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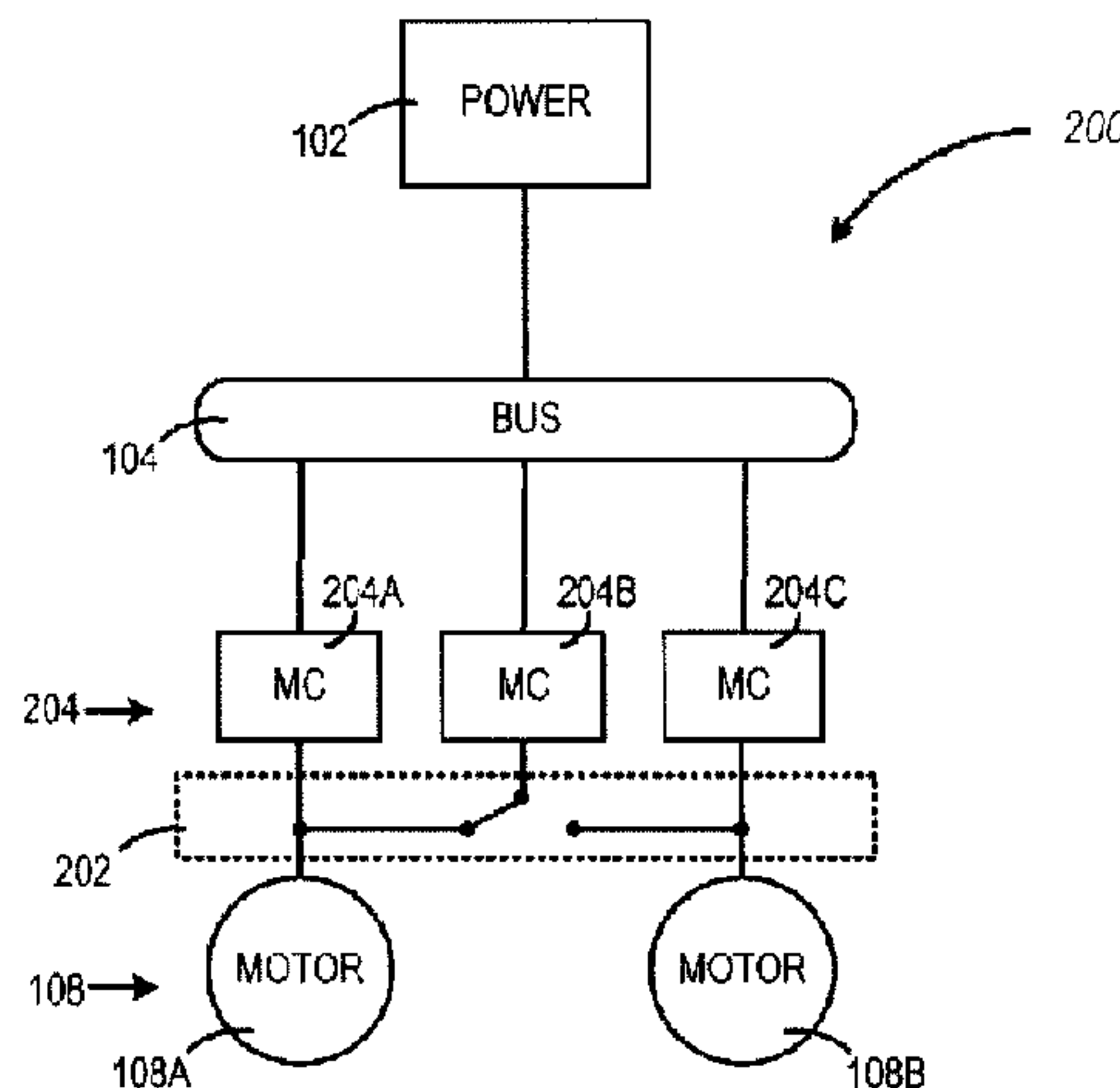
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(57) Abrégé/Abstract:

A method for real time power control over a plurality of motor controllers by at least one processor on a computer system may include determining a power load demand from a first set of motors, selecting a combination of motor controllers to match the power load demand, assigning a first set of system-wide priorities, configuring a power switching network to connect the first set of motors to the motor controllers, receiving from a control unit a power request for a motor, determining a priority designation for that motor, assigning a second set of system-wide priorities, determining a second power load demand from a second set of motors, wherein the second plurality of active motors comprises the first plurality of active motors and the first motor, selecting a second combination of motor controllers necessary to match the second power load demand, and configuring the power switching network in accordance with the second set of system-wide priorities.

ABSTRACT

A method for real time power control over a plurality of motor controllers by at least one processor on a computer system may include determining a power load demand from a first set of motors, selecting a combination of motor controllers to match the power load demand, assigning a first set of system-wide priorities, configuring a power switching network to connect the first set of motors to the motor controllers, receiving from a control unit a power request for a motor, determining a priority designation for that motor, assigning a second set of system-wide priorities, determining a second power load demand from a second set of motors, wherein the second plurality of active motors comprises the first plurality of active motors and the first motor, selecting a second combination of motor controllers necessary to match the second power load demand, and configuring the power switching network in accordance with the second set of system-wide priorities.

SYSTEMS AND METHODS FOR THE CONTROL AND OPERATION OF A PARALLEL MOTOR CONTROLLER ARCHITECTURE

TECHNICAL FIELD

5 **[0001]** Electrical power conversion systems, motor control and distribution systems.

BACKGROUND

10 **[0002]** Motors are used in a large variety of applications. In many applications, a motor is connected to a motor controller that performs a particular function for managing the operations of the motor. For example, motors in aircraft are used to drive control surfaces, environmental systems, and many other systems. These motors typically each receive electrical power from a dedicated motor controller connected in-line between the motor and a power source. The motor controller may include any combination of rectifiers, inverters, and filters that condition the electrical
15 signal received from the power source for use by the motor.

20 **[0003]** In aircraft and other vehicle platforms, there is typically one dedicated motor controller installed within the vehicle for every motor. Each motor controller is sized according to the peak power load demand of the motor that is serviced by the motor controller. For example, a **100** kilowatt (kW) motor would require a **100** kW motor controller, which is a motor controller that is capable of conditioning and providing **100** kW to the motor.

25 **[0004]** Motor controllers can be relatively heavy equipment. Various components of the motor controllers, such as input and output filters, significantly increase the overall weight of each controller. Because the weight of the motor controllers is substantially proportional to the power rating of the controller, the higher the power rating of the motor controller, the heavier the motor controller will be.

[0005] It is with respect to these considerations and others that the disclosure made herein is presented.

SUMMARY

[0006] In accordance with one disclosed aspect there is provided a method for real time power control over a plurality of motor controllers by at least one processor on a computer system. The method involves determining a first power load demand from a first plurality of active motors, the first plurality of active motors being a subset of a plurality of motors. The method involves selecting a first combination of motor controllers of the plurality of motor controllers necessary to provide sufficient power to meet the first power load demand based at least in part on a maximum power output of the plurality of motor controllers, assigning a first set of system-wide priorities based at least in part on the maximum power output and the first power load demand, and configuring a power switching network such that the first plurality of active motors are electrically connected to the first combination of motor controllers in accordance with the first set of system-wide priorities. The method also involves receiving from a first control unit a power request for a first motor, the power request is associated with a first priority level, determining a first priority designation for the first priority level in relation to the first set of system-wide priorities, and assigning a second set of system-wide priorities based at least in part on the first priority designation and the first set of system-wide priorities. The method further involves determining a second power load demand from a second plurality of active motors, the second plurality of active motors including the first plurality of active motors and the first motor, selecting a second combination of motor controllers of the plurality of motor controllers necessary to provide sufficient power to meet the second power load demand, and configuring the power switching network such that the second plurality of active motors are electrically connected to the second combination of motor controllers in accordance with the second set of system-wide priorities.

[0006A] The method may involve receiving a first signal from a second control unit, the first signal being associated with the power request, and adjusting the first priority

designation based on the first signal and thereby adjusting the second set of system-wide priorities.

[0006B] The method may involve determining that the second power load demand is greater than the maximum power output of the plurality of motor controllers, and configuring the power switching network such that a subset of lower priority active motors in the second plurality of motors are electrically disconnected from the second combination of motor controllers.

[0006C] The method may involve determining that the second power load demand is greater than the maximum power output of the plurality of motor controllers, and configuring the power switching network such that the second combination of motor controllers deliver an amount of power to a subset of lower priority active motors that is reduced below an optimal operating amount of power for the subset of lower priority active motors in accordance with the second set of system-wide priorities.

[0006D] The method may involve identifying that the power request is no longer valid, re-assigning the first set of system-wide priorities, and configuring the power switching network such that the amount of power delivered to a subset of lower priority active motors is increased back to the optimal operating amount of power for the subset of lower priority active motors in accordance with the first set of system-wide priorities.

[0006E] The method may involve determining that the maximum power output of the plurality of motor controllers has been reduced to a lower maximum power output, and configuring the power switching network such that a subset of lower priority active motors in the second plurality of motors are electrically disconnected from the second combination of motor controllers.

[0006F] The method may involve determining that the maximum power output of the plurality of motor controllers has been reduced to a lower maximum power output, and configuring the power switching network such that an amount of power delivered to a subset of lower priority active motors is reduced below an optimal operating level for the

subset of lower priority active motors in accordance with the second set of system-wide priorities.

[0006G] The first control unit may be a bus power control unit.

[0006H] The each one of the plurality of motors may be selected from the group consisting of a main engine electric start, a starter, a generator, an electronic engine controller, an auxiliary power unit controller, an auxiliary engine electric start, an auxiliary starter generator, a battery auxiliary engine electric start control unit, an electric taxi motor, a cabin air compressor, a hydraulic pump, a nitrogen generation motor, an environmental control system fan, and a cargo chilling motor.

[0006I] The second control unit may be selected from the group consisting of a generator control unit, an electronic engine controller, an auxiliary power unit controller, an auxiliary generator control unit, a battery voltage boost unit controller, an electric taxi controller, an electric brake controller, an air conditioning pack control unit, a hydraulic pump controller, a nitrogen generation system controller, an environmental control system fan controller, and a cargo chilling system controller.

[0006J] In accordance with another disclosed aspect there is provided a motor control system. The system includes a plurality of motors, a plurality of motor controllers configured for parallel electrical connection, a power switching network electrically connecting the plurality of motors to the plurality of motor controllers, and a parallel modular converter for dynamically controlling the power switching network. The system also includes a computer with at least one processor and a non-transitory storage medium having computer executable instructions stored thereon which, when executed on the computer, cause the computer to determine a first power load demand from a first plurality of active motors, the first plurality of active motors being a subset of the plurality of motors. The computer executable instructions also cause the computer to select a first combination of motor controllers of the plurality of motor controllers necessary to provide sufficient power to meet the first power load demand based at least in part on a maximum power output of the plurality of motor controllers, to assign a first set of system-wide priorities based at least in part on the maximum power output

and the first power load demand, and to configure the power switching network such that the first plurality of active motors are electrically connected to the first combination of motor controllers in accordance with the first set of system-wide priorities. The computer executable instructions further cause the computer to receive from a first control unit a power request for a first motor, the power request being associated with a first priority level, to determine a first priority designation for the first priority level in relation to the first set of system-wide priorities, to assign a second set of system-wide priorities based at least in part on the first priority designation and the first set of system-wide priorities, and to determine a second power load demand from a second plurality of active motors, the second plurality of active motors including the first plurality of active motors and the first motor. The computer executable instructions also cause the computer to select a second combination of motor controllers of the plurality of motor controllers necessary to provide sufficient power to meet the second power load demand, and to configure the power switching network such that the second plurality of active motors are electrically connected to the second combination of motor controllers in accordance with the second set of system-wide priorities.

[0006K] The computer executable instructions stored thereon further cause the computer to receive a first signal from a second control unit, the first signal being associated with the power request, and to adjust the first priority designation based on the first signal and thereby adjusting the second set of system-wide priorities.

[0006L] The computer executable instructions stored thereon further cause the computer to determine that the second power load demand is greater than the maximum power output of the plurality of motor controllers, and to configure the power switching network to cause a subset of lower priority active motors in the second plurality of motors to electrically disconnect from the second combination of motor controllers.

[0006M] The computer executable instructions stored thereon further cause the computer to determine that the second power load demand is greater than the maximum power output of the plurality of motor controllers, and to configure the power

switching network such that the second combination of motor controllers deliver an amount of power to a subset of lower priority active motors that is reduced below an optimal operating amount of power for the subset of lower priority active motors in accordance with the second set of system-wide priorities.

[0006N] The computer executable instructions stored thereon further cause the computer to identify that the power request is no longer valid, to re-assign the first set of system-wide priorities, and to configure the power switching network such that the amount of power delivered to a subset of lower priority active motors is increased back to the optimal operating amount of power for the subset of lower priority active motors in accordance with the first set of system-wide priorities.

[0006O] The computer executable instructions stored thereon further cause the computer to determine that the maximum power output of the plurality of motor controllers has been reduced to a lower maximum power output, and to configure the power switching network to cause a subset of lower priority active motors in the second plurality of motors to electrically disconnect from the second combination of motor controllers.

[0006P] The computer executable instructions stored thereon further cause the computer to determine that the maximum power output of the plurality of motor controllers has been reduced to a lower maximum power output, and to configure the power switching network such that an amount of power delivered to a subset of lower priority active motors is reduced below an optimal operating level for the subset of lower priority active motors in accordance with the second set of system-wide priorities.

[0006Q] The each one of the plurality of motors may be selected from the group consisting of a main engine electric start, a starter, a generator, an electronic engine controller, an auxiliary power unit controller, an auxiliary engine electric start, an auxiliary starter generator, a battery auxiliary engine electric start control unit, an electric taxi motor, a cabin air compressor, a hydraulic pump, a nitrogen generation motor, an environmental control system fan, and a cargo chilling motor.

[0006R] The second control unit may be selected from the group consisting of a generator control unit, an electronic engine controller, an auxiliary power unit controller, an auxiliary generator control unit, a battery voltage boost unit controller, an electric taxi controller, an electric brake controller, an air conditioning pack control
5 unit, a hydraulic pump controller, a nitrogen generation system controller, an environmental control system fan controller, and a cargo chilling system controller.

[0007] The features, functions, and advantages that have been discussed can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments, further details of which can be seen with
10 reference to the following description, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a block diagram showing a conventional motor controller architecture;

15 **[0009]** FIG. 2 is a block diagram showing a parallel motor controller architecture according to various embodiments presented herein;

[0010] FIG. 3 is a power load chart showing an graph of a power load requirement of a cabin air compressor versus a hydraulic motor pump during different phases of aircraft flight according to various embodiments presented herein;

20 **[0011]** FIGS. 4A-4E are block diagrams showing examples of motor controller switching architectures according to various embodiments presented herein;

[0012] FIGS. 5A-5C are block diagrams showing implementations utilizing alternative placements of output filter within a motor controller system according to various embodiments presented herein;

25 **[0013]** FIG. 6 is a flow diagram illustrating a prior art method for controlling a group of motors;

[0014] FIG. 7 is a flow diagram illustrating an embodiment elaborating on the control and operation of the prior art method for controlling a group of motors;

[0015] FIG. 8 is a flow diagram illustrating an embodiment elaborating on the control and operation of the prior art method for controlling a group of motors, specifically
5 directed to a novel main engine electric start operating logic;

[0016] FIG. 9 is a flow diagram illustrating an embodiment elaborating on the control and operation of the prior art method for controlling a group of motors, specifically directed to a novel Auxiliary Power Unit engine electric start operating logic;

[0017] FIG. 10 is a flow diagram illustrating an embodiment elaborating on the
10 control and operation of the prior art method for controlling a group of motors, specifically directed to a novel battery sourced Auxiliary Power Unit engine electric start operating logic;

[0018] FIG. 11 is a flow diagram illustrating an embodiment elaborating on the control and operation of the prior art method for controlling a group of motors,
15 specifically directed to a novel electric taxiing operating logic;

[0019] FIG. 12 is a flow diagram illustrating an embodiment elaborating on the control and operation of the prior art method for controlling a group of motors, specifically directed to a novel cabin air compressor operating logic;

[0020] FIG. 13 is a flow diagram illustrating an embodiment elaborating on the
20 control and operation of the prior art method for controlling a group of motors, specifically directed to a novel hydraulic pump operating logic;

[0021] FIG. 14 is a flow diagram illustrating an embodiment elaborating on the control and operation of the prior art method for controlling a group of motors, specifically directed to a novel nitrogen generation system operating logic;

- [0022] FIG. 15 is a flow diagram illustrating an embodiment elaborating on the control and operation of the prior art method for controlling a group of motors, specifically directed to a novel environmental control system fan operating logic;
- [0023] FIG. 16 is a flow diagram illustrating an embodiment elaborating on the control and operation of the prior art method for controlling a group of motors, specifically directed to a novel cargo refrigeration system operating logic;
- [0024] FIG. 17 is a flow diagram illustrating an embodiment elaborating on the control and operation of the prior art method for controlling a group of motors, specifically directed to a novel load shed and reconfiguration operating logic; and
- [0025] FIG. 18 is a computer architecture diagram showing an illustrative computer hardware and software architecture for a computing system capable of implementing aspects of the embodiments presented herein.

DETAILED DESCRIPTION

- [0026] Motors typically include a motor controller for configuring and providing power to the motor. In a system that includes a group of motors, there are typically an identical number of motors and motor controllers. The motor controllers are most often rated to provide a peak power load that is equivalent to or greater than the peak load of the corresponding motor.
- [0027] Utilizing the concepts and technologies described herein, a system of motors includes a number of motor controllers connected in parallel to a power switching network. By utilizing this architecture as described below, the number of motor controllers and/or the power rating, or power output capability, of each motor controller may be reduced in such a manner as to reduce the overall weight of the motor system. Throughout this disclosure, embodiments are described with respect to motors and motor controllers utilized within an aircraft. An aircraft environment provides a useful example for embodiments described herein since reducing weight

of an aircraft is a universal objective. However, it should be understood that the concepts presented herein are equally applicable to motor systems within any platform, including ships, vehicles, or any other platform in which size and/or weight reduction is a consideration.

5 **[0028]** In the following detailed description, reference is made to the accompanying drawings that form a part hereof, and which are shown by way of illustration, specific embodiments, or examples. Referring now to the drawings, in which like numerals represent like elements through the several figures, a parallel motor controller architecture will be described. FIG. 1 shows a conventional architecture **100** of motor
10 controllers for providing power to motors **108**. According to the conventional architecture **100**, a power source **102** provides power to a bus **104**, which directs power to any number of conventional motor controllers **106**.

[0029] It should be appreciated that for clarity, only two conventional motor controllers **106A** and **106B** and corresponding motors **108A** and **108B** are shown.
15 Each conventional motor controller **106** conditions the received power signal for use by a single connected motor **108**. In the example shown, the conventional motor controller **106A** provides power to the motor **108A**, while the conventional motor controller **106B** provides power to the motor **108B**.

[0030] For illustrative purposes, the conventional architecture **100** may be
20 implemented within an aircraft. According to this implementation, the power source **102** provides an alternating current (AC) or a direct current (DC) signal to the conventional motor controllers **106**. Example conventional motor controllers **106A** and **106B** include, but are not limited to, a cabin air compressor motor controller, a hydraulic electric motor pump motor controller, a generator engine starting motor
25 controller, a nitrogen generation system compressor motor controller, a fan motor controller, and a flight controls actuator motor controller. It should be appreciated that any type of motor controllers **106** and motors **108** may be utilized within any type of vehicle or other platform without departing from the scope of this disclosure.

[0031] Looking now at FIG. 2, a parallel motor controller architecture **200** will be described according to various embodiments. Similar to the example conventional architecture **100** shown in FIG. 1, the parallel motor controller architecture **200** includes the power source **102**, the bus **104**, and the motors **108**. However, in the
5 parallel motor controller architecture **200**, there are multiple parallel motor controllers **204** that are connected in parallel to a power switching network **202**. The power switching network **202** provides power from the parallel motor controllers **204** to the motors **108**. The power switching network **202** includes an electrical circuit that electrically connects the parallel motor controllers **204** to the motors **108** via a series
10 of electrical switches that enable any number of parallel motor controllers **204** to be connected to any given motor **108**. The power switching network **202** may include or be connected to a computing device that controls the electronic switches to couple parallel motor controllers **204** as necessary to provide adequate power to the motors **108** according to the present power load requirements of the motors **108** as they
15 change at any given instant in time. The operations of the power switching network **202** will be described in greater detail below.

[0032] In the example shown in FIG. 2, the three parallel motor controllers **204** each have a power output capability that is lower than that of the conventional motor controllers **106** shown in FIG. 1. For example, the parallel motor controllers **204A**,
20 **204B**, and **204C** may each be capable of providing **50** kW of power such that the combined power output capability of the motor controllers **204** is **150** kW. In contrast, the conventional architecture **100** of FIG. 1 utilizes two conventional motor controllers **106A** and **106B**, each having a power output capability of **100** kW for a combined power output capability of **200** kW. Because the weight of the motor controllers is
25 typically proportional to the power output capability, the parallel motor controller architecture **200** shown in FIG. 2 may weigh less than the conventional architecture **100** shown in FIG. 1, even though three parallel motor controllers **204** are utilized in the parallel motor controller architecture **200** as opposed to two conventional parallel motor controllers **106** utilized in the conventional architecture **100**.

[0033] The concepts and technologies described herein take advantage of the operational characteristics of the motors **108** in vehicle and other implementations in which the peak power loads, or the maximum power requirements, of the motors **108** do not occur simultaneously. In these implementations having complementary power loads on the motors, multiple smaller parallel motor controllers **204** can be utilized instead of the dedicated, larger conventional motor controllers **106** and be dynamically reconfigured as described herein to shift power delivery between motors **108** as the power demands of the motors **108** dictate.

[0034] It should be appreciated that the example shown in FIG. **2** is simplified for clarity. Although only three parallel motor controllers, **204A**, **204B**, and **204C**, are shown as being connected to two motors, **108A** and **108B**, any number of parallel motor controllers **204** may be utilized to provide power to any number of motors **108** according to various embodiments. Similarly, the power switching network **202** is shown as including a single, simple electronic switch for clarity purposes. However, any number and type of switching mechanisms may be utilized within the power switching network **202** to combine the power outputs of the parallel motor controllers **204** for delivery to the motors **108**.

[0035] Turning now to FIG. **3**, an illustrative power load chart **302** will be described. The power load chart **302** shows how the embodiments described herein take advantage of the complimentary power load requirements **304** of two different motors on an aircraft during different phases of flight to utilize parallel motor controllers **204** in providing power to the motors **108**. In this example, the top graph shows the power load requirement **304** of a cabin air compressor during eight flight phases **306**, including ground operations, engine start, taxi, take off, climb, cruise, descent, and landing. The vertical axis represents the present power load requirement **304** of the cabin air compressor.

[0036] The bottom graph shows the power load requirement **304** of a hydraulic electric motor pump during the same eight flight phases **306**. Following the two graphs from left to right through the various flight phases **306**, it can be seen that the

available power, which is the power output capability of all of the parallel motor controllers **204** together for providing power to each of the two motors **108** shown in Figure **2**, remains at **150 kW**. This available power could be provided utilizing the parallel motor controller architecture **200** shown in FIG. **2** in which each of the three
5 parallel motor controllers **204** are rated at **50 kW**. The combined **150 kW** of the three parallel motor controllers **204** is dynamically redistributed between the cabin air compressor and the hydraulic electric motor pump as the current operational demands of the two motors **108** changes during the various flight phases **306**.

[0037] As an example referring to Figures **2** and **3**, it can be seen that during ground
10 operations, **100 kW** of power is provided to the cabin air compressor and **50 kW** of power is provided to the hydraulic electric motor pump. To do so, two parallel motor controllers **204** are connected to the cabin air compressor and one motor controller **204** is connected to the hydraulic electric motor pump. During engine start, the motor controllers **204** may be connected to a generator so that the entire **150 kW** of
15 available power is directed to the generator for engine start.

[0038] During taxi and takeoff the operational demands of the motors **108** leads to a reconfiguration of the power switching network **202** such that the power output to the cabin air compressor is reduced to **50 kW**, while the power output from two of the parallel motor controllers **204** is redirected to the hydraulic electric motor pump.
20 During climb, cruise, and descent, **100 kW** of power is directed to the cabin air compressor and **50 kW** of power is directed to the hydraulic electric motor pump. Finally, during landing when there is a higher demand on the hydraulic electric motor pump due to the lowering of landing gear and certain flight control surfaces, power is shifted to provide **100 kW** of power to the hydraulic electric motor pump and **50 kW** of
25 power to the cabin air compressor.

[0039] It should be understood that the values of the power load requirements **304** of the cabin air compressor and hydraulic electric motor pump are given for illustrative purposes to show the complimentary nature of the power demands of the two motors **108** and the dynamic reconfiguration of the power switching network **202**

to redistribute power as required by the power load requirements of the motors **108**. It should further be appreciated that while only example data for the cabin air compressor and hydraulic electric motor pump are shown, any number and type of motors **108** may be utilized and the available power from all of the parallel motor
5 controllers **204** is dynamically distributed between all of the motors **108**.

[0040] FIG. 4A shows an example power distribution system **400** that will be used throughout FIGS. 4B-4E to illustrate the dynamic reconfiguring of the electrical connections within the power switching network **202** to redirect power from one or more parallel motor controllers **204** to one or more motors **108** as the current
10 operational demands of the motors changes during different phases of flight. Throughout these examples shown in FIGS. 4A-4E, six parallel motor controllers **204A-204F** provide power to four motors **108**, including a generator **108A**, a cabin air compressor **108B**, a pump **108C**, and a fan **108D**.

[0041] FIG. 4B shows an engine start power distribution system **402** that represents
15 the electrical connections within the power switching network **202** during an engine start operation of an aircraft using the generator **108A**. In this scenario, the generator **108A** demands a very large power load. As a result, all of the parallel motor controllers **204A-204E** are electrically connected to the generator **108A**, leaving the motor controller **204F** to provide some power to the fan **108D** for cooling aircraft
20 equipment.

[0042] FIG. 4C shows a takeoff power distribution system **404** that represents the electrical connections within the power switching network **202** during aircraft takeoff. Because the generator **108A** no longer requires power from the parallel motor controllers **204** after engine start, the generator **108A** is shown to be providing power
25 to a bus **450**. The parallel motor controllers **204** that supplied power to the generator **108A** during engine start have been reconfigured to supply power to the cabin air compressor **108B** and the pump **108C**. During takeoff, the power load requirement (**304** in Figure 3) of the pump **108C** is larger than that of the cabin air compressor **108B**. As a result, in this example, two parallel motor controllers **204A** and **204B** are

connected to the cabin air compressor **108B** and three parallel motor controllers **204C-204E** are connected to the pump **108C**.

[0043] FIG. **4D** depicts a cruise power distribution system **406** in which the power switching network **202** is reconfigured during cruise conditions. Because the power load requirements (**304** in Figure **3**) of the cabin air compressor **108B** and the pump **108C** are complimentary (as shown in FIG. **3**), the connection of the parallel motor controller **204C** is switched from the pump **108C** to the cabin air compressor **108B** during cruise to satisfy the higher power load demands of the cabin air compressor **108B**.

[0044] FIG. **4E** shows a hydraulic demand power distribution system **408** in which the power switching network **202** is reconfigured during temporary hydraulic conditions such as raising or lowering the landing gear and reversing the thrust of the engines. As can be seen, four of the six parallel motor controllers **204** are electrically connected to the pump **108C**. As is the case in all of the scenarios presented, as soon as the high power load requirement **304** of the pump **108C** subsides, the power switching network **202** is again reconfigured according to the present power load requirements (**304** in Figure **3**) of all of the motors **108**.

[0045] FIGS. **5A-5C** show alternative configurations **500**, **520**, and **540**, respectively, of a motor controller system to illustrate various placements of an output filter **510** according to various embodiments. Conventional motor controllers utilize filters to aid in conditioning electronic signals for use by a motor **108**. FIG. **5A** shows one embodiment in which parallel motor controllers **204A** and **204B** are connected to the power switching network **202** for providing power to the motor **108**. In this example, the power source **102** provides an AC signal to the parallel motor controllers **204A** and **204B**.

[0046] Each motor controller **204A**, **204B** includes an input filter **502**, output filter **510**, and intermediate filter **506** that is positioned between a rectifier **504** and an inverter **508**. It should be appreciated that the components of the parallel motor

controllers **204** are not limited to those shown in FIGS. **5A-5C** and that the components of any given parallel motor controller **204** may vary from those shown. For example, the power source **102** may provide DC power to the parallel motor controllers **204A**, **204B**, and the parallel motor controllers **204** may include an input
5 filter **502**, an inverter **508**, and an output filter **510**, without requiring a rectifier **504** or any additional filters.

[0047] FIG. **5B** shows an alternative motor controller configuration **520** in which the parallel motor controllers **204A**, **204B** share a single output filter **510**. In this embodiment, the output filter **510** may be connected to the motor **108** so that power
10 received from the power switching network **202** is input into the output filter **510** prior to receipt by the motor **108**. Doing so allows for the removal of the output filters **510** from the parallel motor controllers **204A**, **204B** shown in Figure **5A**. Sharing an output filter **510** rather than including an output filter **510** within every parallel motor controller **204A**, **204B** saves overall system weight since filters can be relatively
15 heavy components.

[0048] To further save weight, the embodiment shown in FIG. **5C** shows an alternative motor controller configuration **540** in which one or more parallel motor controllers **204A**, **204B** do not utilize an output filter. Typically, the output filters such as the type shown at **510** in Figures **5A** and **5B** are used due to the length of the
20 power feeders from the parallel motor controllers **204A**, **204B** in an equipment bay of an aircraft or other vehicle to the motors **108**. The electrical signal from the parallel motor controllers **204A**, **204B** may have a pulse-width modulated or switched (square) waveform that includes significant harmonic content that can be amplified by the impedance of the power feeders by the time that the signals are received by the
25 motors **108**. Output filters **510** within the parallel motor controllers **204A**, **204B** smooth out the waveforms and prevent damage to the motors **108** caused by the amplified harmonics of the unfiltered square waveforms. However, in embodiments in which the parallel motor controllers **204A**, **204B** are located close to the motors **108**, or if radiated emissions from the power feeders are not a consideration, then the

alternative motor controller configuration **540** shown in FIG. **5C** that does not include any output filters may be used to further minimize the weight of the motor controller system.

[0049] It should be appreciated that the logical operations described in FIGs. **6** through **17** are implemented (1) as a sequence of computer implemented acts or program modules running on a computing system and/or (2) as interconnected machine logic circuits or circuit modules within the computing system. The computing system may be a part of or connected to the power switching network **202** shown in Figures **2**, **4A**, **4B** and **5A-5C** and will be described below with respect to FIG. **18**.
The implementation of the logical operations described herein is a matter of choice dependent on the performance and other requirements of the computing system. Accordingly, the logical operations described herein are referred to variously as states operations, structural devices, acts, or modules. These operations, structural devices, acts and modules may be implemented in software, in firmware, in special purpose digital logic, or any combination thereof. It should also be appreciated that more or fewer operations may be performed than shown in the figures and described herein. These operations may also be performed in a different order than those described herein.

[0050] Turning now to FIG. **6**, an illustrative routine **600** from the prior art for controlling a group of motors such as motor **108** shown in Figures **2**, **4A**, **4B** and **5A-5C** will now be described. The routine **600** begins at operation **602**, where the present power load requirements **304** of each motor **108** are determined. This operation and others may be performed by a motor controller reconfiguration application executing on the computer system, either as part of the power switching network **202** shown in Figure **2**, **4A**, **4B** and **5A-5C** or in communication with the power switching network **202**. As described above, the present power load requirement shown at **304** in Figure **3** of a motor **108** represents the operational power demand at that instance in time. As illustrated in FIG. **3**, the present power load requirement **304** of a motor **108** within an aircraft or other vehicle or platform may change according to an operational

phase, such as various flight phases **306**. The present power load requirements **304** of different motors **108** may be complimentary such that an increase in a power requirement for one motor **108** coincides with a corresponding decrease in a power requirement for another motor **108**, which allows for the dynamic reconfiguration of the electrical connections within the power switching network **202** as described herein.

[0051] From operation **602**, the routine **600** continues to operation **604**, where the number of parallel motor controllers **204** to be connected to each motor **108** is determined. As described above, the number of parallel motor controllers **204** to be connected to any given motor **108** may include the least number of parallel motor controllers **204** that are capable of supplying the present power load requirement **304** of the particular motor **108**. For example, if a motor **108** is utilizing **100** kW of power, then two parallel motor controllers **204** capable of each providing **50** kW of power are connected to the motor **108**. At operation **606**, the power switching network **202** is configured to connect the parallel motor controllers **204** to the motors **108** according to the present power load requirements of the motors as determined at operation **604**. It should be appreciated that the power switching network **202** is configured by activation of any number of electronic switches within a circuit connecting the parallel motor controllers **204** to each of the motors **108**.

[0052] From operation **606**, the routine **600** continues to operation **608**, where the motor controller system is monitored for motor action requests. According to one embodiment, a motor action request may be any activation or motion of a switch, lever, control device, or other apparatus used to control a system that utilizes one or more motors **108**. For example, in an aircraft environment, a motor action request may include, but is not limited to, the lowering or raising of landing gear, the activation or motion of a control for moving a flight control surface, and the activation of a pump. It should be appreciated that the motor action request may be the result of an action taken by a person or may be the result of a computer-controlled action. It should also be understood that the monitoring operation may include active

monitoring or polling of any number of systems, or may be passive monitoring such as the receipt of a request.

[0053] At operation **610**, if a motor action request is not received, then the routine **600** returns to operation **608** and the monitoring continues. However, if at operation **610**, it is determined that a motor action request has been made or received, then the routine **600** returns to operation **602**, where the present power load requirements **304** of the motors **108** is reassessed and the routine **600** continues as described above. In this manner, the power switching network **202** may be dynamically reconfigured so as to respond to changes in the power load requirements **304** of the motors **108** by redirecting power from the parallel motor controllers **204** to the applicable motors **108**.

[0054] Turning now to FIG. 7, an illustrative routine **7000** for controlling a group of motors **108** through load shedding and reconfiguration will now be described. The routine **7000** begins at operation **7010**, by determining an Initial Power Load Demand based on a First Power Load Demand for a First Motor and a Second Power Load Demand for a second motor. The next step, at operation **7020**, includes determining the Maximum Power Output from a first motor controller's power capacity, a second motor controller's power capacity, and a third motor controller's capacity. The next step, at operation **7030**, includes determining that the first motor controller's power capacity is sufficient to match the First Power Load Demand and that the second motor controller's power capacity is sufficient to match the Second Power Load Demand. The next step, at operation **7040**, includes assigning a first set of system-wide priorities based at least in part on the Maximum Power Output, the First Power Load Demand, and the Second Power Load Demand. The next step, at operation **7050**, includes configuring a Power Switching Network to couple together the first motor controller to the First Motor and the second motor controller to the Second Motor. The next step, at operation **7070**, includes determining an Updated Power Load Demand based on the Initial Power Load Demand and the Third Power Load Demand. The next step, at operation **7060**, includes receiving a power request from

a control unit for provision of a Third Power Load Demand for a Third Motor. The next step, at operation **7070**, includes determining an Updated Power Load Demand based on the Initial Power Load Demand and the Third Power Load Demand

[0055] Continuing with FIG. 7, following the determination of the Updated Power Load Demand, the next step, at operation **7080**, includes determining that the Updated Power Load Demand is greater than the Maximum Power Output. The next step, at operation **7090**, includes assigning a second set of system-wide priorities that designates the Third Motor with a higher priority level than the Second Motor, and is based at least in part on the Maximum Power Output, the First Power Load Demand, the Second Power Load Demand, and the Third Power Load Demand. The 'OR' split, at step **7100**, represents the two alternative embodiments, wherein starting at step **7111**, the parallel motor controller architecture reconfigures its resources by completely diverting power away from one motor and towards another, whereas starting at step **7121**, the parallel motor controller architecture adapts to requests for power by higher priority motors by only diverting the amount of power needed, while it is needed.

[0056] The reconfiguration embodiment, at step **7111**, includes determining that the third motor controller's power capacity, in combination with the second motor controller's power capacity, are required to match the Third Power Load Demand. The next step, at operation **7112**, includes configuring the Power Switching Network to decouple the second motor controller from the Second Motor, and then couple the second motor controller and the third motor controller to the Third Motor. The next step, at operation **7113**, includes identifying that the power request is no longer valid. The next step, at operation **7114**, includes reassigning the first set of system-wide priorities. The final step of this embodiment, at operation **7115**, includes configuring the Power Switching Network to decouple the second motor controller from the Third Motor, and then recouple the second motor controller to the Second Motor.

[0057] The load shedding embodiment, at step **7121**, includes determining that the third motor controller's power capacity, in combination with a first portion of the

second motor controller's power capacity is sufficient to match the Third Power Load Demand. The next step, at operation **7122**, includes configuring the Power Switching Network to couple the second motor controller to the Third Motor, to direct the second motor controller to deliver the first portion of the second motor controller's power capacity to the Third Motor, and to couple the third motor controller to the Third Motor. The next step, at operation **7123**, includes identifying that the power request is no longer valid. The next step, at operation **7124**, includes reassigning the first set of system-wide priorities. The final step of this embodiment, at operation **7125**, includes configuring the Power Switching Network to decouple the second motor controller from the Third Motor, and then recouple the second motor controller to the Second Motor thereby fully matching the Second Power Load Demand.

[0058] Turning now to FIG. **8**, an illustrative routine **800** specifically directed to a novel main engine electric start operating logic will now be described. The routine **800** begins at operation **810**, where a Bus Power Control Unit determines how much power is available for a Parallel Modular Converter that controls the Power Switching Network (**202**). The Bus Power Control Unit sends a power command to the Parallel Modular Converter and sends a main engine electric start mode request to a Generator Control Unit to cause it to open the Generator Circuit Breaker and apply excitation to the starter/generator as shown at **812**.

[0058a] At operation **820** the Parallel Modular Converter receives a torque command **118** from an Electronic Engine Controller and receives and configures the Power Switching Network **204** for an engine start mode.

[0058b] At operation **830** the Parallel Modular Converter selects an appropriate motor control algorithm based on the information it has available to it.

[0058c] At operation **840** the Parallel Modular Converter applies power to the motor starter/generator, and speed feedback information is shared between the Parallel Modular Converter and the Electronic Engine Controller that monitors motor speed as shown at **841**.

[0058d] At operation **850** if a starter cutoff speed is not achieved, operation **840** begins again. However, if the starter cutoff speed is achieved, then the Parallel Modular Converter will initiate a soft shutdown and exit the starter/generator motoring mode as shown at **860**.

- 5 **[0058e]** At operation **880** the Bus Power Control Unit will release the power budget to other systems, and will communicate to the Electronic Engine Controller and Generator Control Unit to indicate that the mode is no longer the Main Engine Electric Start mode. At operation **881** the Electronic Engine Controller engine is running, while at operation **882** the Generator Control Unit will remove excitation and
10 start a transition to a generate mode.

[0059] Turning now to FIG. **9**, an illustrative routine **900** specifically directed to a novel auxiliary power unit engine electric start operating logic will now be described. The routine **900** begins at operation **910**, where the Bus Power Control Unit determines how much power is available for the Parallel Modular Converter. The Bus
15 Power Control Unit sends a power command to the Parallel Modular Converter and sends an Auxiliary Engine Electric Start (AEES) mode command to an auxiliary generator control unit as shown at **912** to cause the Auxiliary Generator Control Unit to open the Auxiliary Starter Generator Circuit Breaker and apply excitation to the starter/generator.

- 20 **[0059a]** At operation **920** the Parallel Modular Converter configures the Power Switching Network **202** for engine start.

[0059b] At operation **930** the Parallel Modular Converter selects the appropriate motor control algorithm based on the information it has available to it.

- [0059c]** At operation **940** the Parallel Modular Converter applies power to the motor
25 starter/generator and speed feedback information is shared between the Parallel Modular Converter and the Auxiliary Power Unit Controller that monitors motor speed as shown at **941**.

[0059d] At operation **950** if the starter cutoff speed is not achieved then operation **940** begins again. However, if the starter cutoff speed is achieved, then the Parallel Modular Converter will initiate a soft shutdown and exit the starter/generator motoring mode as shown at **960**.

- 5 **[0059e]** At operation **980** the Bus Power Control Unit will release the power budget to other systems, and will communicate to the Auxiliary Power Unit Controller and the Auxiliary Generator Control Unit to indicate that the mode is no longer the Auxiliary Engine Electric Start mode. At operation **981** the auxiliary engine is running, while at operation **982** the Auxiliary Generator Control Unit will remove excitation and start
10 transition to a generate mode.

[0060] Turning now to FIG. **10**, an illustrative routine **1000** specifically directed to a novel battery sourced Auxiliary Power Unit engine electric start operating logic will now be described. The routine **1000** begins at operation **1010**, where the Bus Power Control Unit will determine how much power is available for the Parallel Modular
15 Converter. The Bus Power Control Unit sends a power command to the Parallel Modular Converter and sends a Battery Auxiliary Engine Electric start mode command to a Battery Voltage Boost Unit. An Auxiliary Power Unit Controller sends a torque command to the Parallel Modular Converter at **1011**.

[0060a] At operation **1012** the Battery Voltage Boost Unit initiates power conversion
20 to provide excitation power for an auxiliary starter generator and high voltage for the Parallel Modular Converter.

[0060b] At **1013** the Auxiliary Generator Control Unit opens the Auxiliary Starter Generator Circuit Breaker and applies excitation to the starter/generator.

[0060c] At operation **1020** the Parallel Modular Converter configures the Power
25 Switching Network for battery auxiliary power unit start.

[0060d] At operation **1030** the Parallel Modular Converter selects the appropriate motor control algorithm based on the information it has available to it.

[0060e] At operation **1040** the Parallel Modular Converter applies power to the motor starter/generator and speed feedback information is shared between the Parallel Modular Converter and the Auxiliary Power Unit Controller that monitors motor speed **1041**.

5 [0060f] At operation **1050** if the starter cutoff speed is not achieved, operation **1040** begins again. However, if the starter cutoff speed is achieved, then the Parallel Modular Converter will initiate a soft shutdown and exit the starter/generator motoring mode as shown at **1060**.

10 [0060g] At operation **1080** the Bus Power Control Unit will release the power budget to other systems, and will communicate to the Auxiliary Power Unit Controller and the Auxiliary Generator Control Unit that the Battery Auxiliary Engine Electric Start mode is no longer set.

15 [0060h] At operation **1081** the auxiliary engine is running, while at operation **1083** the Auxiliary Generator Control Unit removes excitation and starts transition to a generate mode, and at operation **1082** the Battery Voltage Boost Unit stops power conversion for the Auxiliary Starter Generator excitation and the Parallel Modular Converter.

20 [0061] Turning now to FIG. **11**, an illustrative routine **1100** specifically directed to a novel electric taxiing operating logic will now be described. The routine **1100** begins at operation **1110**, where the Bus Power Control Unit will determine how much power is available for the Parallel Modular Converter. The Bus Power Control Unit sends a power command to the Parallel Modular Converter and sends an electric taxi mode request to an Electric Taxi Controller as shown at **1111**. The Electric Taxi Controller sends a brake status request to an Electric Brake Controller and receives brake status signals from the Electric Brake Controller, as shown at **1112**. The Electric Taxi Controller sends torque, speed and acceleration commands to the Parallel Modular Converter.

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[0061a] At operation **1120** the Parallel Modular Converter configures the Power Switching Network for Electric Taxi mode in response to the power command from the Bus Power Control Unit and the torque, speed and acceleration/deceleration status from the Electric Taxi Controller Parallel Modular Converter, and the status of
5 the brakes provided by the Electric Taxi Controller.

[0061b] At operation **1130** the Parallel Modular Converter selects the appropriate motor control algorithm based on the information it has available to it.

[0061c] At operation **1140** the Parallel Modular Converter applies power to the Electric Taxi motor and speed, acceleration, and deceleration feedback information is
10 shared between the Parallel Modular Converter and the Electric Taxi Controller that monitors motor speed, acceleration, and deceleration rates as shown at **1141**.

[0061d] At operation **1150** the Parallel Modular Converter monitors the Bus Power Control Unit and the Electric Taxi Controller, and if a stop command has not been received then operation **1140** begins again. However, if a stop command has been
15 received, then the Parallel Modular Converter will initiate a soft shutdown and exit the Electric Taxi motor mode as shown at **1160**.

[0061e] At operation **1180** the Bus Power Control Unit will release the power budget to other systems, and will communicate to the Electric Taxi Controller that the Electric Taxiing mode is ended. At operation **1181** the airplane is not taxiing, and at operation
20 **1182** the Electric Brakes Controller provides the status of the electric brakes.

[0062] Turning now to FIG. **12**, an illustrative routine **1200** specifically directed to a novel cabin air compressor operating logic will now be described. The routine **1200** begins at operation **1201**, where an Air Conditioning Pack Control Unit sends a Cabin Air Compressor mode request to the Bus Power Control Unit. The Air Conditioning
25 Pack Control Unit also sends a speed command to the Parallel Modular Converter. At operation **1210** the Bus Power Control Unit will determine how much power is available for the Parallel Modular Converter.

[0062a] At operation **1220** the Parallel Modular Converter configures the Power Switching Network for Cabin Air Compressor mode.

[0062b] At operation **1230** the Parallel Modular Converter selects the appropriate motor control algorithm based on the information it has available to it.

5 **[0062c]** At operation **1240** the Parallel Modular Converter applies power to the Cabin Air Compressor motor and speed feedback information is shared between the Parallel Modular Converter and the Air Conditioning Pack Control Unit that monitors motor speed **1241**.

[0062d] At operation **1250** the Parallel Modular Converter monitors the Bus Power
10 Control Unit and the Air Conditioning Pack Control Unit Controller, and if a stop command has not been received, operation **1240** begins again. However, if a stop command has been received, then the Parallel Modular Converter will initiate a soft shutdown and exit the Cabin Air Compressor motor mode as shown at **1260**. At operation **1280** the Bus Power Control Unit will release the power budget to other
15 systems, and will communicate to the Air Conditioning Pack Control Unit that the Cabin Air Compressor mode is no longer set. At operation **1281** the Cabin Air Compressor is shut down.

[0063] Turning now to FIG. **13**, an illustrative routine **1300** specifically directed to a novel hydraulic pump operating logic will now be described. The routine **1300** begins
20 at operation **1301**, where a Hydraulic Pump Controller sends a Hydraulic Pump mode request to the Bus Power Control Unit and a speed command to the Parallel Modular Converter.

[0063a] At operation **1310** the Bus Power Control Unit will determine how much power is available for the Parallel Modular Converter. At operation **1320** the Parallel
25 Modular Converter configures the Power Switching Network for the Hydraulic Pump mode and that operation is informed by the Hydraulic Pump Controller's speed command.

[0063b] At operation **1330** the Parallel Modular Converter selects the appropriate motor control algorithm based on the information it has available to it.

[0063c] At operation **1340** the Parallel Modular Converter applies power to the Hydraulic Pump motor and speed feedback information is shared between the
5 Parallel Modular Converter and the Hydraulic Pump Controller that monitors motor speed as shown at **1341**.

[0063d] At operation **1350** the Parallel Modular Converter monitors the Bus Power Control Unit and the Hydraulic Pump Controller, and if a stop command has not been received, operation **1340** begins again. However, if a stop command has been
10 received, then the Parallel Modular Converter will initiate a soft shutdown and exit the Hydraulic Pump motor mode is shown at **1360**.

[0063e] At operation **1380** the Bus Power Control Unit will release the power budget to other systems, and will communicate to the Hydraulic Pump Controller that the Hydraulic Pump mode is no longer in effect.

15 [0063f] At operation **1390** the Hydraulic Pump is shut down.

[0064] Turning now to FIG. **14**, an illustrative routine **1400** specifically directed to a novel nitrogen generation system operating logic will now be described. The routine **1400** begins at operation **1401**, where a Nitrogen Generation System Controller sends a Nitrogen Generation System mode request to the Bus Power Control Unit
20 and sends a speed command to the Parallel Modular Converter.

[0064a] At operation **1410** the Bus Power Control Unit will determine how much power is available for the Parallel Modular Converter.

[0064b] At operation **1420** the Parallel Modular Converter configures the Power Switching Network for the Nitrogen Generation System mode and that operation is
25 informed by the Nitrogen Generation System Controller's speed command.

[0064c] At operation **1430** the Parallel Modular Converter selects the appropriate motor control algorithm based on the information it has available to it.

[0064d] At operation **1440** the Parallel Modular Converter applies power to the Nitrogen Generation System motor and speed feedback information is shared
5 between the Parallel Modular Converter and the Nitrogen Generation System Controller that monitors motor speed **1441**.

[0064e] At operation **1450** the Parallel Modular Converter monitors the Bus Power Control Unit and the Nitrogen Generation System Controller, and if a stop command has not been received, operation **1440** begins again. However, if a stop command
10 has been received, then the Parallel Modular Converter will initiate a soft shutdown and exit the Nitrogen Generation System motor mode **1460**.

[0064f] At operation **1480** the Bus Power Control Unit will release the power budget to other systems, and will communicate to the Nitrogen Generation System Controller that the Nitrogen Generation System mode is no longer in effect. At operation **1481**
15 the Nitrogen Generation System compressor is shut down.

[0065] Turning now to FIG. **15**, an illustrative routine **1500** specifically directed to a novel environmental control system fan operating logic will now be described. The routine **1500** begins at operation **1501**, where an Environmental Control System Fan Controller sends an Environmental Control System Fan mode request to the Bus
20 Power Control Unit and sends a speed command to the Parallel Modular Converter.

[0065a] At operation **1510** the Bus Power Control Unit will determine how much power is available for the Parallel Modular Converter.

[0065b] At operation **1520** the Parallel Modular Converter configures the Power Switching Network for the Environmental Control System Fan mode and that
25 operation is informed by the Environmental Control System Fan Controller's speed command.

[0065c] At operation **1530** the Parallel Modular Converter selects the appropriate motor control algorithm based on the information it has available to it.

[0065d] At operation **1540** the Parallel Modular Converter applies power to the Environmental Control System Fan motor and speed feedback information is shared
5 between the Parallel Modular Converter and the Environmental Control System Fan Controller that monitors motor speed as shown at **1541**.

[0065e] At operation **1550** the Parallel Modular Converter monitors the Bus Power Control Unit and the Environmental Control System Fan Controller, and if a stop command has not been received, operation **1540** begins again. However, if a stop
10 command has been received, then the Parallel Modular Converter will initiate a soft shutdown and exit the Environmental Control System Fan motor mode as shown at **1560**.

[0065f] At operation **1580** the Bus Power Control Unit will release the power budget to other systems, and will communicate to the Environmental Control System Fan
15 Controller that the Environmental Control System Fan is no longer in effect. At operation **1581** the Environmental Control System Fan is shut down.

[0066] Turning now to FIG. **16**, an illustrative routine **1600** specifically directed to a novel cargo refrigeration system operating logic will now be described. The routine **1600** begins at operation **1601**, where a Cargo Chilling System Controller sends a
20 Cargo Chilling System mode request to the Bus Power Control Unit and sends a speed command to the Parallel Modular Converter. At operation **1610** the Bus Power Control Unit will determine how much power is available for the Parallel Modular Converter. At operation **1620** the Parallel Modular Converter configures the Power Switching Network for the Cargo Chilling System mode and that operation is
25 informed by the Cargo Chilling System Controller's speed command.

[0066a] At operation **1630** the Parallel Modular Converter selects the appropriate motor control algorithm based on the information it has available to it.

[0066b] At operation **1640** the Parallel Modular Converter applies power to the Cargo Chilling System motor and speed feedback information is shared between the Parallel Modular Converter and the Cargo Chilling System Controller that monitors motor speed as shown at **1641**.

5 **[0066c]** At operation **1650** the Parallel Modular Converter monitors the Bus Power Control Unit and the Cargo Chilling System Controller, and if a stop command has not been received, operation **1640** begins again. However, if a stop command has been received, then the Parallel Modular Converter will initiate a soft shutdown and exit the Cargo Chilling System motor mode **1660**.

10 **[0066d]** At operation **1680** the Bus Power Control Unit will release the power budget to other systems, and will communicate to the Cargo Chilling System Controller that the Cargo Chilling System mode is no longer in effect.

[0066e] At operation **1681** the Cargo Chilling System compressor is shut down.

15 **[0067]** Turning now to FIG. **17**, an illustrative routine **1700** specifically directed to a novel load shed and reconfiguration operating logic will now be described. The routine **1700** begins at operation **1710**, wherein the Parallel Modular Converter receives a signal from the Bus Power Control Unit **1711**, communicating a particular mode request and the power associated with that mode to the Parallel Modular Converter. The Parallel Modular Converter then establishes its configuration
20 including the total number of motor controllers (or modules), the power of each, and if any have failed.

[0067a] At operation **1720**, a determination is made as to what modes are currently running and what power is being consumed as a result of those running modes.

25 **[0067b]** At operation **1730**, a determination is made as to the current power capacity that is still available for use in other modes.

[0067c] At step **1740**, if the current power capacity is not less than the power needed for the mode requested by the Bus Power Control Unit, then the Parallel Modular Converter runs the motors in the requested mode at the power associated with the requested mode. The Parallel Modular Converter system then determines its
5 remaining power capacity to account for the running of this new mode, as shown at **1741**, and the Bus Power Control Unit is informed about this at step **1742**.

[0067d] If the current power capacity is less than the power needed for the requested mode, then a determination of priority of the requested mode is made relative to other running modes as shown at **1750**. If the priority of the requested
10 mode is less than or equal to all other currently running modes, then the Parallel Modular Converter runs the motors in the requested mode at only the currently available capacity, the Parallel Modular Converter sets the remaining power capacity to zero as shown at **1760** and at **1761** the Bus Power Control Unit is informed that the requested mode is operational at reduced power and that the Parallel Modular
15 Converter available power capacity is zero.

[0068] At step **1770**, if the priority of the requested mode is greater than at least one other currently running mode, and if it is possible to reduce the power delivered to that at least one other currently running mode **1771**, then the total power for any such modes with lower priority will be reduced so as to provide the balance of power
20 needed to match the power requested for the requested mode, and the Parallel Modular Converter will run the motors associated with the requested mode and set the remaining power capacity to zero as shown at **1772** while informing the Bus Power Control Unit as shown at **1773** that a lower priority mode is running at a power lower than requested and that the total remaining Parallel Modular Converter power
25 capacity is zero.

[0068a] At step **1776**, if an incremental reduction in the power delivery for the lower priority modes is not possible, then a determination of the maximum possible reduction is calculated assuming the motors associated with all lower priority modes

are shut down. At **1777** the motors associated with the requested mode are provided with the power formerly directed to the lower priority modes.

[0069] At step **1780**, if the priority of the requested mode is greater than at least two other currently running modes, one of which has a greater priority than at least one
5 other currently running mode, and if it is possible to reduce the power delivered to that at least one other lower priority modes **1781**, then the total power for any such lowest priority modes will be reduced as shown at **1782** so as to provide the balance of power needed to match the power requested for the motors associated with the requested mode, and the Parallel Modular Converter will run the motors associated
10 with the requested mode and as shown at **1783** will inform the Bus Power Control Unit which lower priority modes are run at lower power and that the remaining Parallel Modular Converter power capacity is zero. At **1781**, if it is not possible to incrementally reduce the power for the lowest priority modes, then at **1786**, a determination of the maximum possible reduction is calculated as a result of
15 completely shutting down all lowest priority modes and partially shutting down all modes with a priority lower than the requested mode but greater than the lowest priority modes, the motors associated with the requested mode are provided with the power formerly directed to those lower priority modes, and the Bus Power Control Unit is informed accordingly as shown at **1788**. At step **1787**, if the reduction in the
20 power delivery described at step **1786** is not possible, then at **1790**, a determination of the maximum possible power reduction is calculated assuming the motors associated with all lower priority modes are shut down, the motors associated with the requested mode are provided with the power formerly directed to the motors associated with those lower priority modes and the Bus Power Control Unit is
25 informed accordingly as shown at **1788**. This process may be repeated until it is executed for all lower priority modes and/or the motors associated with the requested mode receive all of the power associated with the requested mode or the request to operate in the requested mode is no longer valid. One way in which incremental reductions may not be possible is that the requested mode is not operable with only
30 the added amount of power provided by the incremental reductions.

[0070] FIG. 18 shows an illustrative computer architecture for a computer 1800, housed within an aircraft 1801, capable of executing the software components described herein for providing power and to a group of motors such as shown at 108 in Figure 2 in the manner presented above. The computer architecture shown in FIG. 5 18 illustrates a conventional desktop, laptop, or server computer and may be utilized to execute any aspects of the methods presented herein. As described above, the computer 1800 may be a part of the power switching network shown at 202 in Figure 2 or may be communicatively linked to the power switching network 202. While the embodiment may be housed within an aircraft, alternative embodiments within the 10 scope of the present disclosure may be implemented on systems contained within a jet aircraft, a propeller aircraft, a helicopter, a hovercraft, a land vehicle, a sea vehicle, or any other system independently controlling a series of motor controllers and motors.

[0071] The computer architecture shown in FIG. 18 includes a central processing 15 unit 1802 (CPU), a system memory 1808, including a random access memory 1814 (RAM) and a read-only memory (ROM) 1816, and a system bus 1804 that couples the memory to the CPU 1802. A basic input/output system containing the basic routines that help to transfer information between elements within the computer 1800, such as during startup, is stored in the ROM 1816. The computer 1800 further 20 includes a mass storage device 1810 for storing an operating system 1818, application programs, and other program modules, which are described in greater detail herein.

[0072] The mass storage device 1810 is connected to the CPU 1802 through a mass storage controller (not shown) connected to the bus 1804. The mass storage 25 device 1810 and its associated computer-readable media provide non-volatile storage for the computer 1800. Although the description of computer-readable media contained herein refers to a mass storage device, such as a hard disk or CD-ROM drive, it should be appreciated by those skilled in the art that computer-readable

media can be any available computer storage media that can be accessed by the computer **1800**.

[0073] By way of example, and not limitation, computer-storage media may include volatile and non-volatile, removable and non-removable media implemented in any method or technology for storage of information such as computer-readable instructions, data structures, program modules or other data. For example, computer-storage media includes, but is not limited to, RAM, ROM, EPROM, EEPROM, flash memory or other solid state memory technology, CD-ROM, digital versatile disks (DVD), HD-DVD, BLU-RAY, or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by the computer **1800**.

[0074] According to various embodiments, the computer **1800** may operate in a networked environment using logical connections to remote computers through a network such as the network **1822**. The computer **1800** may connect to the network **1822** through a network interface unit **1806** connected to the bus **1804**. It should be appreciated that the network interface unit **1806** may also be utilized to connect to other types of networks and remote computer systems. The computer **1800** may also include an input/output controller **1812** for receiving and processing input from a number of other devices, including a keyboard, mouse, or electronic stylus (not shown in FIG. **18**). Similarly, an input/output controller may provide output to a display screen, a printer, or other type of output device (also not shown in FIG. **18**).

[0075] As mentioned briefly above, a number of program modules and data files may be stored in the mass storage device **1810** and RAM **1814** of the computer **1800**, including an operating system **1818** suitable for controlling the operation of a networked desktop, laptop, or server computer. The mass storage device **1810** and RAM **1814** may also store one or more program modules. In particular, the mass storage device **1810** and the RAM **1814** may store the motor controller reconfiguration application **1820** that is operative to perform the operations described

above. The mass storage device **1810** and the RAM **1814** may also store other types of program modules.

[0076] Based on the foregoing referring to Figures **2** and **3**, it should be appreciated that technologies for reconfiguring a power switching network **202** to redirect power
5 from any number of parallel motor controllers **204** to one or more motors **108** as the present power load requirements **304** of the motors **108** change are provided herein. Utilizing the embodiments described herein, the number of parallel motor controllers **204** that service a group of motors **108** within an aircraft, vehicle, or other platform may increase or remain the same as with conventional systems. However, because
10 the dynamic reconfiguration of the electrical connections within the power switching network **202** connecting the parallel motor controllers **204** to the motors **108** as described herein allows for power output capability of the parallel motor controllers **204** to be reduced, the overall weight of a motor controller system may be reduced.

[0077] From the foregoing, it will be appreciated that specific embodiments have
15 been described herein for purposes of illustration on an aircraft, but that various modifications may be made without deviating from the principles described herein. For example, the motor controllers may have more or fewer than the number of fixed modes described in certain embodiments above. The modes may correspond to different flight regimes than those discussed above. Certain embodiments were
20 described in the context of particular systems (e.g., hydraulic pump motors, ECS systems, and nitrogen generation systems), but may be applied to other systems and/or combinations of systems in other embodiments. Aspects of the concepts described herein in the context of particular embodiments may be combined or eliminated in other embodiments. For example, aspects of the backup motor
25 controller functions may be provided in combination with motor controllers operating with a fixed number of predetermined modes. Further, while advantages associated with certain embodiments have been described in the context of those embodiments, other embodiments may also exhibit such advantages, and not all embodiments need necessarily exhibit all such advantages.

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

1. A method for real time power control over a plurality of motor controllers by at least one processor on a computer system, the method comprising:

determining a first power load demand from a first plurality of active motors, wherein the first plurality of active motors is a subset of a plurality of motors;

selecting a first combination of motor controllers of the plurality of motor controllers necessary to provide sufficient power to meet the first power load demand based at least in part on a maximum power output of the plurality of motor controllers;

assigning a first set of system-wide priorities based at least in part on the maximum power output and the first power load demand;

configuring a power switching network such that the first plurality of active motors are electrically connected to the first combination of motor controllers in accordance with the first set of system-wide priorities;

receiving from a first control unit a power request for a first motor, wherein the power request is associated with a first priority level;

determining a first priority designation for the first priority level in relation to the first set of system-wide priorities;

assigning a second set of system-wide priorities based at least in part on the first priority designation and the first set of system-wide priorities;

5

determining a second power load demand from a second plurality of active motors, wherein the second plurality of active motors comprises the first plurality of active motors and the first motor;

10

selecting a second combination of motor controllers of the plurality of motor controllers necessary to provide sufficient power to meet the second power load demand; and

15

configuring the power switching network such that the second plurality of active motors are electrically connected to the second combination of motor controllers in accordance with the second set of system-wide priorities.

2. The method of claim 1, further comprising:

20

receiving a first signal from a second control unit, wherein the first signal is associated with the power request; and

25

adjusting the first priority designation based on the first signal and thereby adjusting the second set of system-wide priorities.

3. The method of claim 2, further comprising:

determining that the second power load demand is greater than the maximum power output of the plurality of motor controllers; and

5

configuring the power switching network such that a subset of lower priority active motors in the second plurality of motors are electrically disconnected from the second combination of motor controllers.

10 4. The method of claim 2, further comprising:

determining that the second power load demand is greater than the maximum power output of the plurality of motor controllers; and

15

configuring the power switching network such that the second combination of motor controllers deliver an amount of power to a subset of lower priority active motors that is reduced below an optimal operating amount of power for the subset of lower priority active motors in accordance with the second set of system-wide priorities.

20

5. The method of claim 4, further comprising:

identifying that the power request is no longer valid;

25

re-assigning the first set of system-wide priorities; and

configuring the power switching network such that the amount of power delivered to a subset of lower priority active motors is increased back to the optimal operating amount of power for the subset of lower

priority active motors in accordance with the first set of system-wide priorities.

6. The method of claim 2, further comprising:

5

determining that the maximum power output of the plurality of motor controllers has been reduced to a lower maximum power output; and configuring the power switching network such that a subset of lower priority active motors in the second plurality of motors are electrically disconnected from the second combination of motor controllers.

10

7. The method of claim 2, further comprising:

15

determining that the maximum power output of the plurality of motor controllers has been reduced to a lower maximum power output; and

configuring the power switching network such that an amount of power delivered to a subset of lower priority active motors is reduced below an optimal operating level for the subset of lower priority active motors in accordance with the second set of system-wide priorities.

20

8. The method of claim 1, wherein said first control unit is a bus power control unit.

- 25 9. The method of claim 1, wherein said each one of said plurality of motors may be selected from the group consisting of a main engine electric start, a starter, a generator, an electronic engine controller, an auxiliary power unit controller, an auxiliary engine electric start, an auxiliary starter generator, a battery auxiliary engine electric start control unit, an electric taxi motor, a cabin air

compressor, a hydraulic pump, a nitrogen generation motor, an environmental control system fan, and a cargo chilling motor.

5 **10.** The method of claim 2, wherein said second control unit is selected from the group consisting of a generator control unit, an electronic engine controller, an auxiliary power unit controller, an auxiliary generator control unit, a battery voltage boost unit controller, an electric taxi controller, an electric brake controller, an air conditioning pack control unit, a hydraulic pump controller, a nitrogen generation system controller, an environmental control system fan controller, and a cargo chilling system controller.

10 **11.** A motor control system, comprising:

15 a plurality of motors;

 a plurality of motor controllers configured for parallel electrical connection;

20 a power switching network electrically connecting the plurality of motors to the plurality of motor controllers; and

25 a parallel modular converter for dynamically controlling the power switching network, comprising a computer with at least one processor and a non-transitory storage medium having computer executable instructions stored thereon which, when executed on the computer, cause the computer to:

determine a first power load demand from a first plurality of active motors, wherein the first plurality of active motors is a subset of the plurality of motors;

5 select a first combination of motor controllers of the plurality of motor controllers necessary to provide sufficient power to meet the first power load demand based at least in part on a maximum power output of the plurality of motor controllers;

10 assign a first set of system-wide priorities based at least in part on the maximum power output and the first power load demand;

15 configure the power switching network such that the first plurality of active motors are electrically connected to the first combination of motor controllers in accordance with the first set of system-wide priorities;

20 receive from a first control unit a power request for a first motor, wherein the power request is associated with a first priority level;

25 determine a first priority designation for the first priority level in relation to the first set of system-wide priorities;

25 assign a second set of system-wide priorities based at least in part on the first priority designation and the first set of system-wide priorities;

 determine a second power load demand from a second plurality of active motors, wherein the second plurality of active motors comprises the first plurality of active motors and the first motor;

select a second combination of motor controllers of the plurality of motor controllers necessary to provide sufficient power to meet the second power load demand; and

5

configure the power switching network such that the second plurality of active motors are electrically connected to the second combination of motor controllers in accordance with the second set of system-wide priorities.

10

12. The system of claim **11**, wherein said computer executable instructions stored thereon further cause the computer to:

15

receive a first signal from a second control unit, wherein the first signal is associated with the power request; and

adjust the first priority designation based on the first signal and thereby adjusting the second set of system-wide priorities.

20 **13.** The system of claim **12**, wherein said computer executable instructions stored thereon further cause the computer to:

25

determine that the second power load demand is greater than the maximum power output of the plurality of motor controllers; and

configure the power switching network to cause a subset of lower priority active motors in the second plurality of motors to electrically disconnect from the second combination of motor controllers.

14. The system of claim **12**, wherein said computer executable instructions stored thereon further cause the computer to:

5 determine that the second power load demand is greater than the maximum power output of the plurality of motor controllers; and

10 configure the power switching network such that the second combination of motor controllers deliver an amount of power to a subset of lower priority active motors that is reduced below an optimal operating amount of power for the subset of lower priority active motors in accordance with the second set of system-wide priorities.

15. The system of claim **14**, wherein said computer executable instructions stored thereon further cause the computer to:

15

 identify that the power request is no longer valid;

 re-assign the first set of system-wide priorities; and

20 configure the power switching network such that the amount of power delivered to a subset of lower priority active motors is increased back to the optimal operating amount of power for the subset of lower priority active motors in accordance with the first set of system-wide priorities.

25

16. The system of claim **12**, wherein said computer executable instructions stored thereon further cause the computer to:

5 determine that the maximum power output of the plurality of motor controllers has been reduced to a lower maximum power output; and

10 configure the power switching network to cause a subset of lower priority active motors in the second plurality of motors to electrically disconnect from the second combination of motor controllers.

17. The system of claim **12**, wherein said computer executable instructions stored thereon further cause the computer to:

15 determine that the maximum power output of the plurality of motor controllers has been reduced to a lower maximum power output; and

20 configure the power switching network such that an amount of power delivered to a subset of lower priority active motors is reduced below an optimal operating level for the subset of lower priority active motors in accordance with the second set of system-wide priorities.

18. The system of claim **11**, wherein said each one of said plurality of motors may be selected from the group consisting of a main engine electric start, a starter, a generator, an electronic engine controller, an auxiliary power unit controller, 25 an auxiliary engine electric start, an auxiliary starter generator, a battery auxiliary engine electric start control unit, an electric taxi motor, a cabin air compressor, a hydraulic pump, a nitrogen generation motor, an environmental control system fan, and a cargo chilling motor.

- 5 **19.** The system of claim **12**, wherein said second control unit is selected from the group consisting of a generator control unit, an electronic engine controller, an auxiliary power unit controller, an auxiliary generator control unit, a battery voltage boost unit controller, an electric taxi controller, an electric brake controller, an air conditioning pack control unit, a hydraulic pump controller, a nitrogen generation system controller, an environmental control system fan controller, and a cargo chilling system controller.

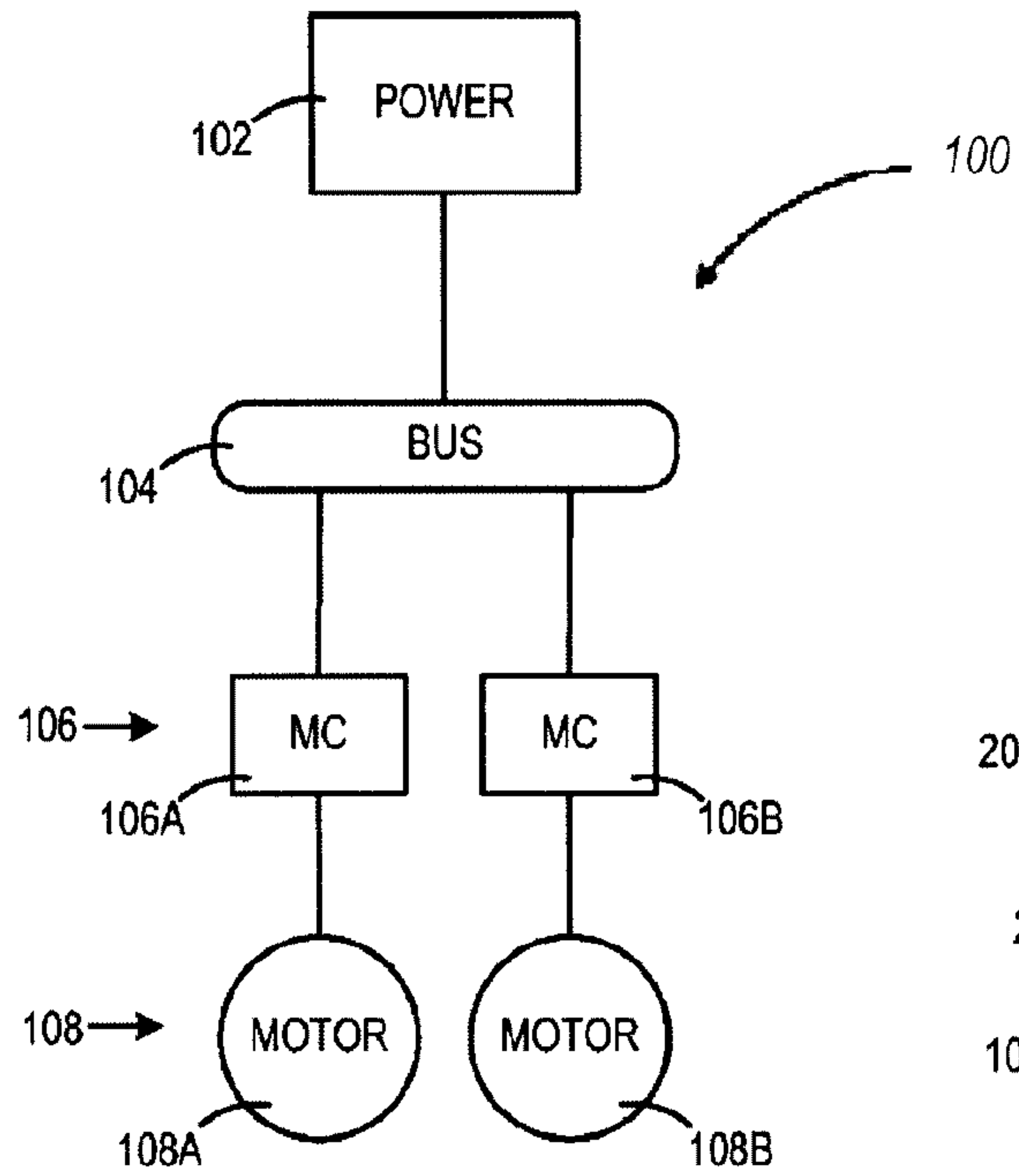


Fig. 1
(PRIOR ART)

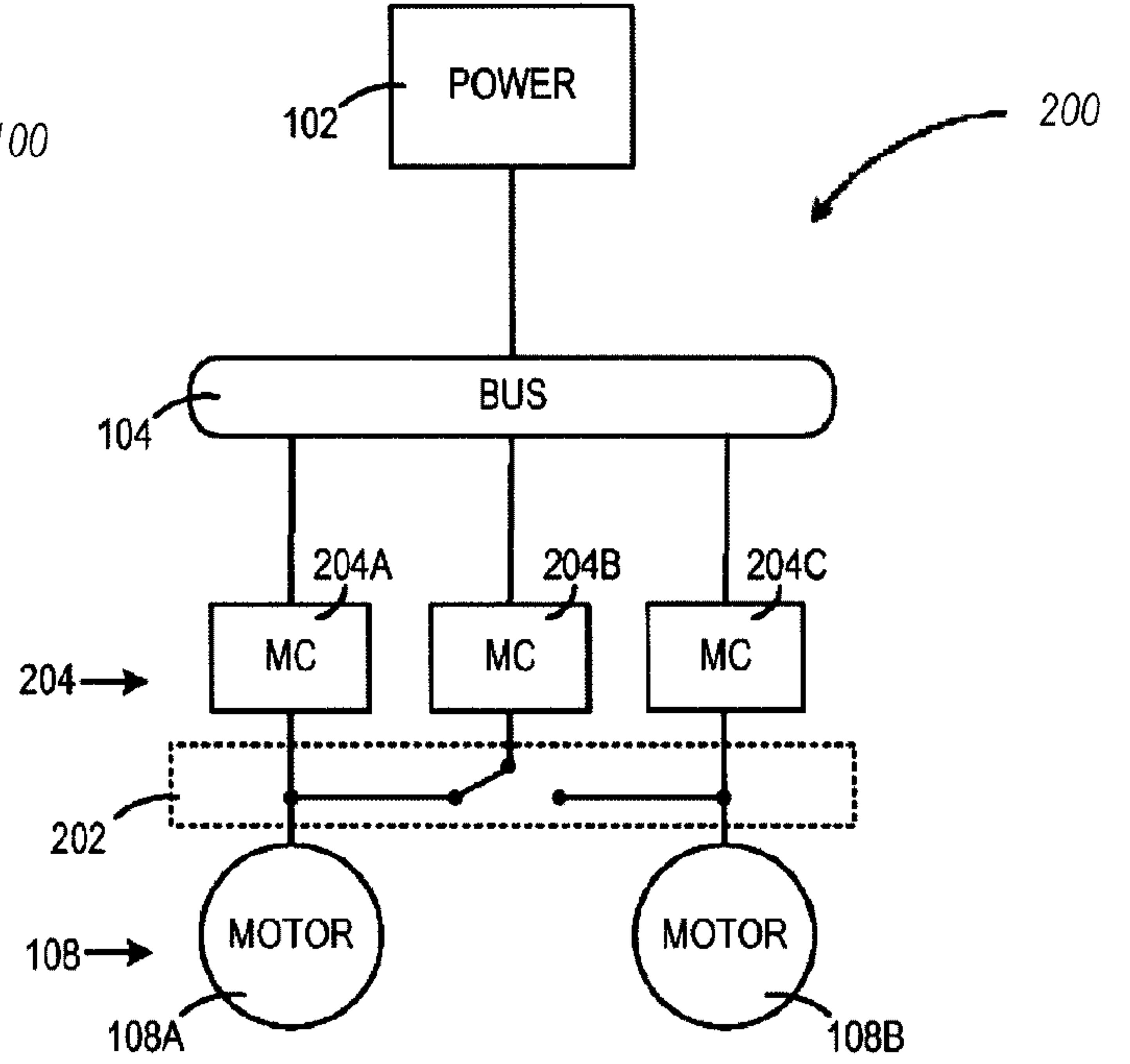


Fig. 2

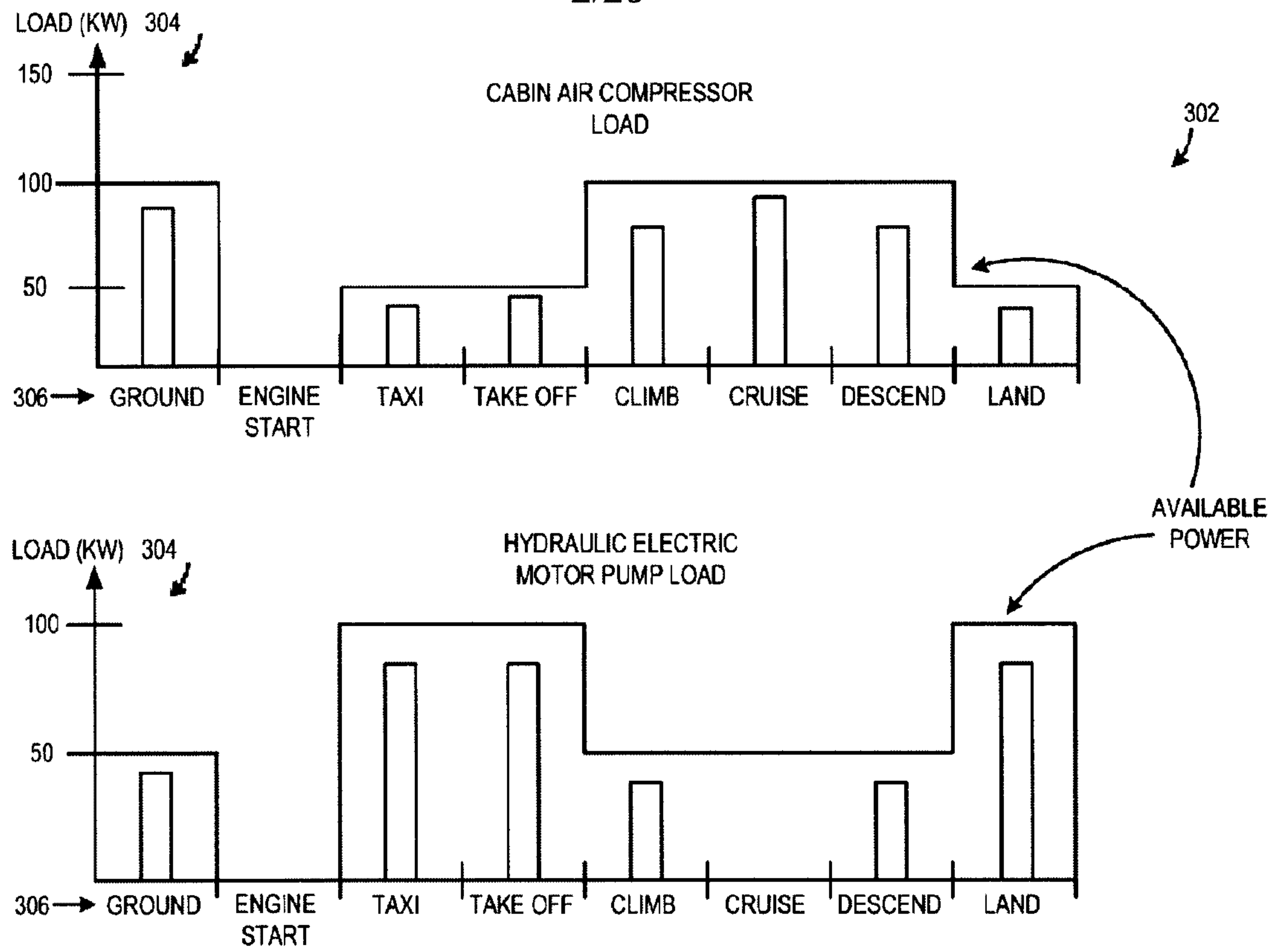
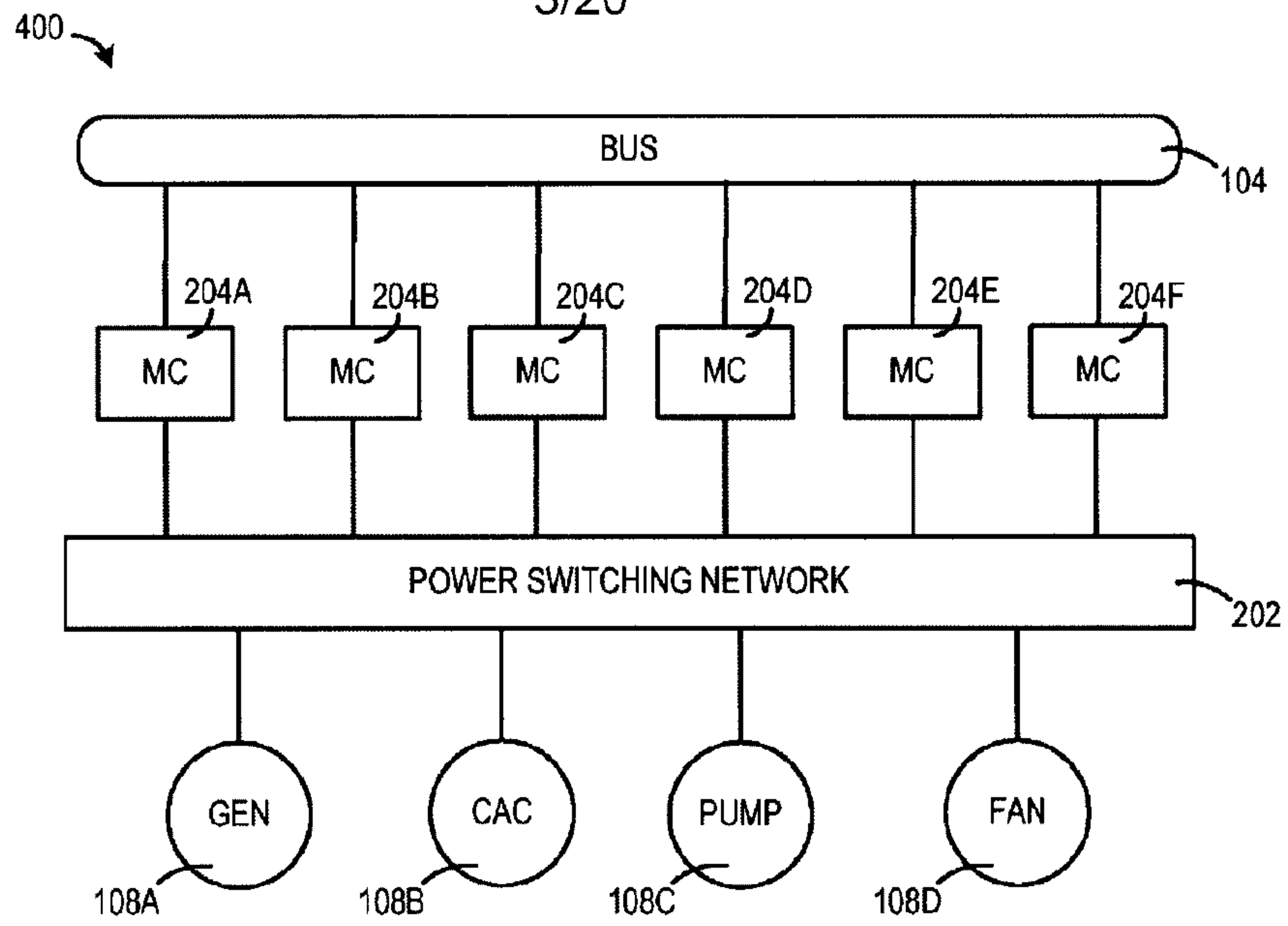
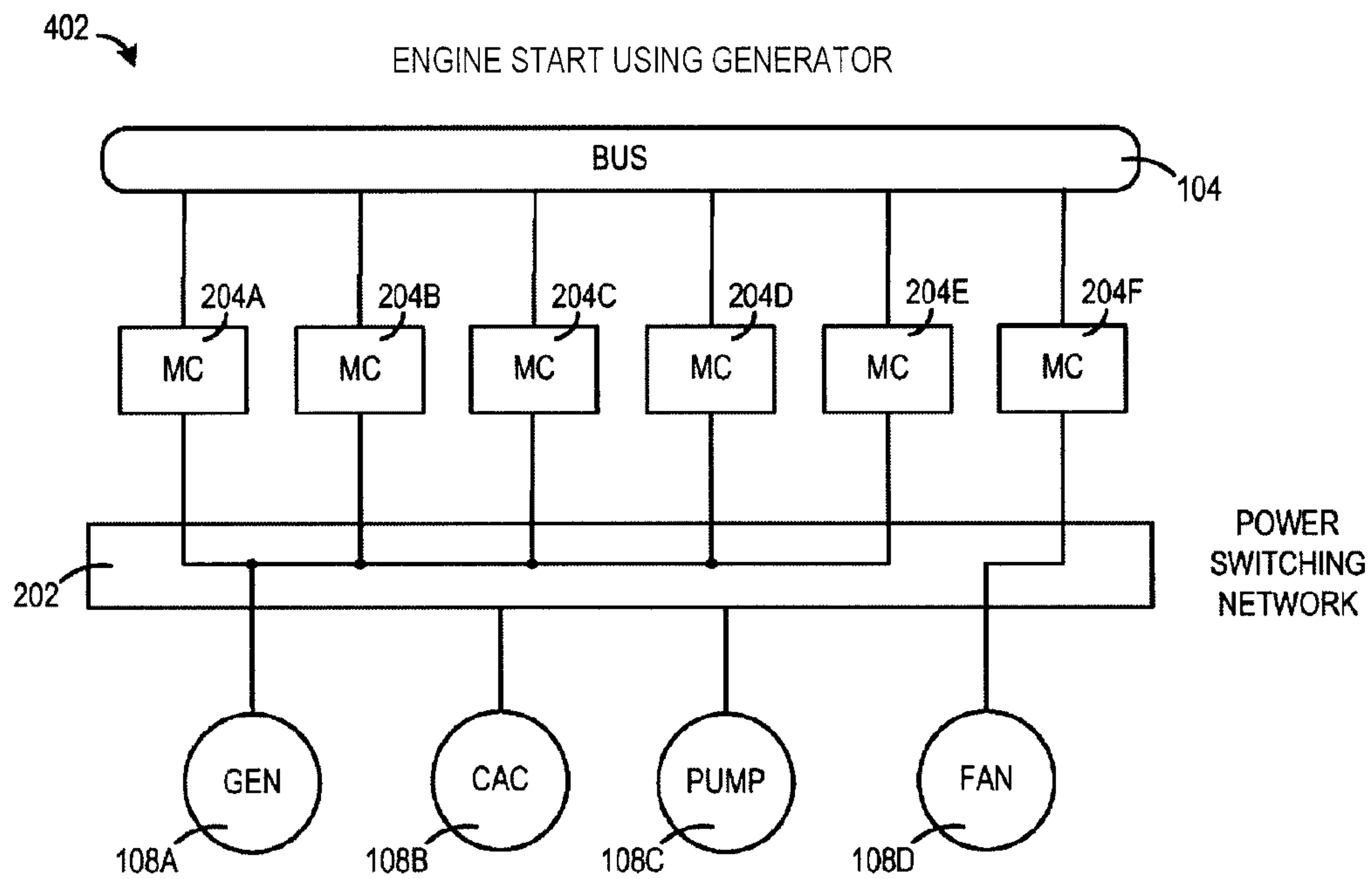


Fig. 3

**Fig. 4A****Fig. 4B**

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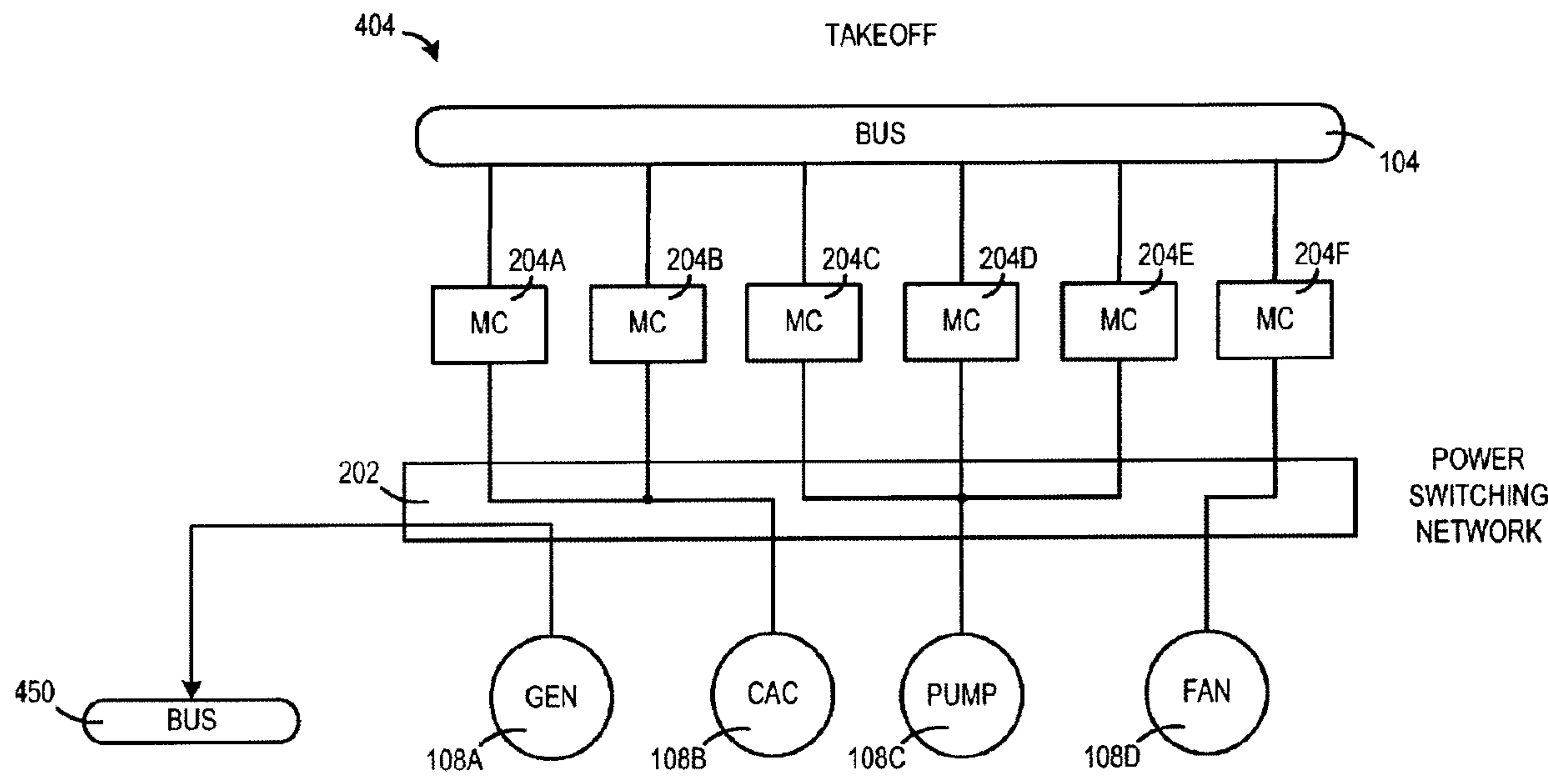


Fig. 4C

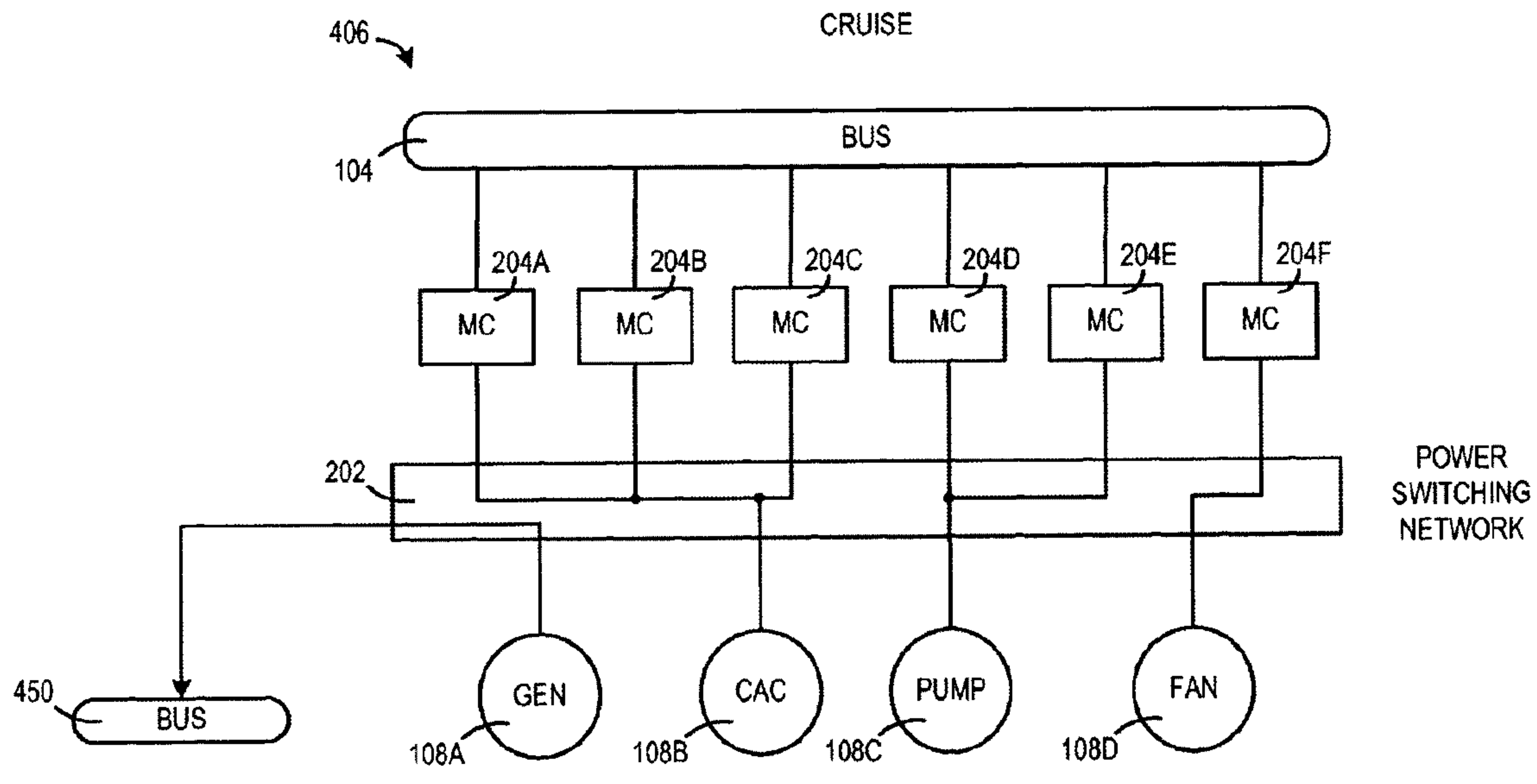


Fig. 4D

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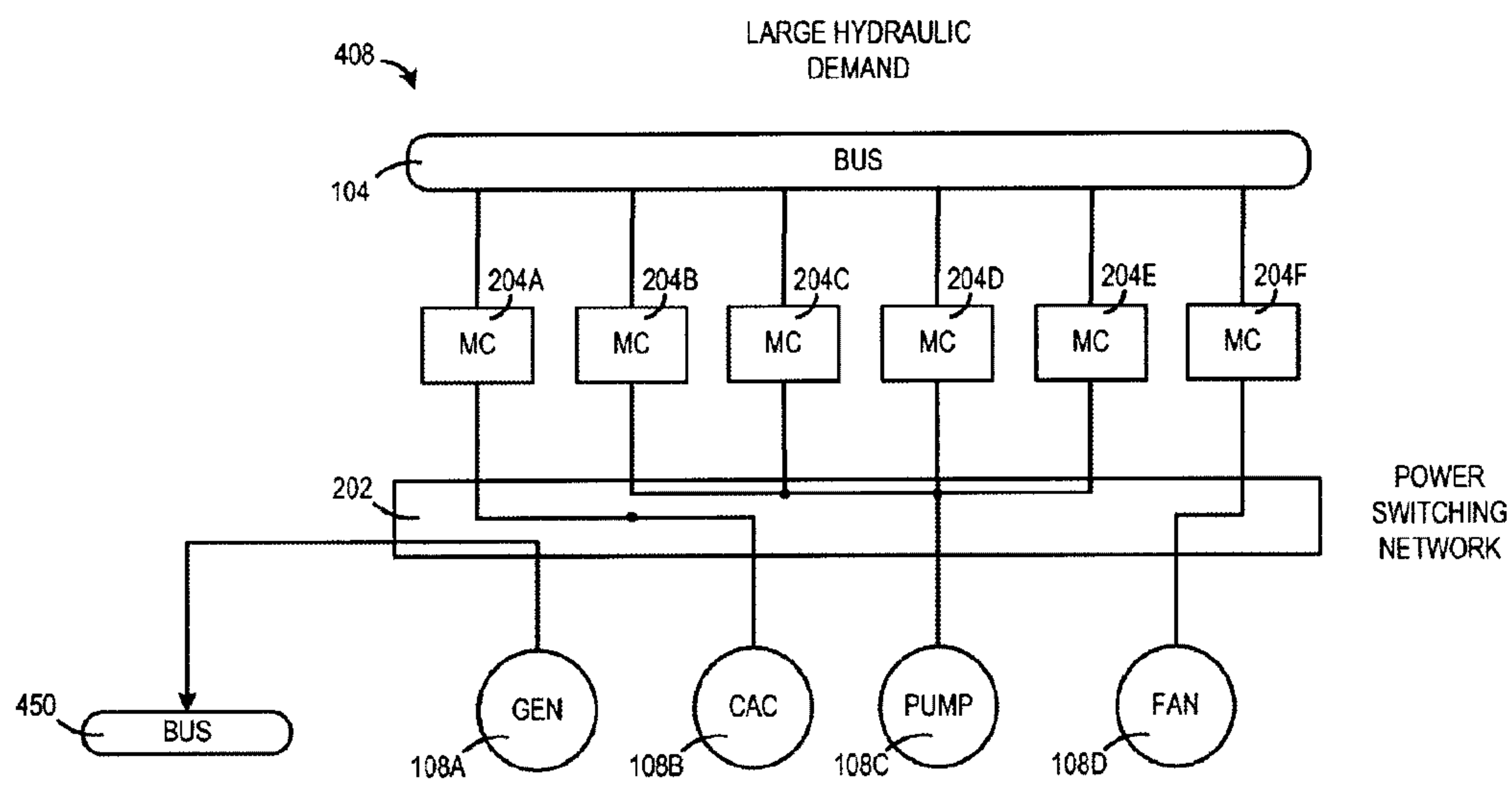


Fig. 4E

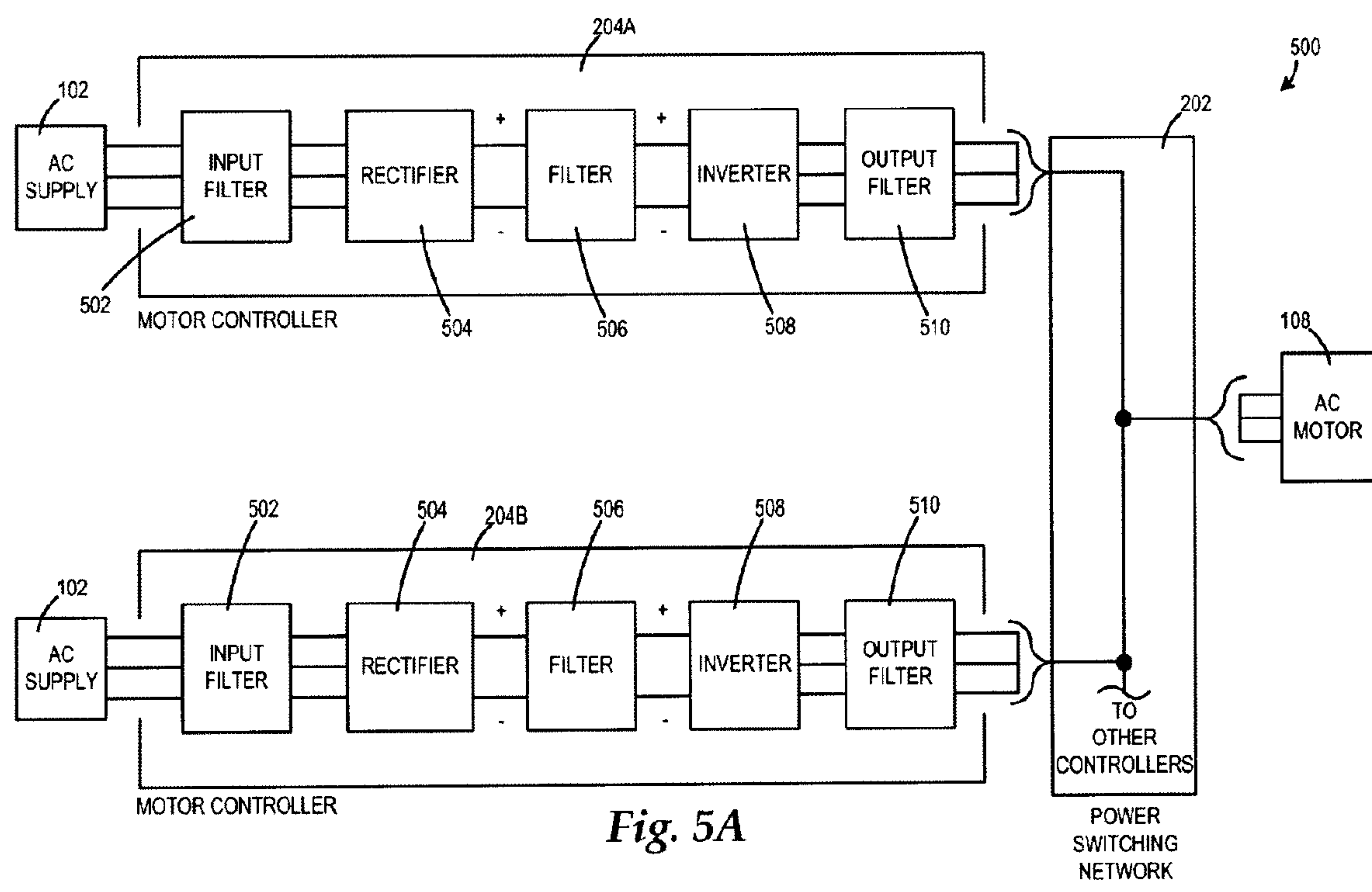
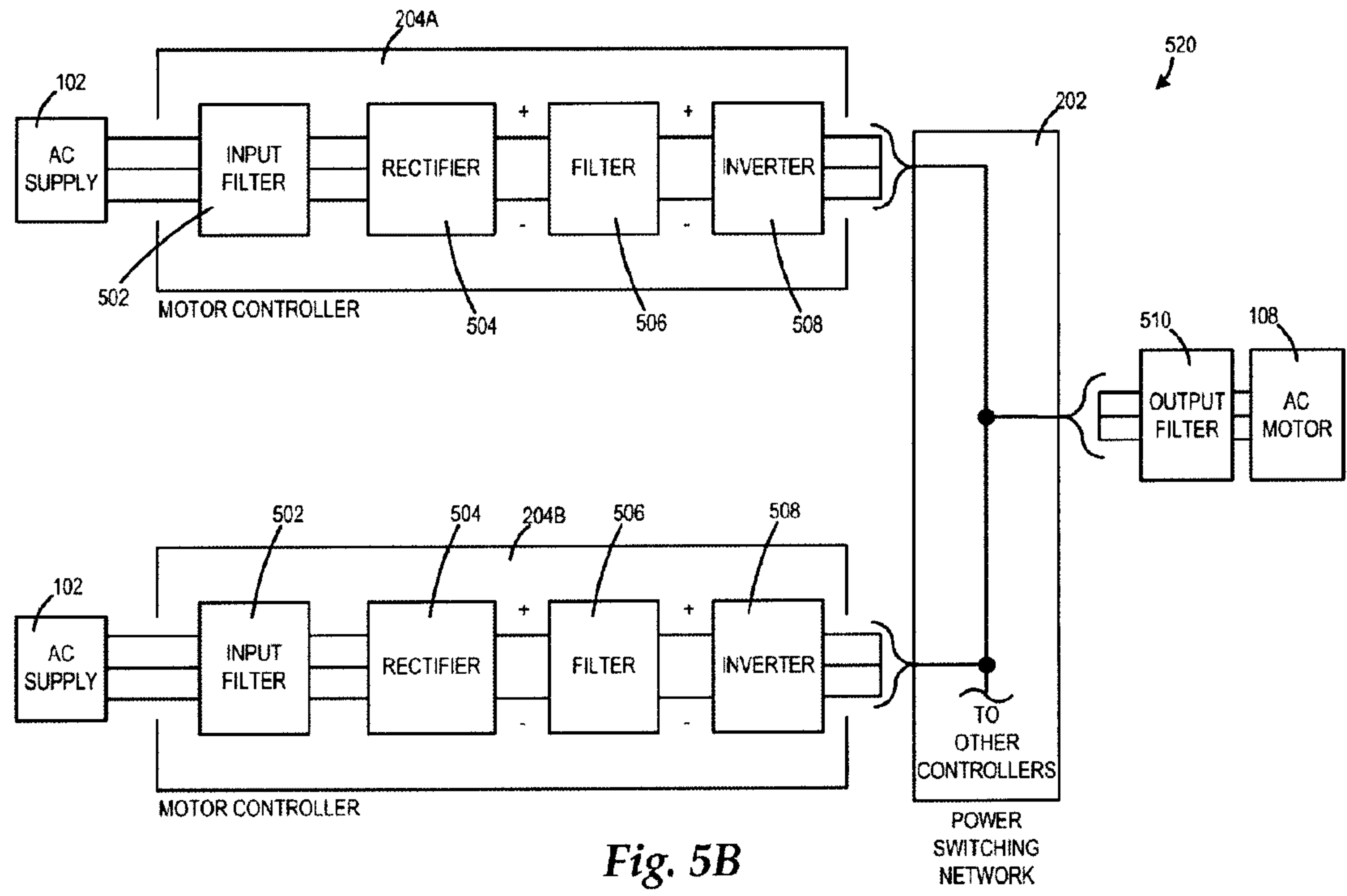


Fig. 5A

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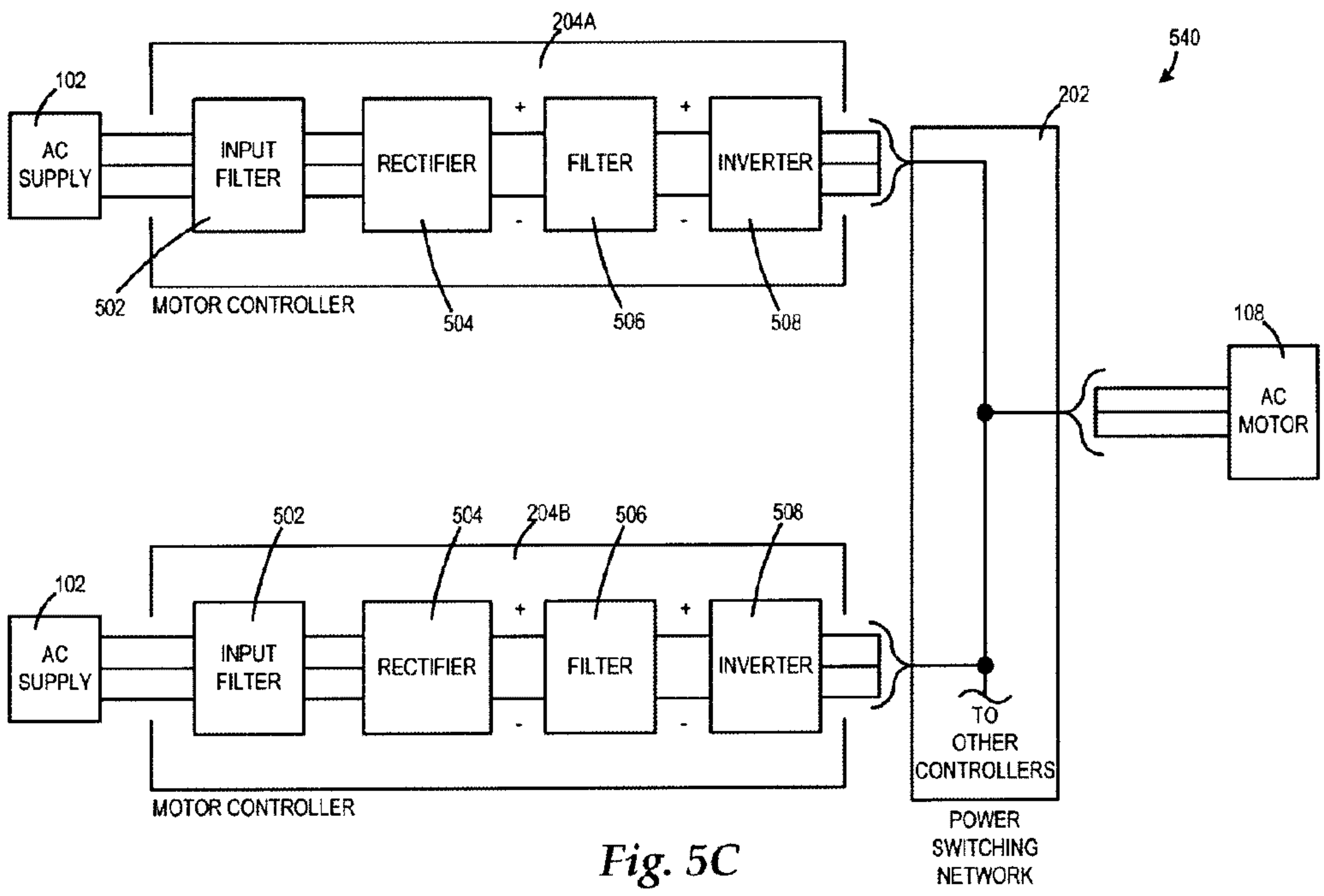


Fig. 5C

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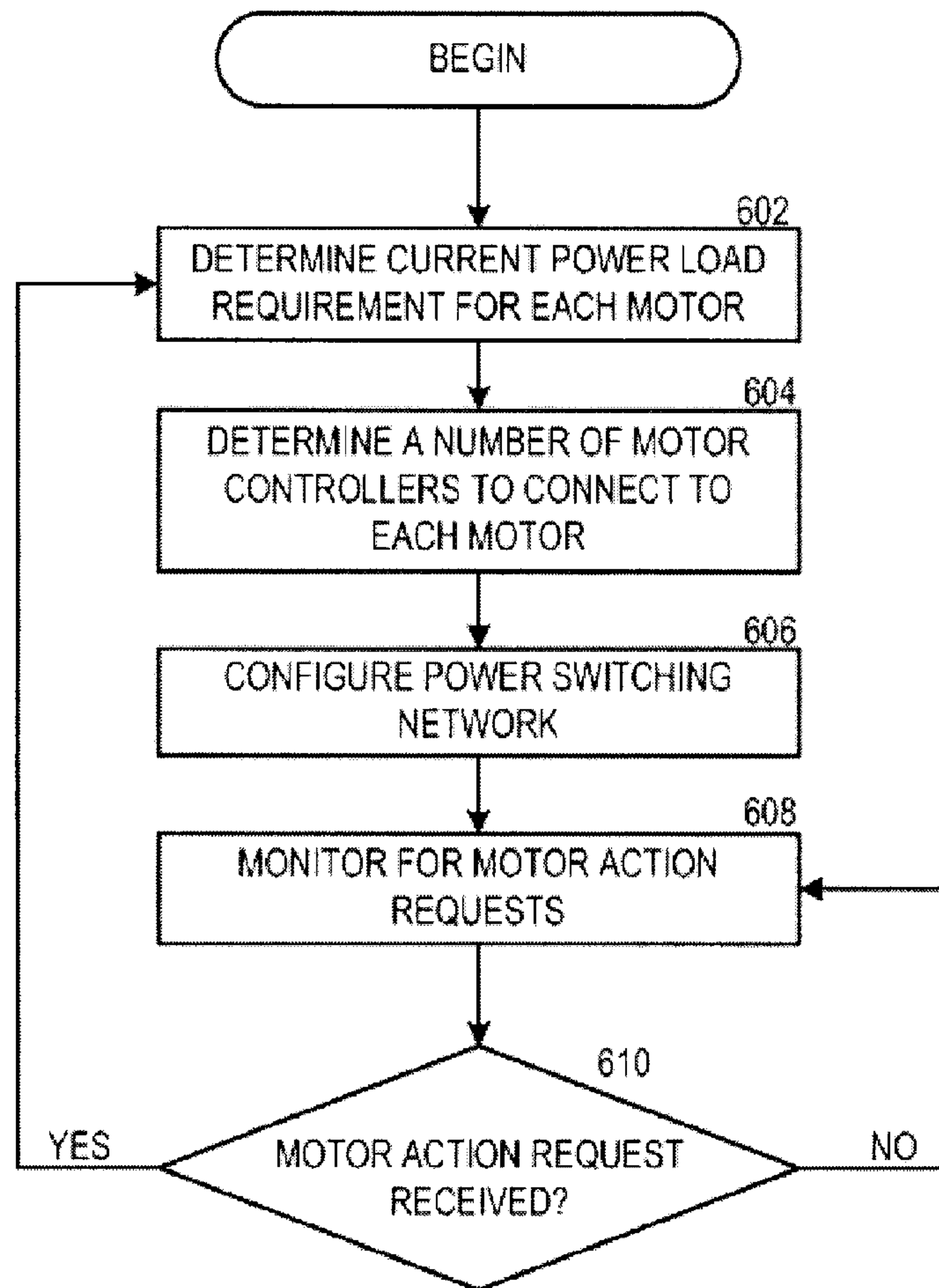


Fig. 6
(PRIOR ART)

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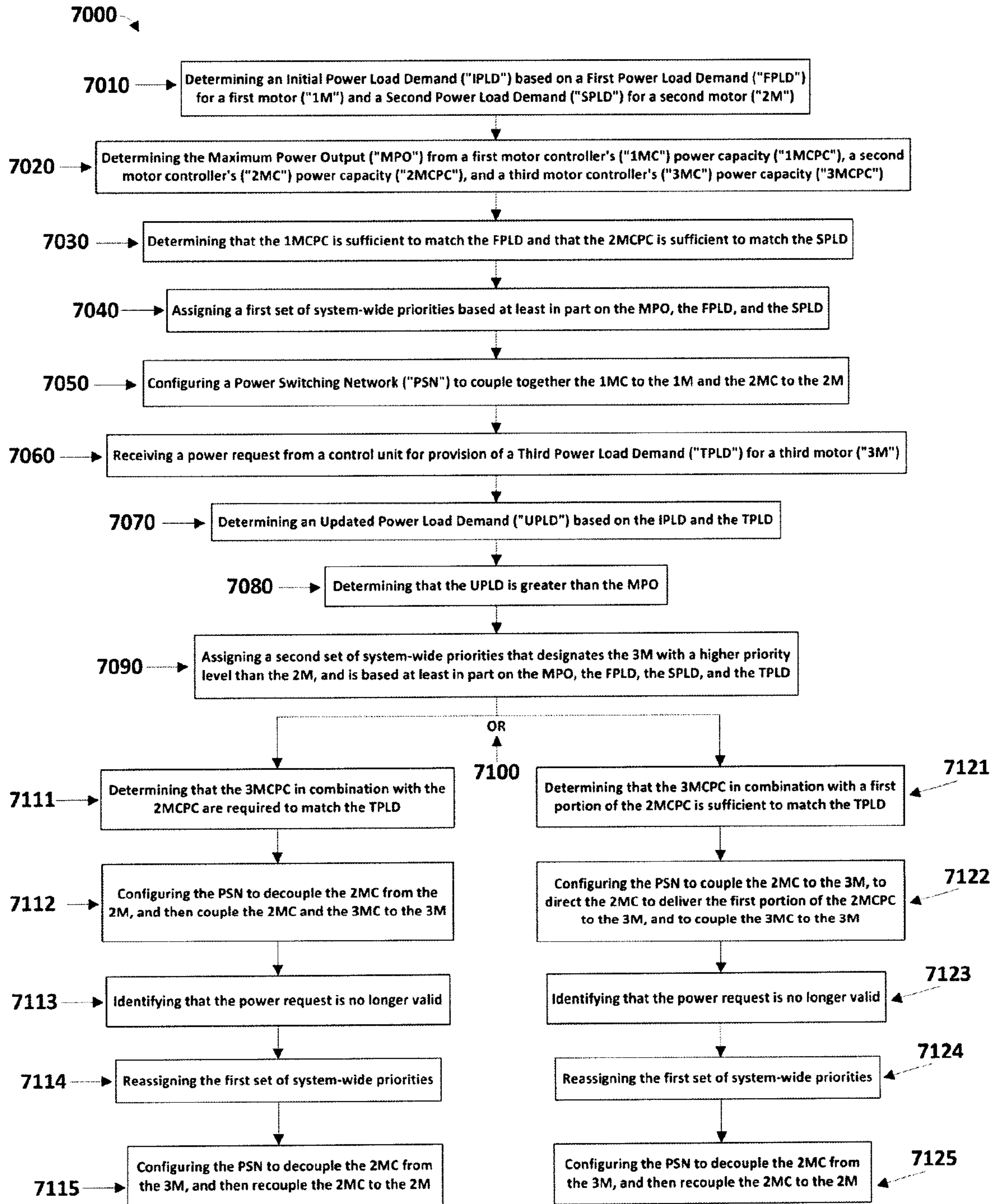


Fig. 7

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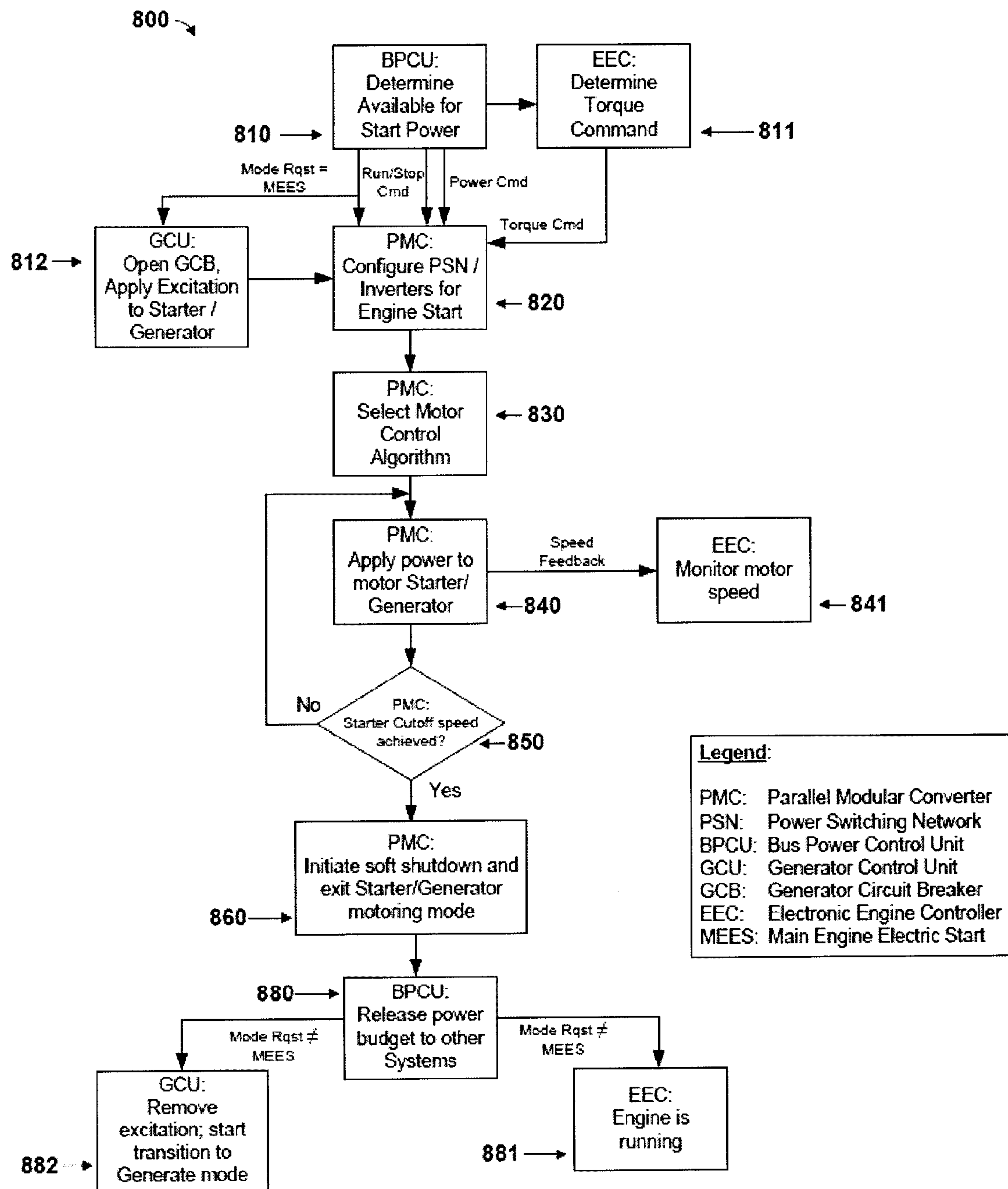


Fig. 8

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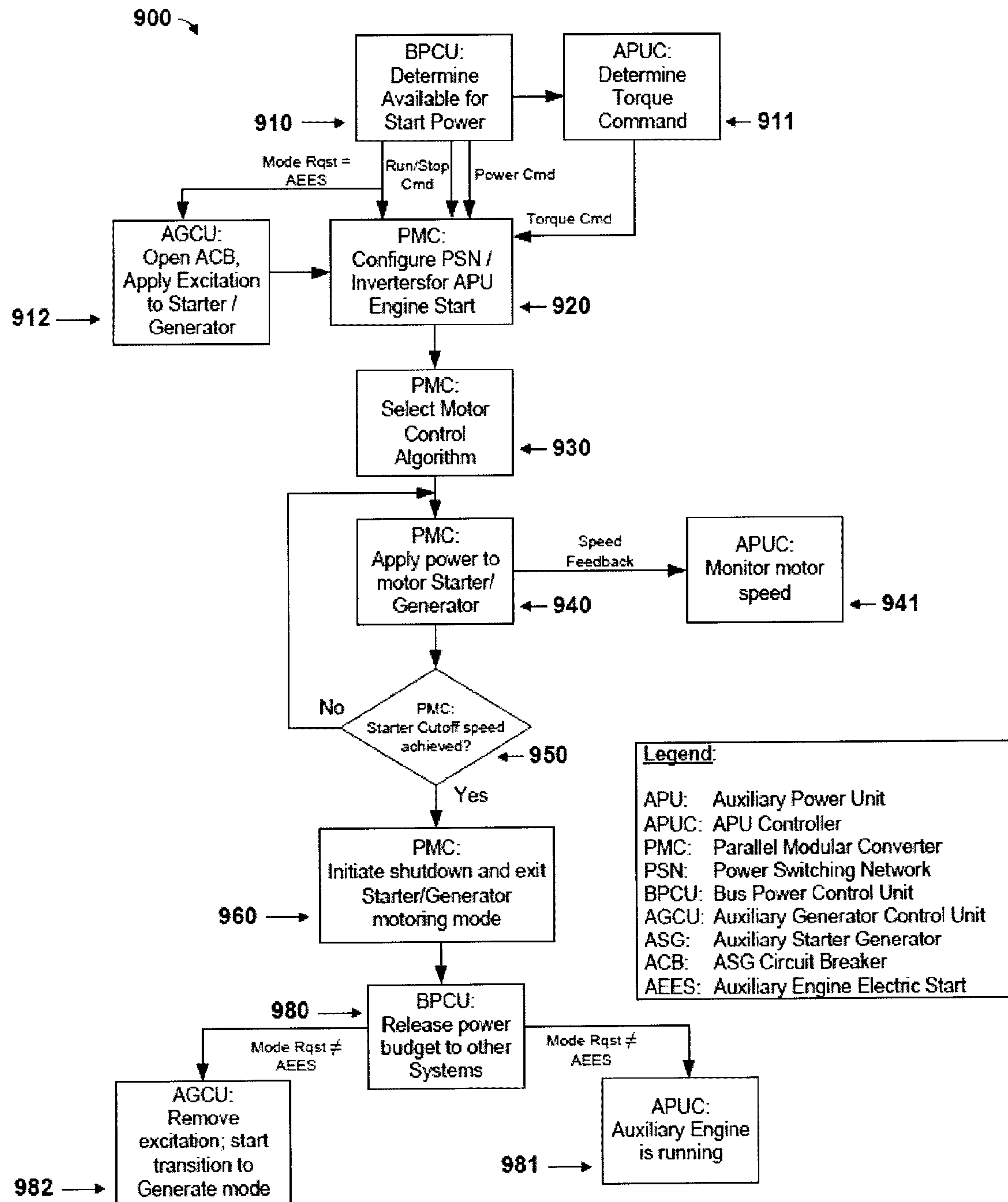


Fig. 9

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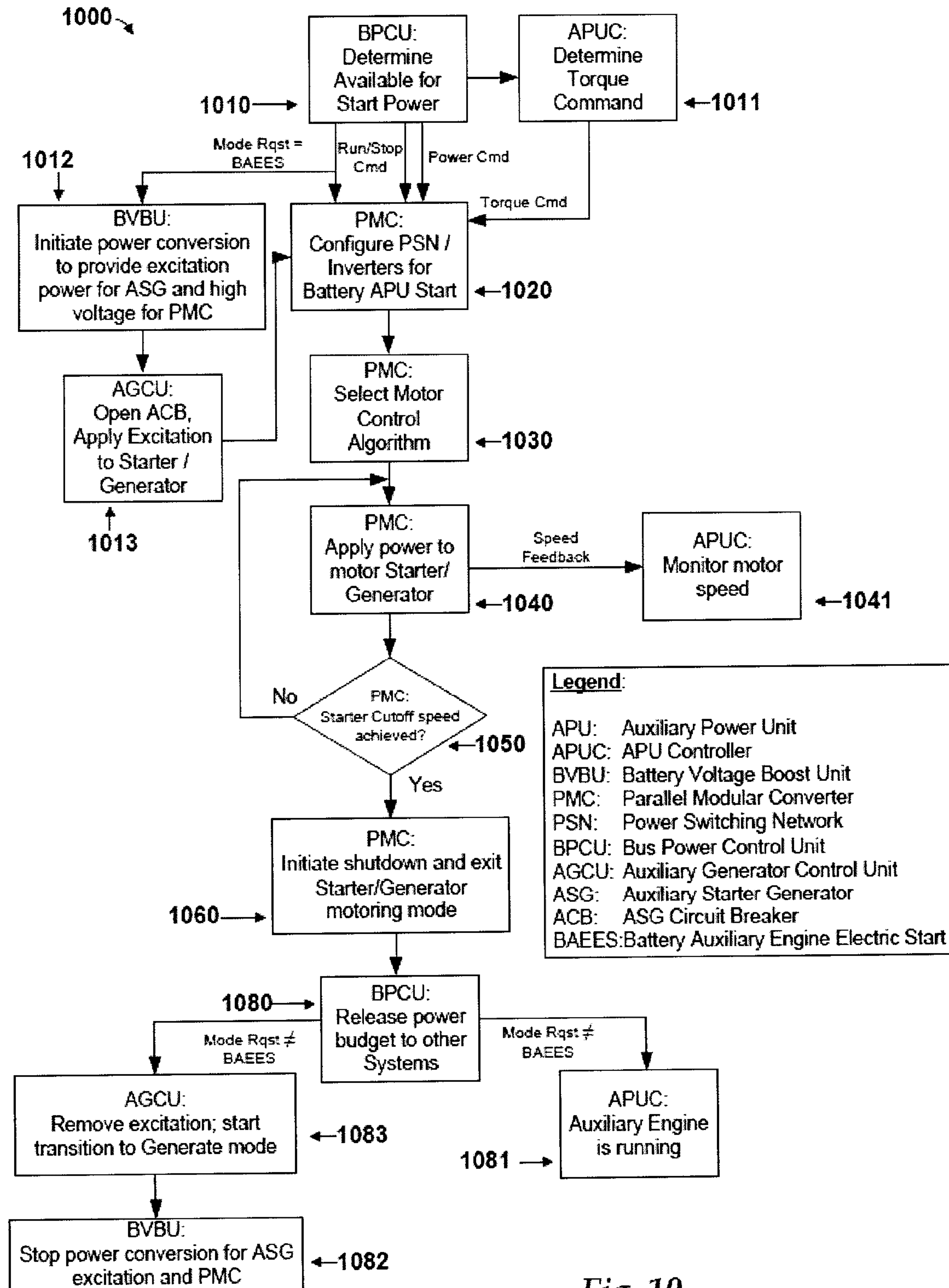
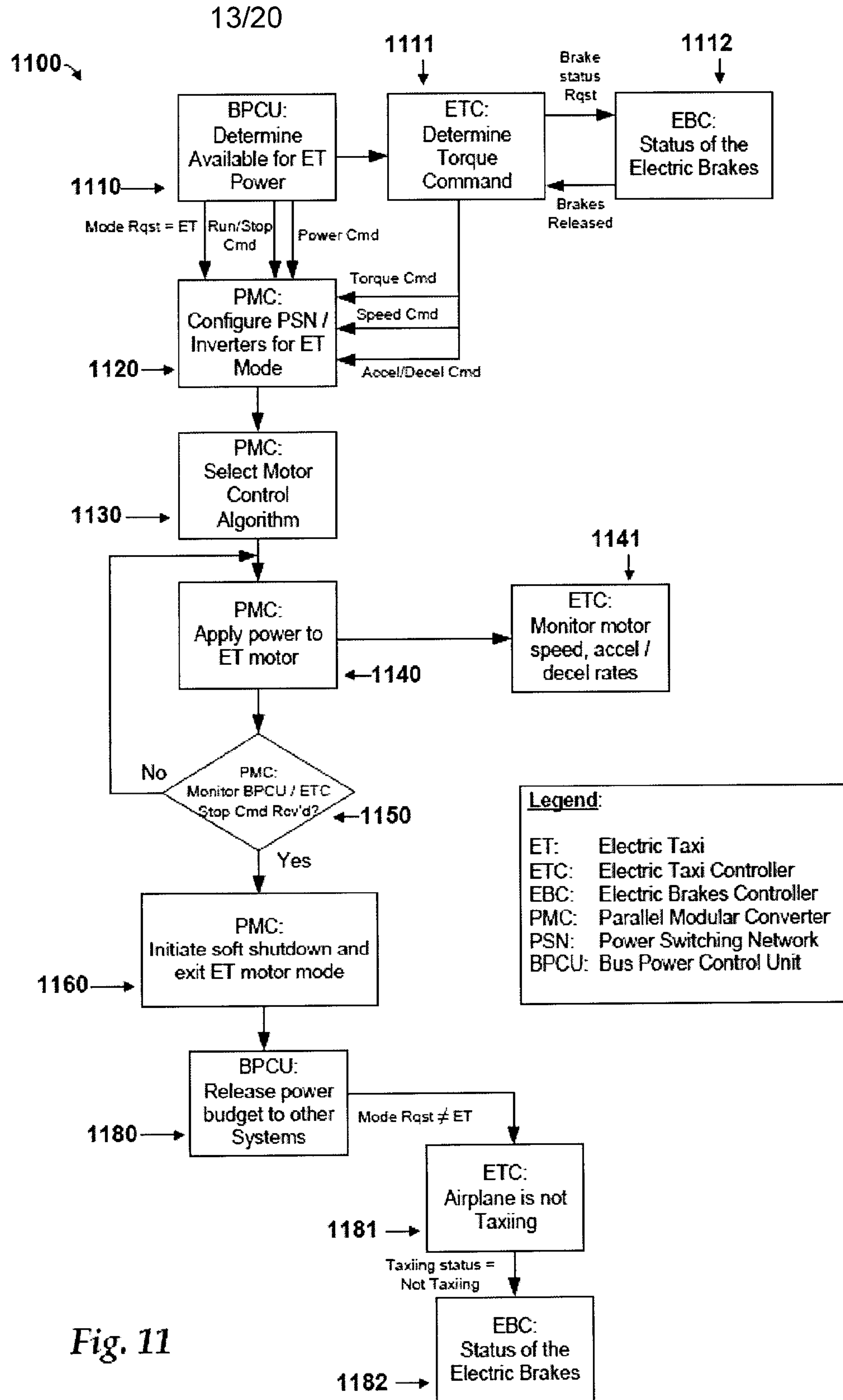


Fig. 10



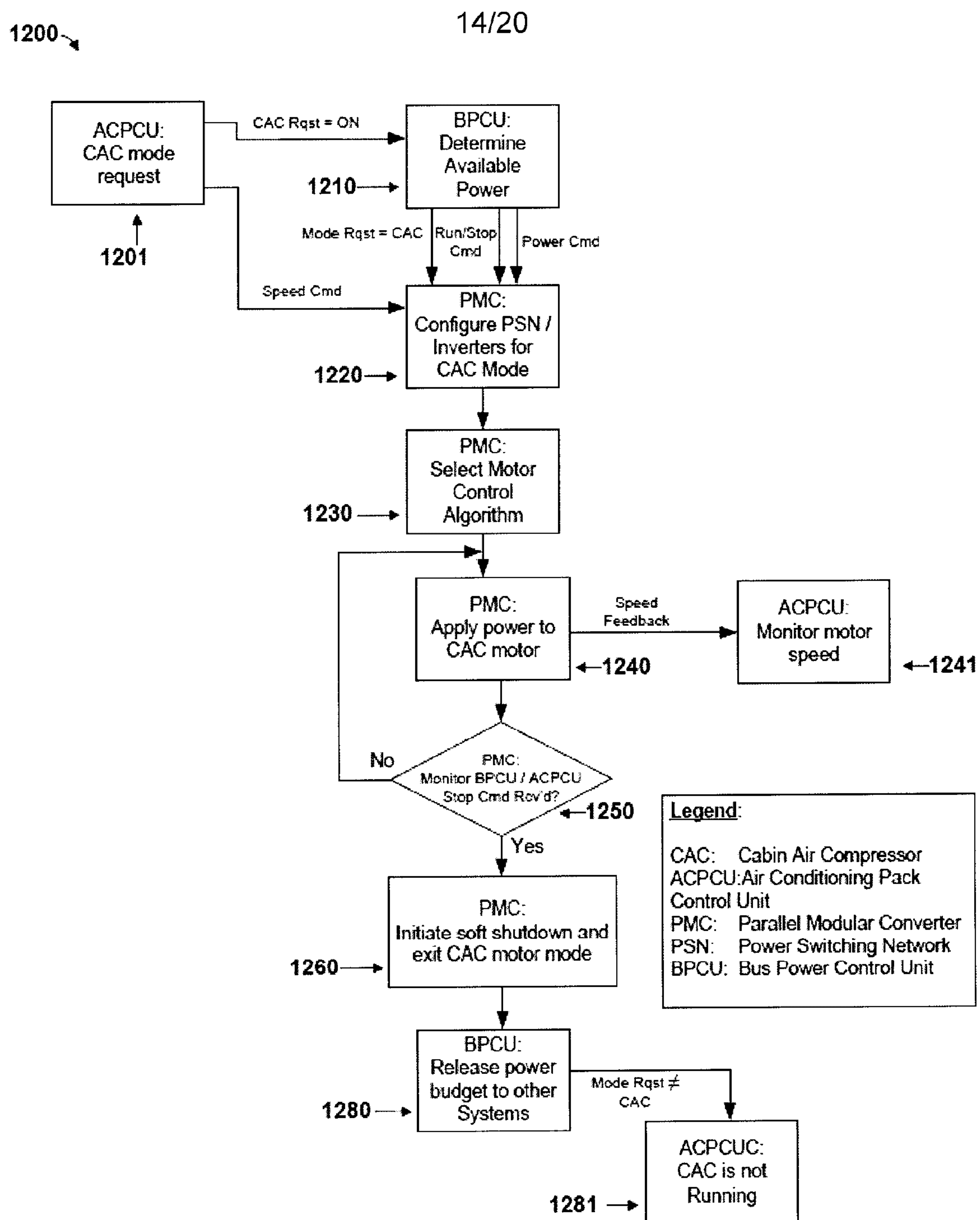
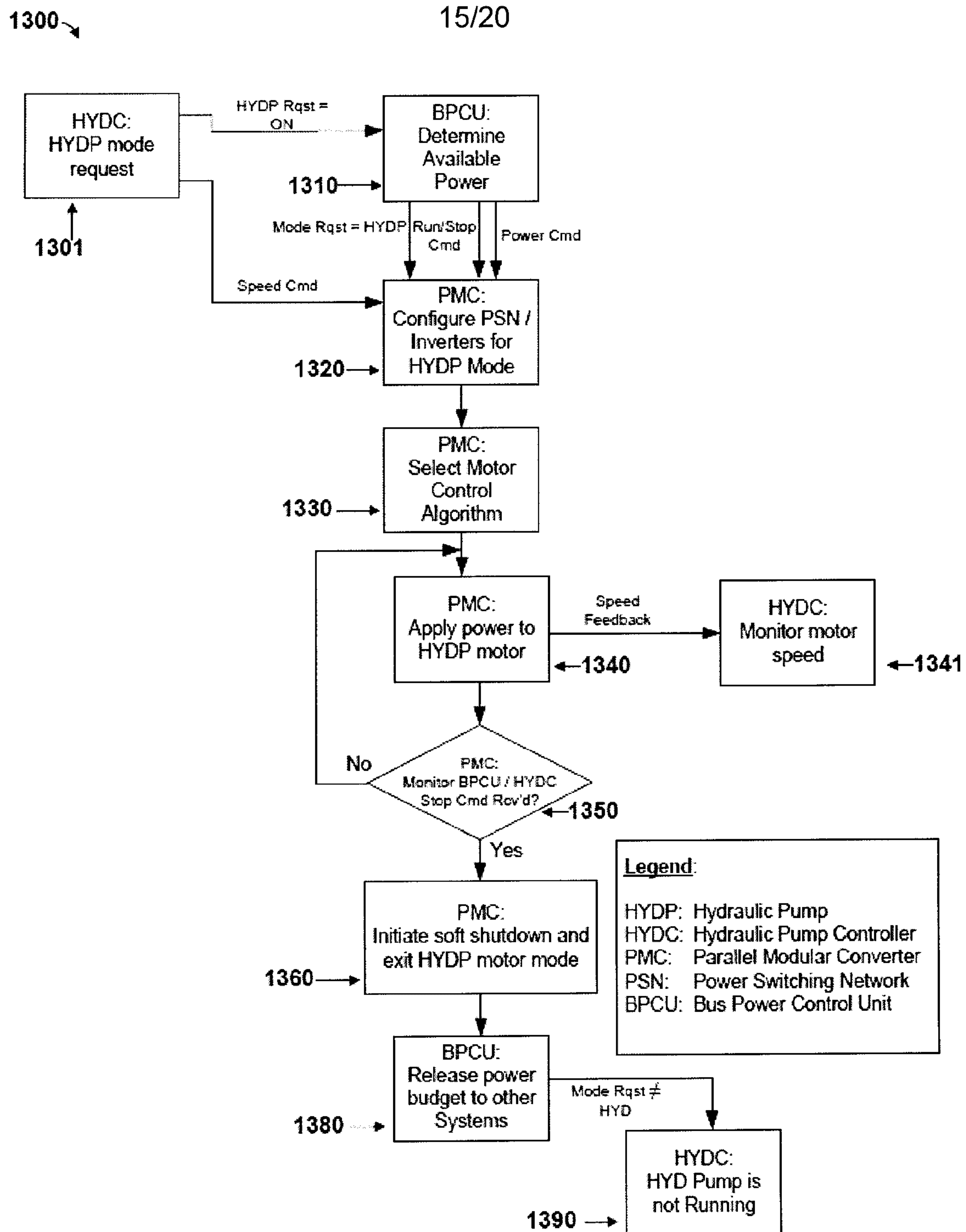


Fig. 12



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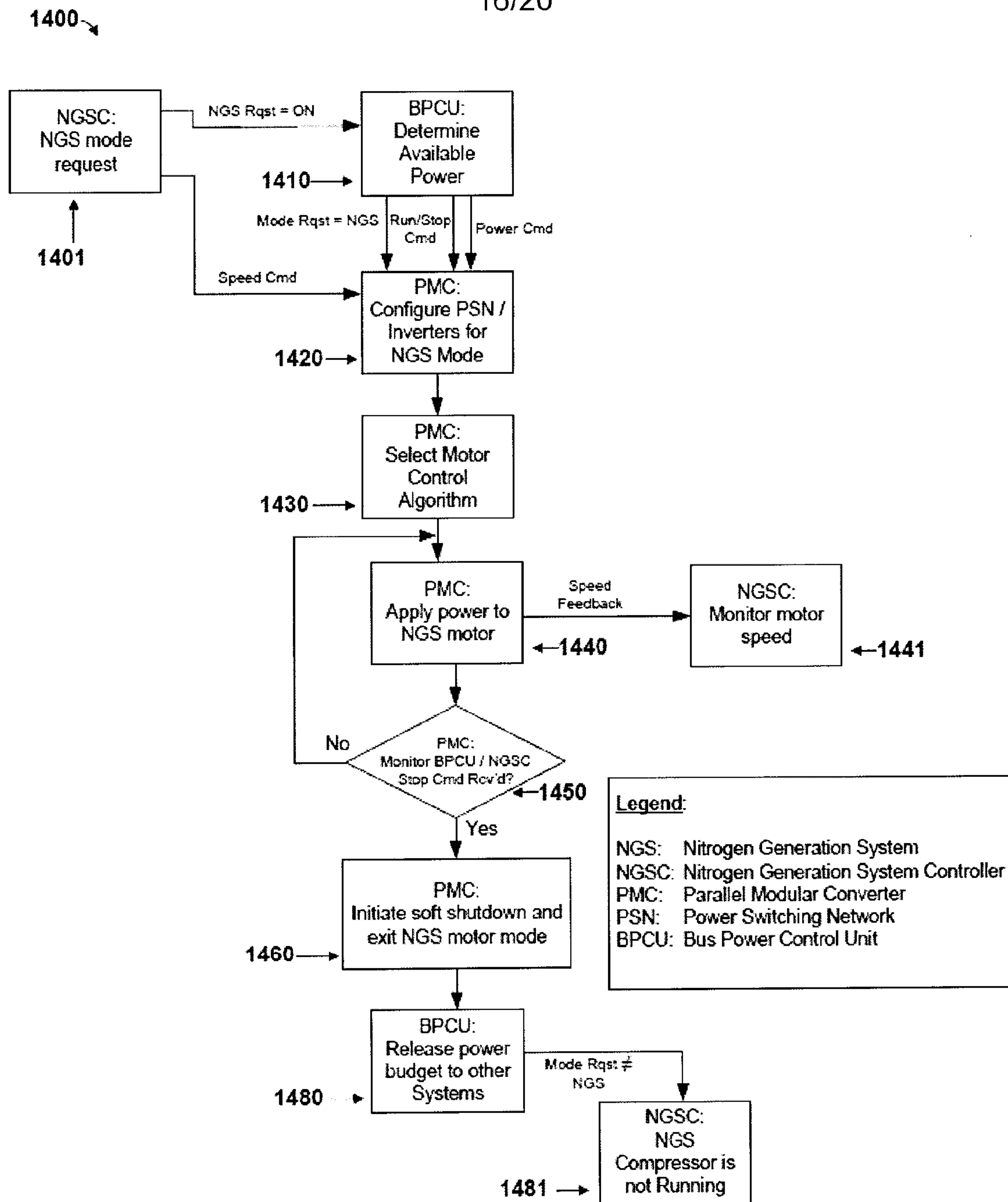


Fig. 14

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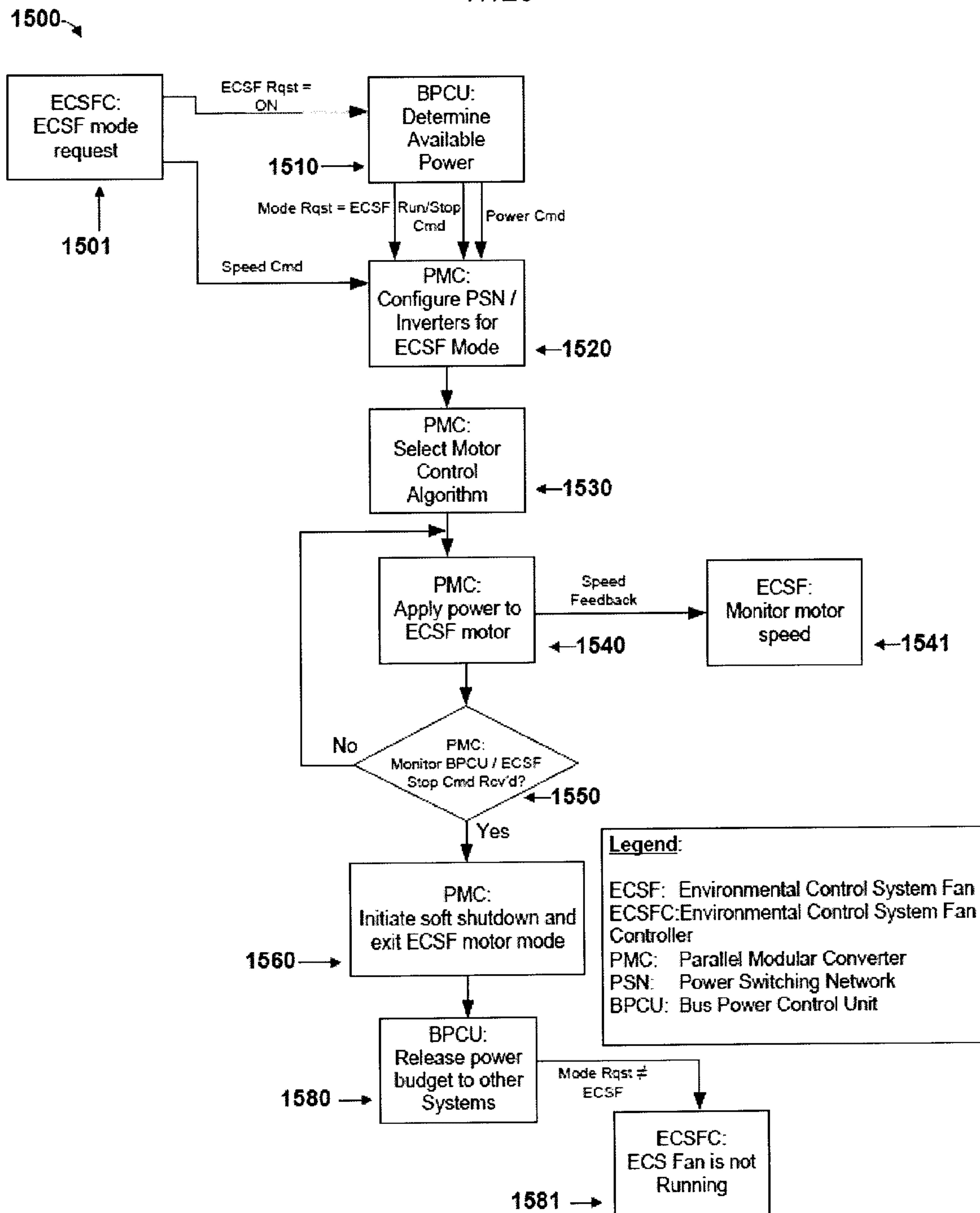


Fig. 15

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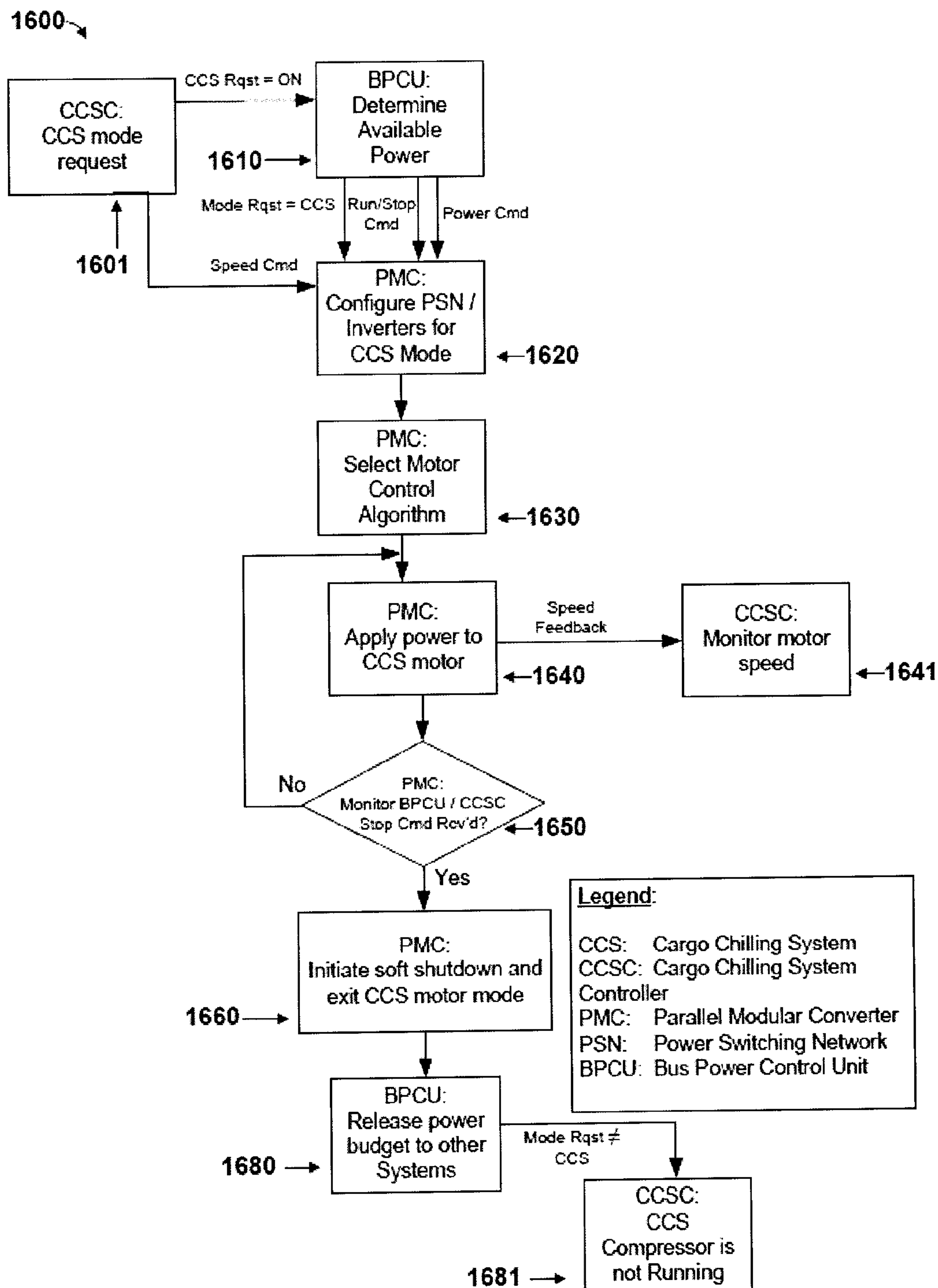


Fig. 16

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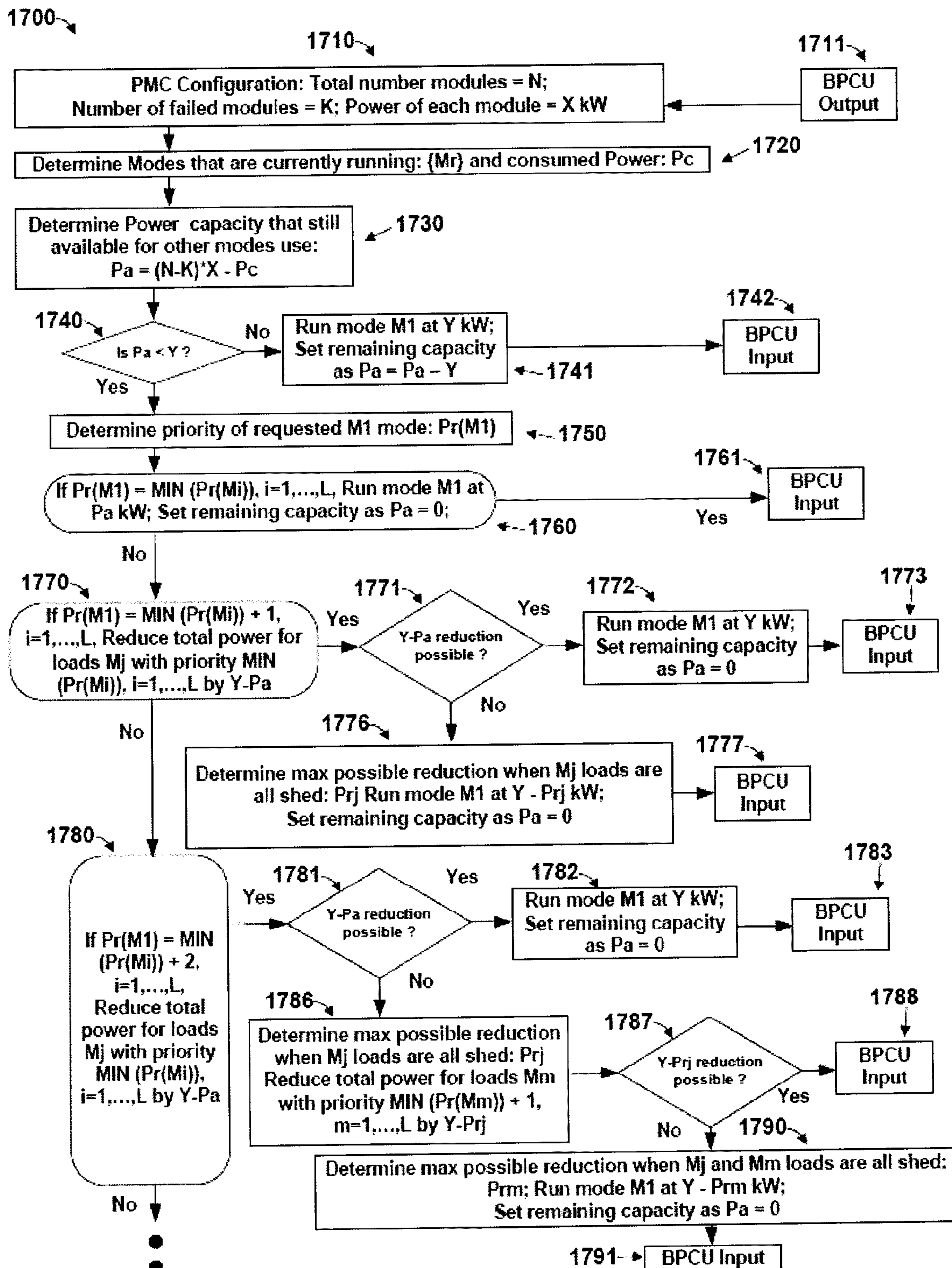
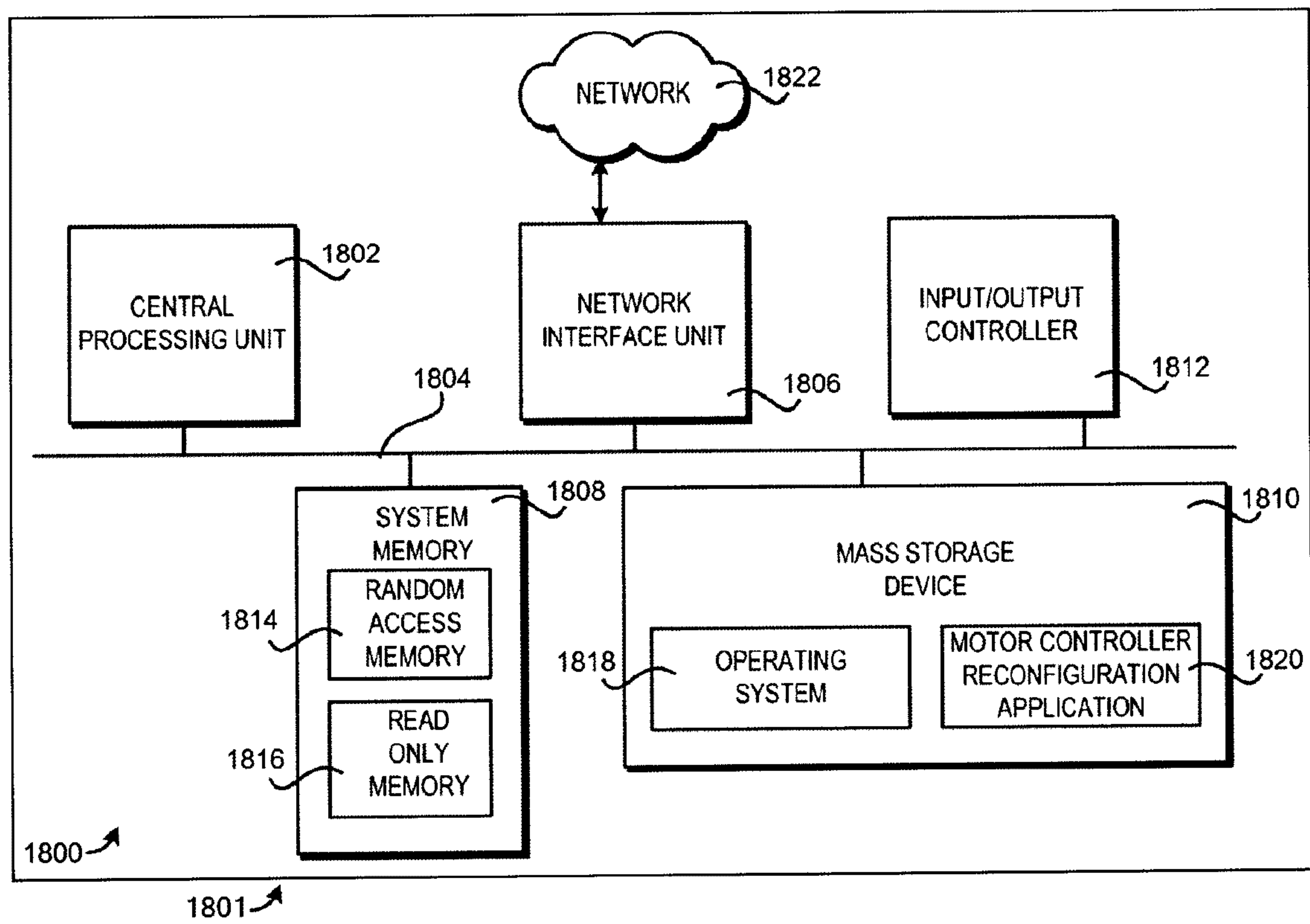


Fig. 17

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*Fig. 18*

