC voltage threshold level, then providing a constant DC voltage at a single DC power output of the DC-DC voltage converter module;

- receiving a DC voltage measurement at each of other DC power output of the DC-DC voltage converter module;

- determining whether a magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level;

- determining that a magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level, then determining whether each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal;

- determining that each DC-DC voltage converter of the DC-DC voltage converter module has not received the system parallel signal, then transmitting a module parallel signal to all DC-DC voltage converters in the DC-DC voltage converter module; and

- either (a) determining that each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal, (b) determining that the magnitude of each DC voltage measurement is greater than the first DC voltage threshold level, or (c) determining that the system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module, then transmitting the system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system.

8. The non-transitory computer readable medium of claim 7, wherein the second DC voltage threshold level is zero volts.

9. The non-transitory computer readable medium of claim 7, wherein the process further comprises:

upon transmitting the system parallel signal to the all DC-DC voltage converters of the DC-DC voltage converter system, then providing, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter system, a same DC voltage;

upon transmitting the module parallel signal to the all DC-DC voltage converters of the DC-DC voltage converter module, then providing, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter module, the same DC voltage; and

determining that a magnitude of each received DC voltage measurement is not greater than the first DC voltage threshold level, then providing, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter module, an independently derived DC voltage.

10. The non-transitory computer readable medium of claim 9, wherein the process further comprises:

determining whether the DC-DC voltage converter module is a last DC-DC voltage converter module. of the DC-DC voltage converter system, whose DC power outputs are evaluated to determine whether they are electrically connected; and

determining that the DC-DC voltage converter module is not a last DC-DC voltage converter module. of the DC-DC voltage converter system, whose DC power outputs are so evaluated, then selecting a next DC-DC voltage converter module.

11. The non-transitory computer readable medium of claim 9, wherein the same DC voltage is a fixed DC voltage.

12. The non-transitory computer readable medium of claim 7, wherein the first DC voltage threshold level is equal to or less than the constant DC voltage.

13. An apparatus configured to determine whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of

all of one or more of DC-DC voltage converter modules are electrically connected, the apparatus comprising:

processing circuitry configured to:

set each DC-DC voltage converter of a DC-DC voltage converter module to provide a DC voltage level, at a DC power output of a DC-DC voltage converter, at or below a second DC voltage threshold level;

determine whether a system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module;

determine that the system parallel signal has not been received by each DC-DC voltage converter of the DC-DC voltage converter module, then receiving a DC voltage measurement of each DC power output of the DC-DC voltage converter module;

determine whether a magnitude of each DC voltage measurement is greater than a first DC voltage threshold level;

determine that the magnitude of each DC voltage measurement is not greater than the first DC voltage threshold level, then providing a constant DC voltage at a single DC power output of the DC-DC voltage converter module;

receive a DC voltage measurement at each of other DC power output of the DC-DC voltage converter module;

determine whether a magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level;

determine that a magnitude of each received DC voltage measurement is greater than the first DC voltage threshold level, then determining whether each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal;

determine that each DC-DC voltage converter of the DC-DC voltage converter module has not received the system parallel signal, then transmitting a module parallel signal to all DC-DC voltage converters in the DC-DC voltage converter module; and

either (a) determine that each DC-DC voltage converter of the DC-DC voltage converter module has received the system parallel signal, (b) determine that the magnitude of each DC voltage measurement is greater than the first DC voltage threshold level, or (c) determine that the system parallel signal has been received by each DC-DC voltage converter of the DC-DC voltage converter module, then transmitting the system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system; and

at least two DC-DC voltage converters which are communicatively coupled to the processing circuitry.

14. The apparatus of claim 13, wherein the second DC voltage threshold level is zero volts.

15. The apparatus of claim 13, wherein the processing circuitry is further configured to:

upon transmitting the system parallel signal to the all DC-DC voltage converters of the DC-DC voltage converter system, then provide, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter system, a same DC voltage;

upon transmitting the module parallel signal to the all DC-DC voltage converters of the DC-DC voltage converter module, then provide, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter module, the same DC voltage; and

determine that a magnitude of each received DC voltage measurement is not greater than the first DC voltage threshold level, then providing, at a DC power output of each DC-DC voltage converter of the DC-DC voltage converter module, an independently derived DC voltage.

16. The apparatus of claim 15, wherein the processing circuitry is further configured to:

determine whether the DC-DC voltage converter module is a last DC-DC voltage converter module. of the DC-DC voltage converter system, whose DC power outputs are evaluated to determine whether they are electrically connected; and

determine that the DC-DC voltage converter module is not a last DC-DC voltage converter module. of the DC-DC voltage converter system, whose DC power outputs are so evaluated, then selecting a next DC-DC voltage converter module.

17. The apparatus of claim 15, wherein the same DC voltage is a fixed DC voltage.

18. The apparatus of claim 13, wherein the first DC voltage threshold level is equal to or less than the constant DC voltage.

19. A method for determining whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected, the method comprising:

at a first time, providing a constant DC voltage to be provided a single DC power output of a first DC-DC voltage converter module;

receiving DC voltage measurements at other DC power outputs of the DC-DC voltage converter system;

determining whether a magnitude of (a) each of the DC voltage measurements or (b) at least one DC voltage measurement of a DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level;

determining that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level, then providing a system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system;

determining that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of the different DC-DC voltage converter module is not greater than a first DC voltage threshold level, then determining whether each of the DC voltage measurements at the other DC power outputs of a same DC-DC voltage converter module is greater than the first DC voltage threshold level;

determining that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is greater than the first DC voltage threshold level, then providing a module parallel signal to all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage;

(i) determining that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is not greater than the first DC voltage threshold level or (ii) upon providing the module parallel signal to the all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage, then determining whether the constant DC voltage at a single DC power output was provided by a last DC-DC voltage converter module of the DC-DC voltage converter system; and

determining that the constant DC voltage at a single DC power output was not provided by a last DC-DC voltage converter module of the DC-DC voltage converter system, then at a subsequent time, providing the constant DC voltage at a single DC power output of a next DC-DC voltage converter module.

20. The method of claim 19, further comprising:

either (p) upon providing the system parallel signal to the all DC-DC voltage converters or (q) determining that the constant DC voltage at a single DC power output was provided by a last DC-DC voltage converter module of the DC-DC voltage converter system, then determining whether, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has been received or generated;

upon determining that, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has been received or generated, then providing, at an output of each DC-DC voltage converter of the DC-DC voltage converter system, a same DC voltage; and

upon determining that, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has not been received or generated, then:

(x) determining, for each DC-DC voltage converter module, whether a module parallel signal has been received or generated by each DC-DC voltage converter in the DC-DC voltage converter module;

(y) providing, at a DC power output of each DC-DC voltage converter of a DC-DC voltage converter module which has received or obtained the module parallel signal, the same DC voltage; and

(z) providing, at each DC power output of each DC-DC voltage converter which has not received or generated the system or the module parallel signal, a DC voltage which has been derived independently of other DC-DC voltage converters.

21. The method of claim 19, wherein the first DC voltage threshold level is equal to or less than the constant DC voltage.

22. The method of claim 19, wherein the same DC voltage is a fixed DC voltage.

23. A non-transitory computer readable medium storing a program causing at least one processor to execute a process configured to determine whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected, the process comprising:

at a first time, providing a constant DC voltage to be provided a single DC power output of a first DC-DC voltage converter module;

receiving DC voltage measurements at other DC power outputs of the DC-DC voltage converter system;

determining whether a magnitude of (a) each of the DC voltage measurements or (b) at least one DC voltage measurement of a DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level;

determining that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level, then providing a system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system;

determining that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of the different DC-DC voltage converter module is not greater than a first DC voltage threshold level, then determining whether each of the DC voltage measurements at the other DC power outputs of a same DC-DC voltage converter module is greater than the first DC voltage threshold level;

determining that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is greater than the first DC voltage threshold level, then providing a module parallel signal to all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage;

(i) determining that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is not greater than the first DC voltage threshold level or (ii) upon providing the module parallel signal to the all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage, then determining whether a constant DC voltage at a single DC power output was provided by a last DC-DC voltage converter module of the DC-DC voltage converter system; and

determining that the constant DC voltage at a single DC power output was not provided by a last DC-DC voltage converter module of the DC-DC voltage converter system, then at a subsequent time, providing the constant DC voltage at a single DC power output of a next DC-DC voltage converter module.

24. The non-transitory computer readable medium of claim 23, wherein the process further comprises:

either (p) upon providing the system parallel signal to the all DC-DC voltage converters or (q) determining that the constant DC voltage at a single DC power output was provided by a last DC-DC voltage converter module of the DC-DC voltage converter system, then determining whether, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has been received or generated;

upon determining that, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has been received or generated, then providing, at an output of each DC-DC voltage converter of the DC-DC voltage converter system, a same DC voltage; and

upon determining that, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has not been received or generated, then:

(x) determining, for each DC-DC voltage converter module, whether the module parallel signal has been received or generated by each DC-DC voltage converter in the DC-DC voltage converter module;

(y) providing, at a DC power output of each DC-DC voltage converter of a DC-DC voltage converter module which has received or obtained the module parallel signal, the same DC voltage; and

(z) providing, at each DC power output of each DC-DC voltage converter which has not received or generated the system or the module parallel signal, a DC voltage which has been derived independently of other DC-DC voltage converters.

25. The non-transitory computer readable medium of claim 23, wherein the first DC voltage threshold level is equal to or less than the constant DC voltage.

26. The non-transitory computer readable medium of claim 23, wherein the same DC voltage is a fixed DC voltage.

27. An apparatus configured to determine whether all direct current (DC) power outputs of a DC-DC voltage converter system are electrically connected or whether all DC power outputs of all of one or more of DC-DC voltage converter modules are electrically connected, the apparatus comprising:

processing circuitry configured to:

at a first time, provide a constant DC voltage to be provided a single DC power output of a first DC-DC voltage converter module;

receive DC voltage measurements at other DC power outputs of the DC-DC voltage converter system;

determine whether a magnitude of (a) each of the DC voltage measurements or (b) at least one DC voltage measurement of a DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level;

determine that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of a different DC-DC voltage converter module is greater than a first DC voltage threshold level, then providing a system parallel signal to all DC-DC voltage converters of the DC-DC voltage converter system;

determine that the magnitude of (a) each of the DC voltage measurements of the other DC power outputs or (b) the at least one DC voltage measurement of the DC power output of the different DC-DC voltage converter module is not greater than a first DC voltage threshold level, then determining whether each of the DC voltage measurements at the other DC power outputs of a same DC-DC voltage converter module is greater than the first DC voltage threshold level;

determine that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is greater than the first DC voltage threshold level, then providing a module parallel signal to all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage;

(i) determine that each of the DC voltage measurements at the other DC power outputs of the same DC-DC voltage converter module is not greater than the first DC voltage threshold level or (ii) upon providing the module parallel signal to the all DC-DC voltage converters in the same DC-DC voltage converter module providing the constant DC voltage, then determining whether the constant DC voltage at a single DC power output was provided by a last DC-DC voltage converter module of the DC-DC voltage converter system; and

determine that the constant DC voltage at a single DC power output was not provided by a last DC-DC voltage converter module of the DC-DC voltage converter system, then at a subsequent time, providing the constant DC voltage at a single DC power output of a next DC-DC voltage converter module; and

at least two DC-DC voltage converters communicatively coupled to the processing circuitry.

28. The apparatus of claim 27, wherein the processing circuitry is further configured to:

either (p) upon providing the system parallel signal to the all DC-DC voltage converters or (q) determining that the constant DC voltage at a single DC power output was provided by a last DC-DC voltage converter module of the DC-DC voltage converter system, then determine whether, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has been received or generated;

upon determining that, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has been received or generated, then provide, at an output of each DC-DC voltage converter of the DC-DC voltage converter system, a same DC voltage; and

upon determining that, for each DC-DC voltage converter of the DC-DC voltage converter system, the system parallel signal has not been received or generated, then:

(x) determine, for each DC-DC voltage converter module, whether the module parallel signal has been received or generated by each DC-DC voltage converter in the DC-DC voltage converter module;

(y) provide, at a DC power output of each DC-DC voltage converter of a DC-DC voltage converter module which has received or obtained the module parallel signal, the same DC voltage; and

(z) provide, at each DC power output of each DC-DC voltage converter which has not received or generated the system or the module parallel signal, a DC voltage which has been derived independently of other DC-DC voltage converters.

29. The apparatus of claim 27, wherein the first DC voltage threshold level is equal to or less than the constant DC voltage.

30. The apparatus of claim 27, wherein the same DC voltage is a fixed DC voltage.

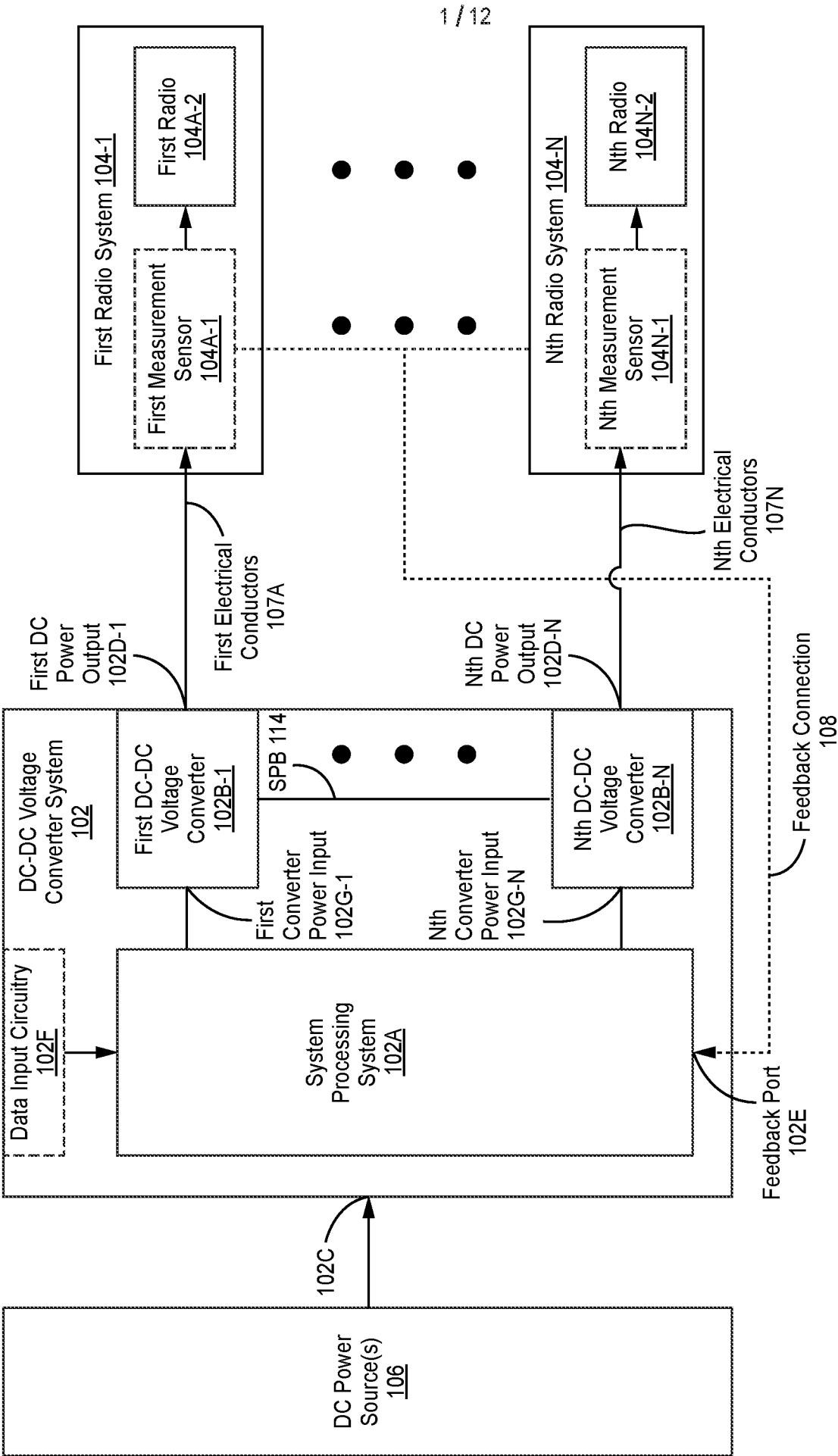
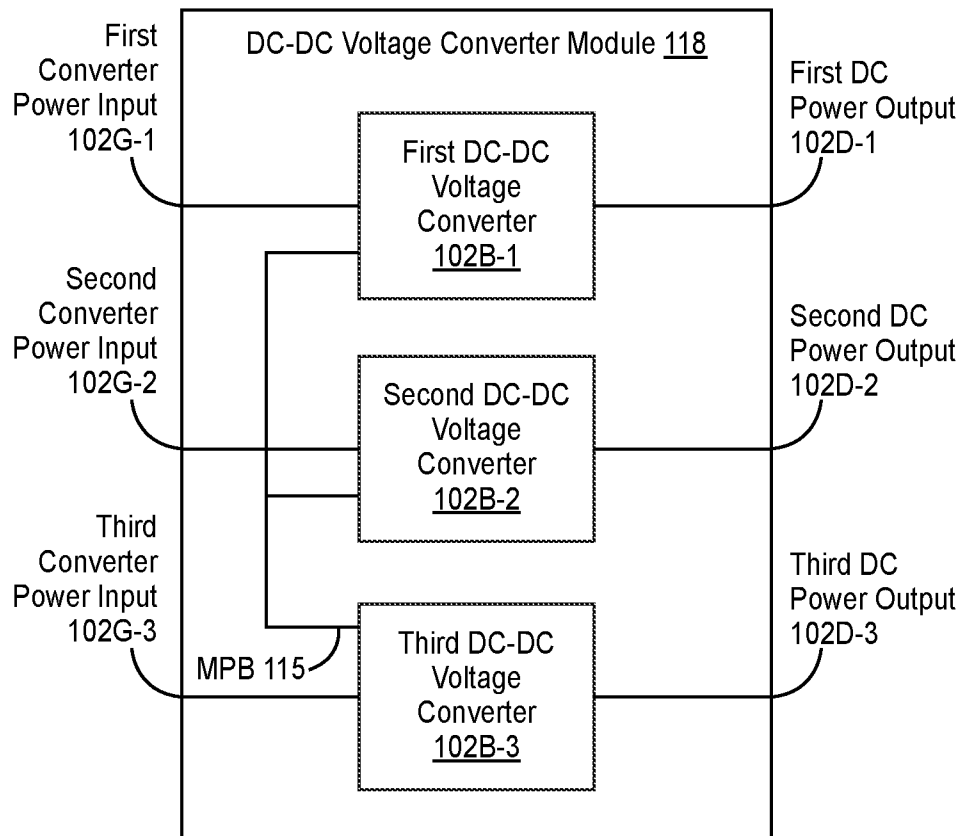


FIG. 1A

**FIG. 1B**

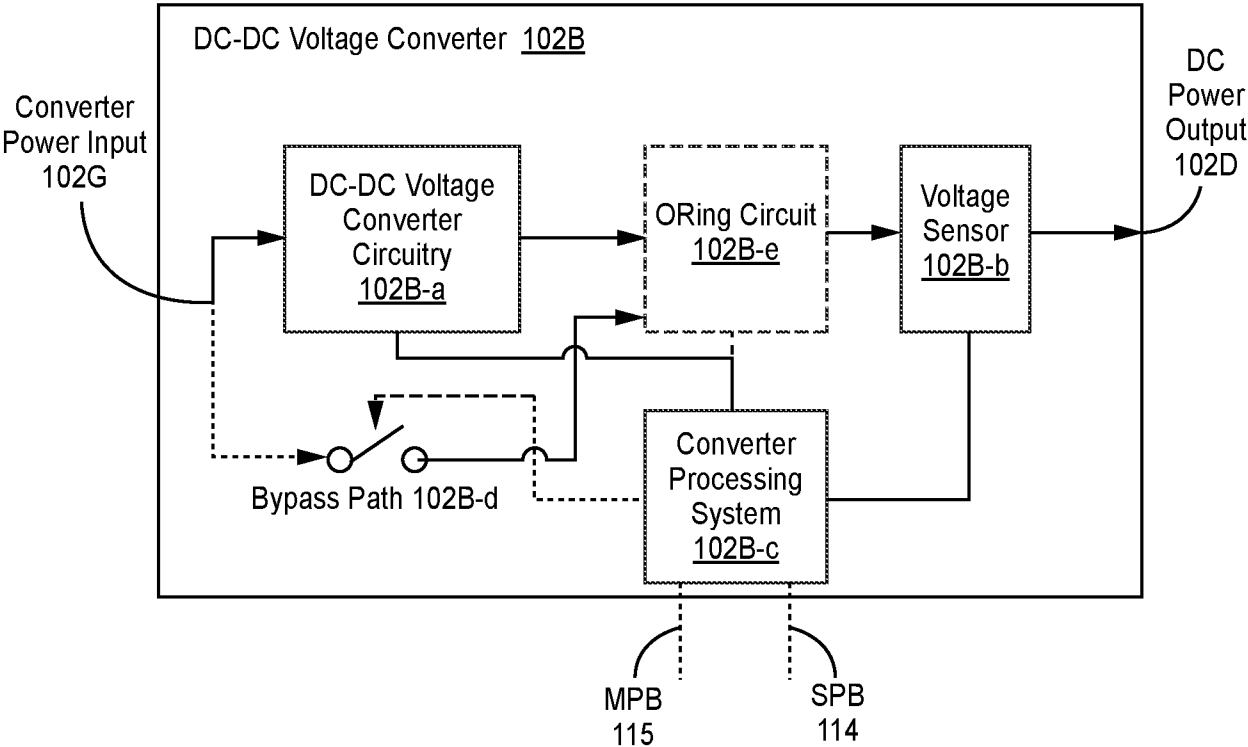


FIG. 1C

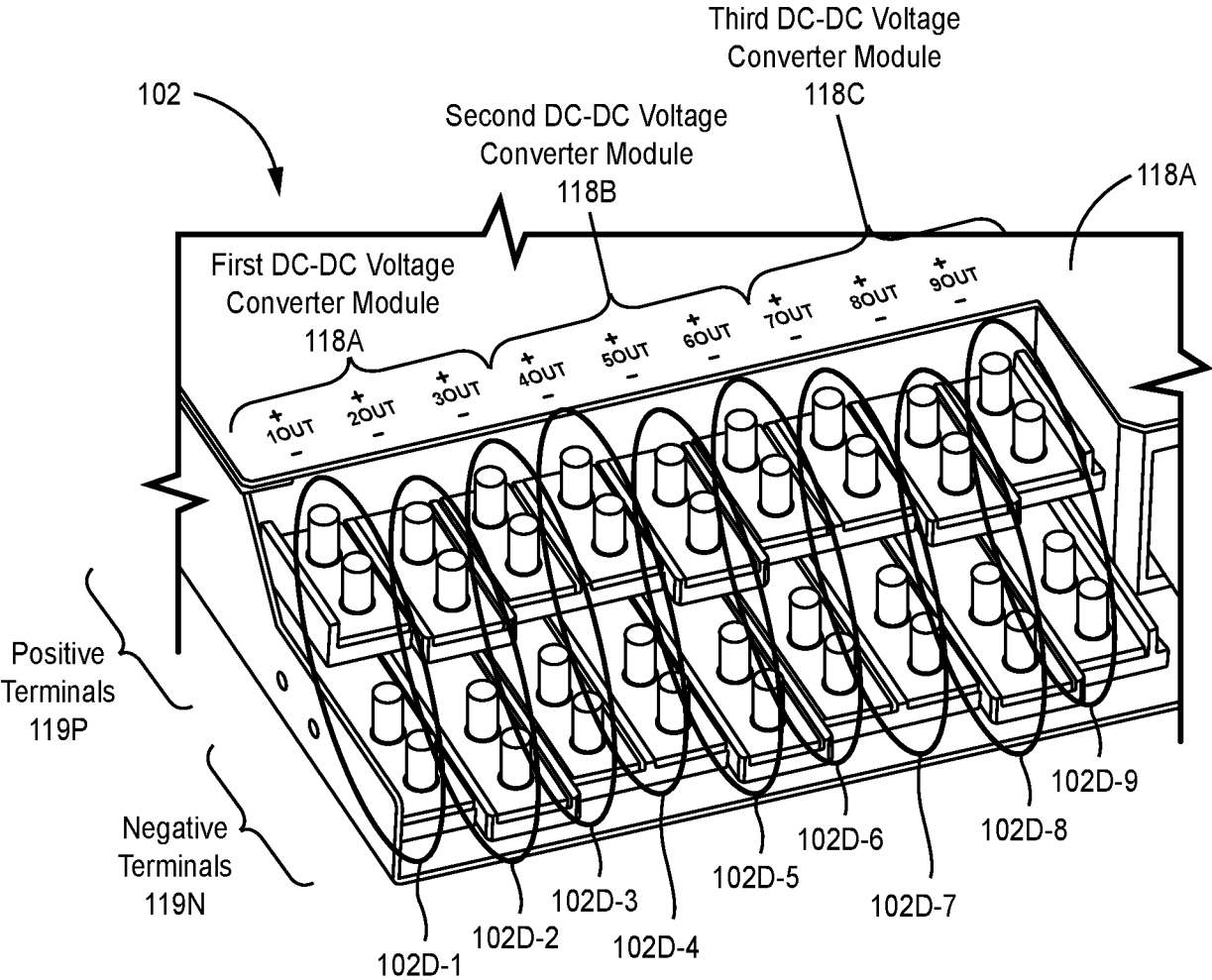


FIG. 1D

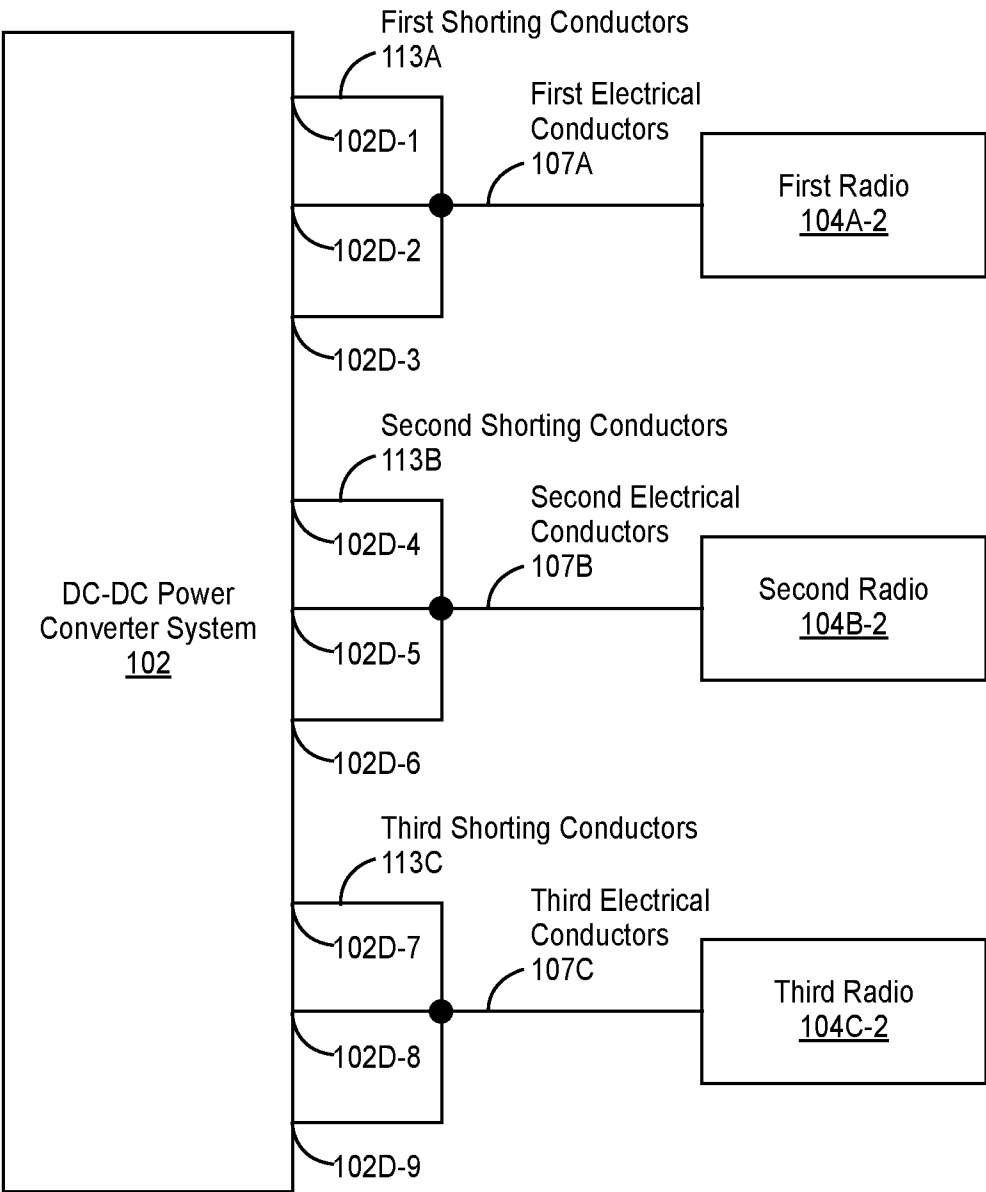


FIG. 1E

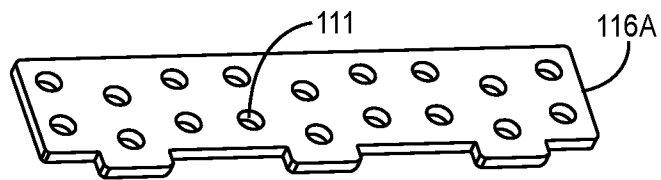


FIG. 1F

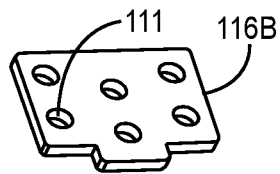


FIG. 1G

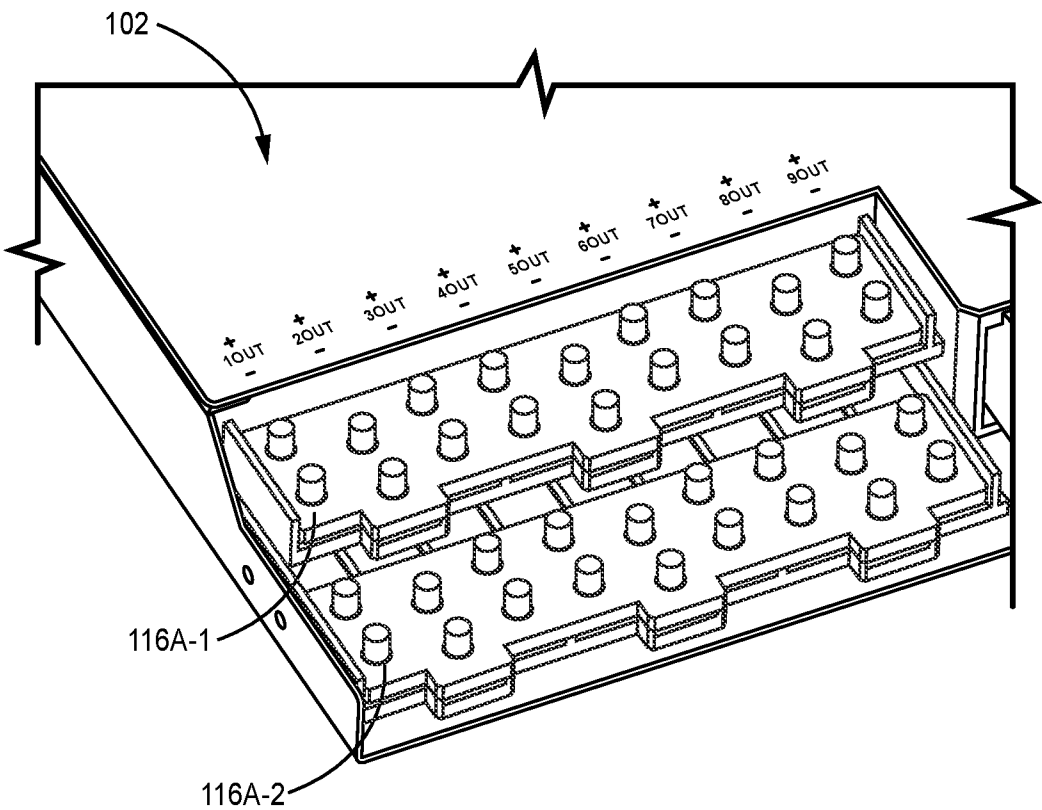


FIG. 1H

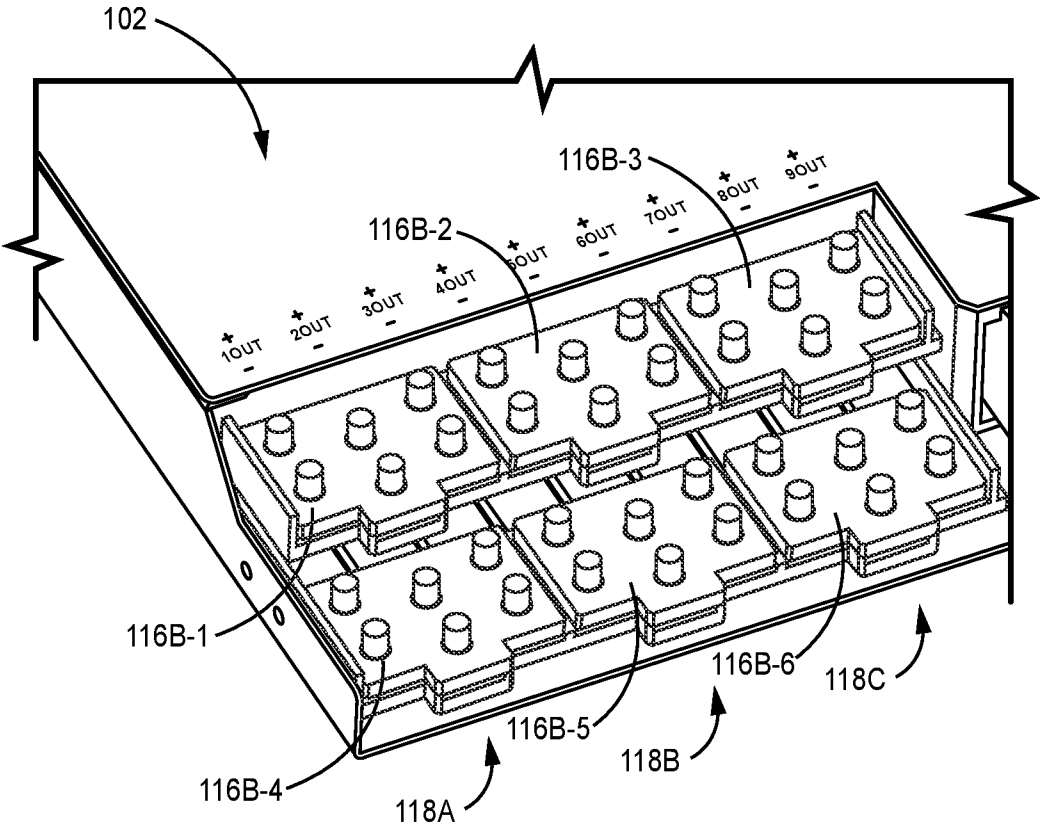
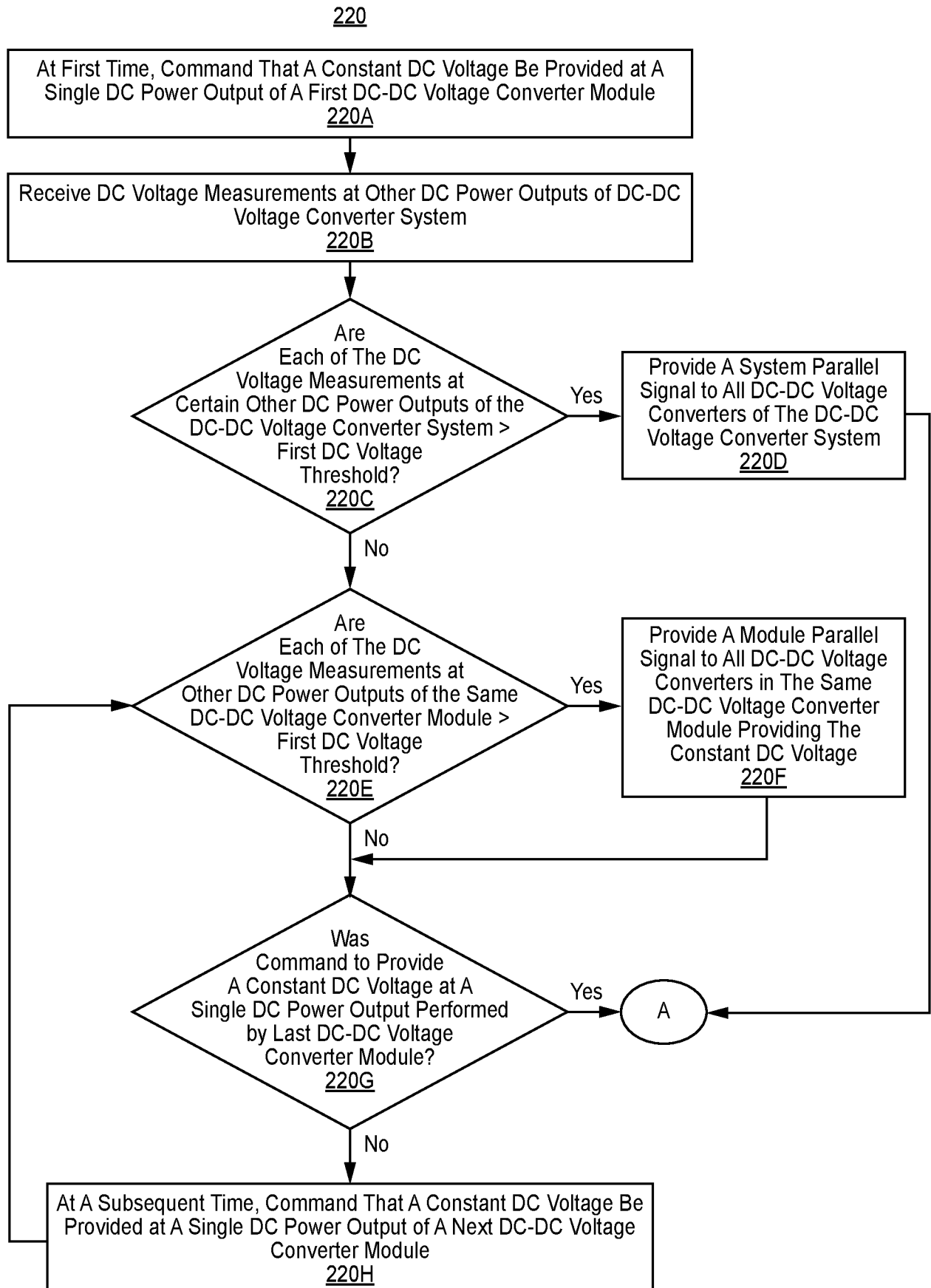
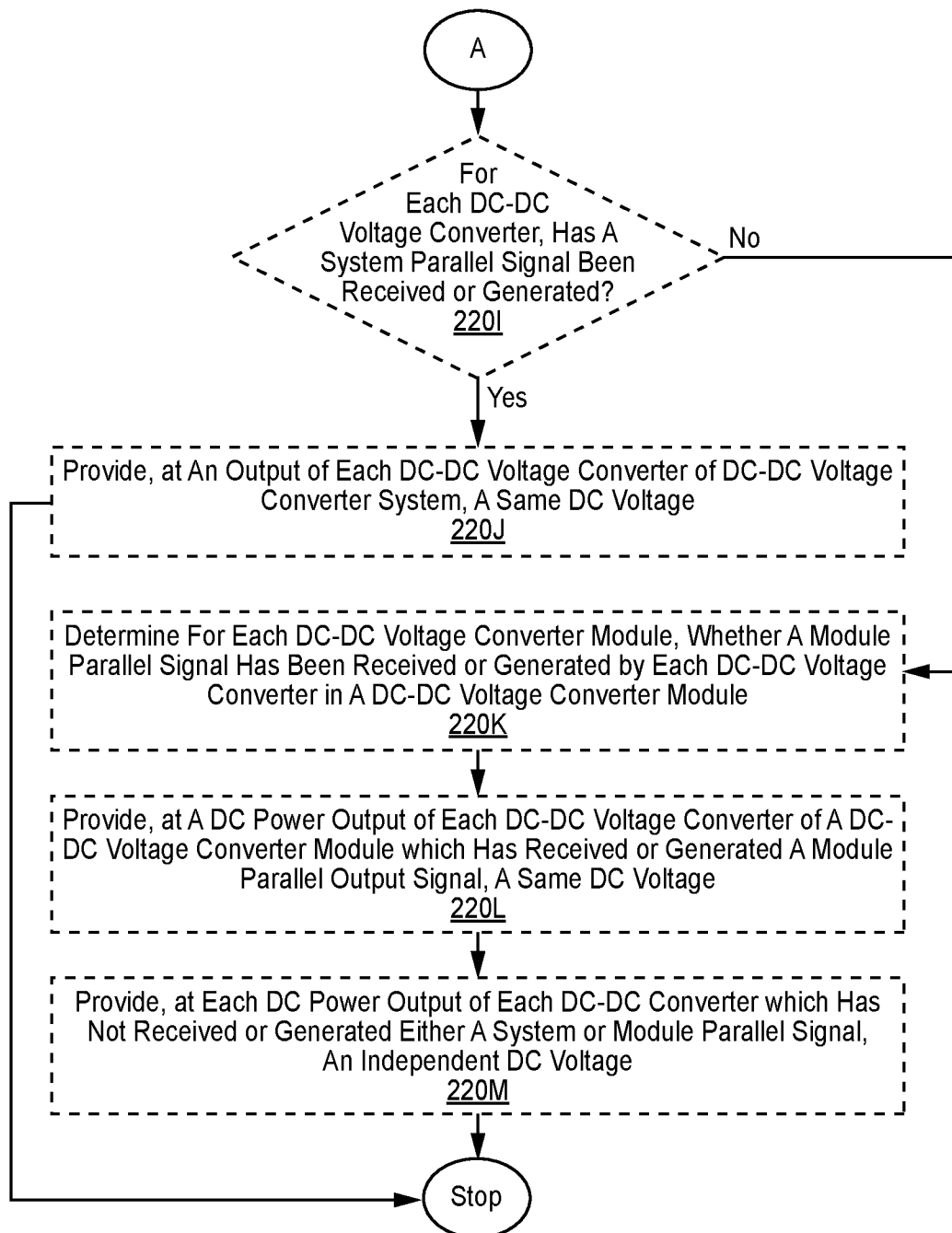


FIG. 11

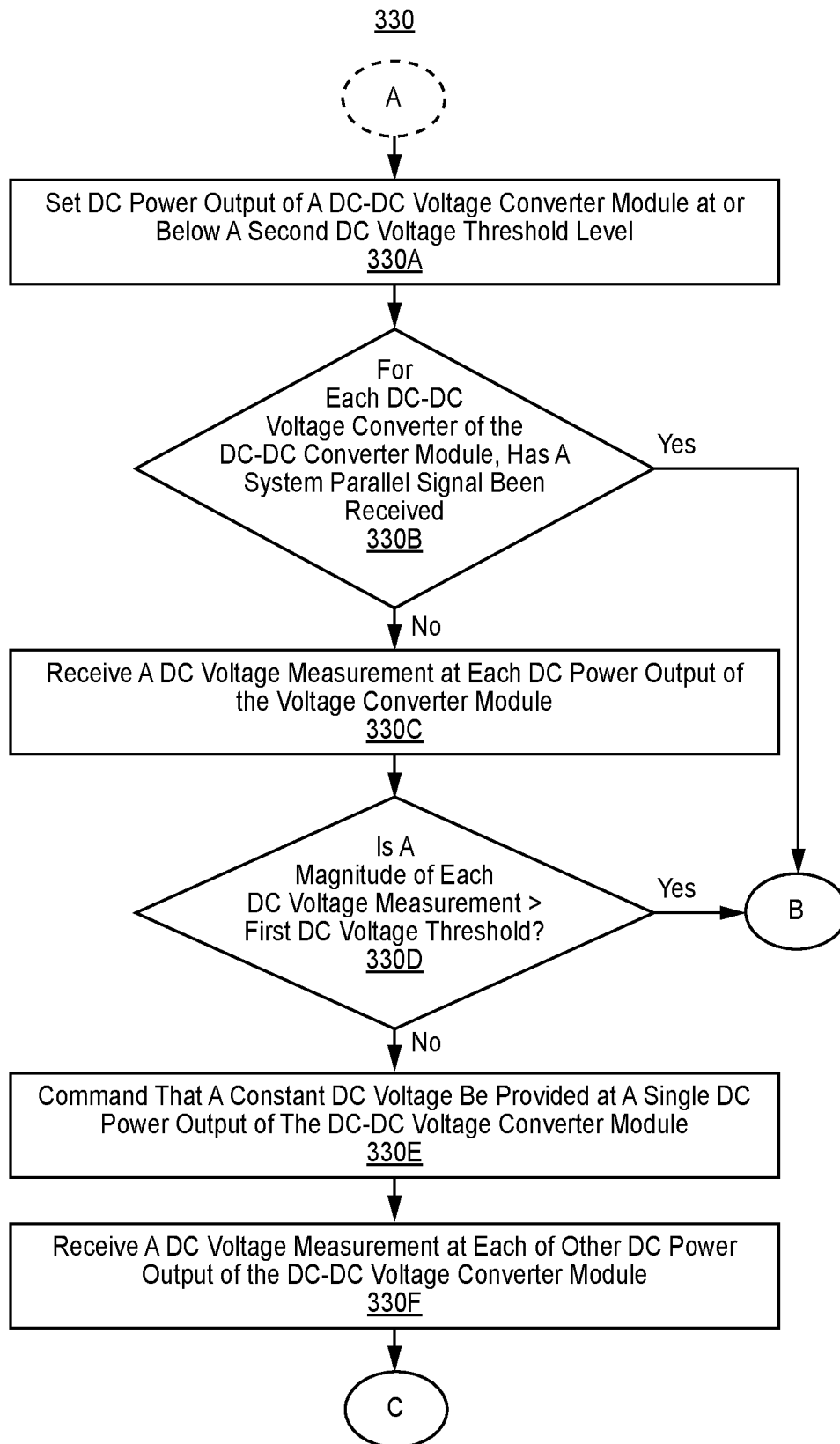
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**FIG. 2**

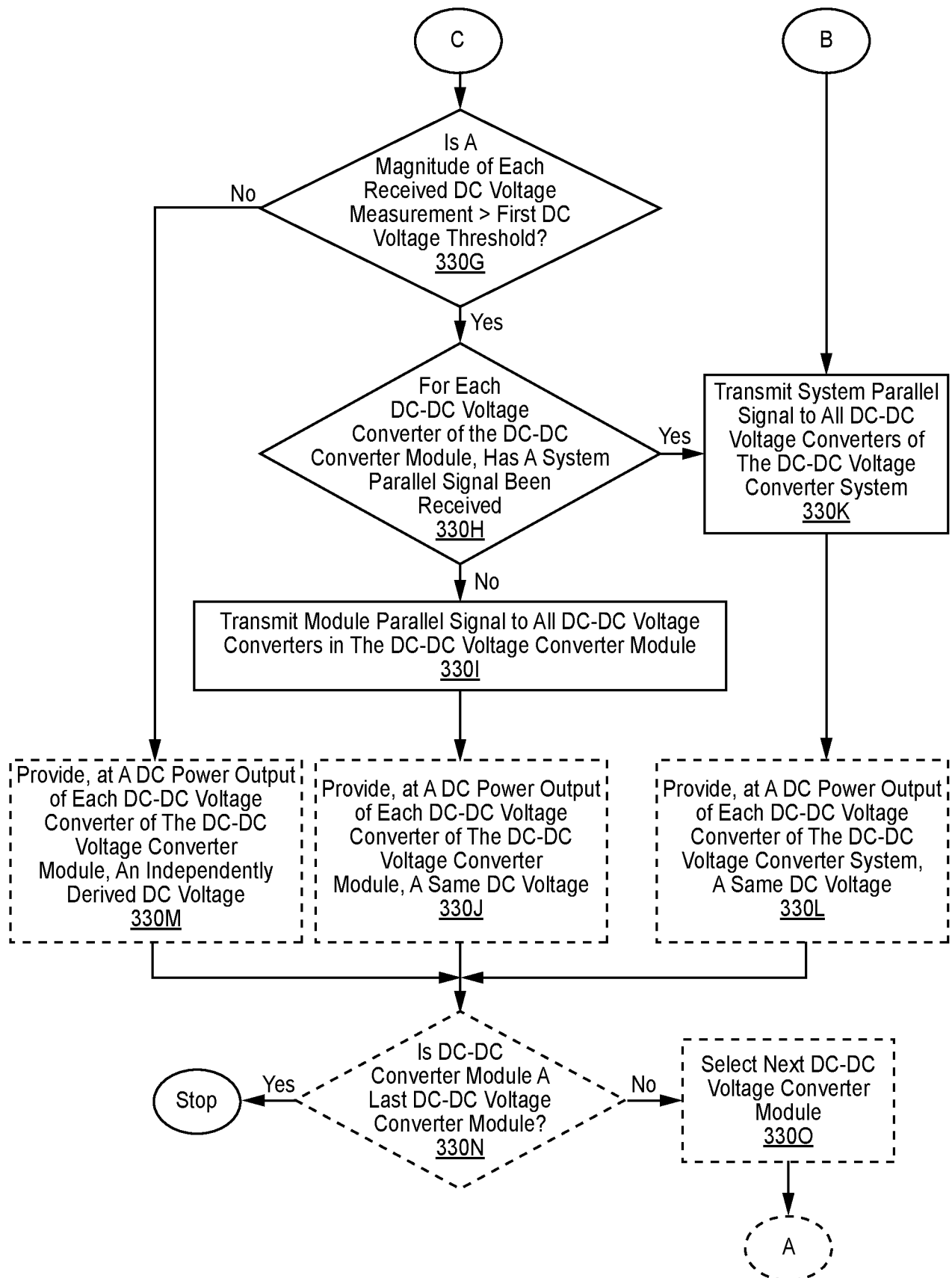
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**FIG. 2 (cont'd)**

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**FIG. 3**

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**FIG. 3 (cont'd)**

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/019964

A. CLASSIFICATION OF SUBJECT MATTER INV. H02M1/00 H02M3/158 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H02M H02J Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/008892 A1 (AUGESKY CHRISTIAN [AT] ET AL) 8 January 2015 (2015-01-08) paragraph [0003] - paragraph [0071] figures 3-5 -----	1 - 30
A	US 2018/120797 A1 (MORITA SATOSHI [JP] ET AL) 3 May 2018 (2018-05-03) the whole document -----	1 - 30
A	WO 2012/116378 A2 (TESUCO SERVICES PTY LTD [ZA]; DA PONTE MANUEL DOS SANTOS [ZA] ET AL.) 30 August 2012 (2012-08-30) the whole document -----	1 - 30
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
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Date of the actual completion of the international search 13 June 2024		Date of mailing of the international search report 22/07/2024
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Lochhead, Steven

INTERNATIONAL SEARCH REPORT

Information on patent family members

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