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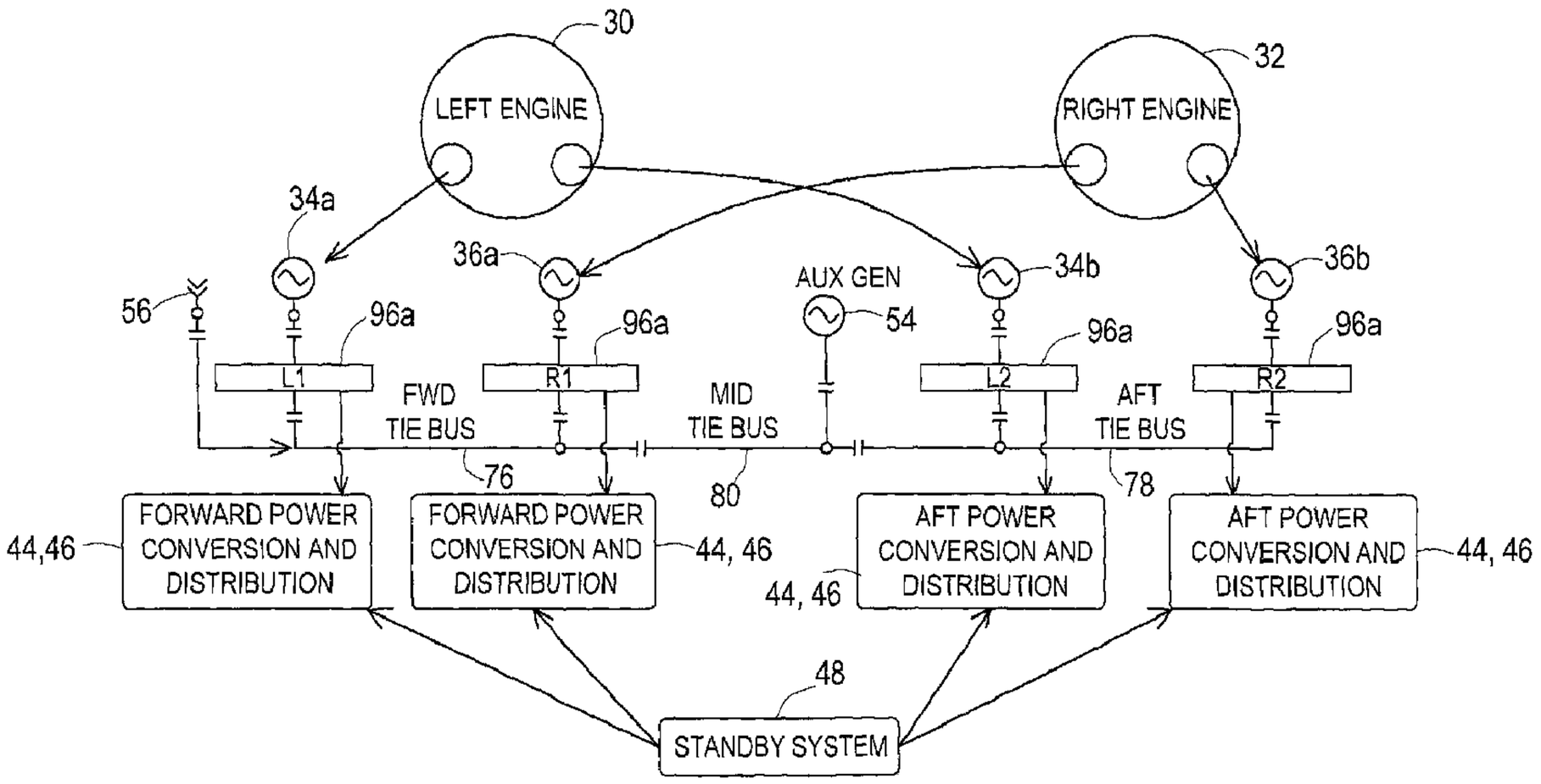

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MEC for controlling and distributing primary power to other MECs spatially distribute throughout a vehicle. In one or more configurations, the PPSNDs have a universal structure in that each includes a common power input source and a plurality of common power outputs. In one or more configurations, primary power sources to the vehicle are switched without a perceivably visible break in power.

ABSTRACT OF THE DISCLOSURE

A solid state primary power switching network for modular equipment centers (MECs) distributing primary power throughout a vehicle. The solid state primary power switching network includes multiple primary power switch network devices (PPSNDs) of a MEC for controlling and distributing primary power to other MECs spatially distribute throughout a vehicle. In one or more configurations, the PPSNDs have a universal structure in that each includes a common power input source and a plurality of common power outputs. In one or more configurations, primary power sources to the vehicle are switched without a perceivably visible break in power.

MODULAR EQUIPMENT CENTER SOLID STATE PRIMARY POWER SWITCHING NETWORK

BACKGROUND

The field of the embodiments presented herein is directed toward modular vehicle architectures, and more particularly, to power switching within distributed power and data aircraft architectures.

Most commercial aircraft have one or more centralized equipment bays for housing electrical power and communications equipment. Power and data are distributed from the centralized equipment bays throughout the entire aircraft to control all functions within the aircraft. The centralized equipment bays are displaced from one another across one or more section breaks in the aircraft. Typically, one centralized equipment bay is in a forward section and the other is in an aft section of the aircraft.

Generators driven by the main propulsive engines generate three-phase primary electrical power for the aircraft. The primary power is first routed to the aft equipment bay and then through the aircraft to the forward equipment bay. The primary power is then centrally configured for distribution throughout the rest of the aircraft to service various equipment loads. Centralized bus power control units within the equipment bays control all power functions throughout the aircraft. After the centralized conversions, secondary power is routed to remote power distribution units to service the equipment loads throughout the aircraft or directly to equipment loads.

All functions of the aircraft are reliant upon the centralized power and communications equipment. If either the power or data from the centralized equipment bays is severed, the receiving equipment goes into a standby state where it becomes difficult for the flight crew to determine the state of the corresponding systems. Also, the backbone of the

communication network must be oversized because of the high bandwidth demands during peak times to and from the centralized communication equipment.

Composite aircraft do not have an aluminum chassis to serve as the return current path or network. Consequently, either a complex network of wires must be added to provide a current return path for all circuits or dedicated return wires must be added for each equipment load. For example, conductive wiring must be added that extend longitudinally along the length of the composite aircraft as well as laterally across the width of the composite aircraft. This solution adds cost, manufacturing and maintenance complexity, increased voltage drop, and undesirable weight to the composite aircraft. Thus, attempts to reduce weight in composite aircraft by minimizing wiring have been counteracted by the need for increased lightning protection components and other reasons in composite aircraft.

The aluminum chassis (e.g. components that make up the frame or skin or combination thereof) of traditional aircraft, as well as any other conductive metal structure of the aircraft, is tied together to form a current return network for returning a voltage reference point to the source distribution grounding point. The current return network also provides lightning protections as well as personal safety protection path. However, in composite aircraft where the chassis may be formed of an insulation material, the routing of wires from the generators, to the forward and aft equipment bays, to the remote power distribution units and the equipment loads they service, and back to the forward equipment bay via the current return network, creates a large wire loop. In a composite aircraft, this long wire loop may induce a large current during a lighting strike to the aircraft under certain conditions. To address this concern, the wire loop may be shielded but this large wire loop and its shielding would undesirably contribute a significant amount of weight in the aircraft.

Commercial aircraft may be manufactured in separate sections that are then connected together to assemble a complete aircraft. Various systems in the aircraft may have components that are distributed across multiple sections. Before the sections are finally

assembled together, many of the components in a section are installed and tested to confirm that they were assembled correctly. Therefore, to test and verify a section, the portions of the systems that are not yet present in the build sequence have to be emulated. Once section installations have been tested, final assembly of the sections forming the aircraft can be performed that would make repairs to errors found after this stage more difficult to correct due to limited accessibility.

In today's aircraft, one of the reasons final assembly is such a time consuming process is because of the large number of primary and secondary power connections and the large number of data connections between adjacent sections. Aircraft could be built at a faster rate and orders for completed aircraft could be filled more quickly by functionally testing systems earlier in the build cycle, thus eliminating the need to emulate some equipment located in other parts of the aircraft, reducing the number of connections across section breaks, eliminating integration panels, and by minimizing the weight and complexity of aircraft wiring.

It is with respect to these and other considerations that the disclosure herein is presented.

SUMMARY

It should be appreciated that this Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to be used to limit the scope of the claimed subject matter.

According to one embodiment disclosed herein, a primary power switching network for use with a vehicle is provided. The power switching network comprises modular equipment centers (MECs) spatially distributed throughout the vehicle. Each of the MECs is configured for a primary power input for receiving distributed primary power. Equipment loads throughout the vehicle are serviced by the nearest MEC. The primary power switching network further comprises primary power switching network devices (PPSNDs) within one or more of the MECs. The PPSNDs have a common configuration

relative to one another such that each PPSND comprises at least one common power input source and common power outputs.

According to another embodiment disclosed herein, a solid state primary power switching network for use with a vehicle is provided. The power switching network comprises first and second MECs spatially distributed throughout the vehicle. First and second primary power sources distribute poly-phase power to the first and second MECSs. Equipment loads throughout the vehicle are serviced by the nearest of the first and second MECs. PPSNDs within each of the first and second MECs, share a common configuration relative to one another such that each of the PPSNDs comprise a common power input source and common power outputs. Each PPSND within the first MEC receives a different phase of the three-phase primary power from the first primary power source and each PPSND within the second MEC receives a different phase of the three-phase primary power from the second primary power source.

According to yet another embodiment disclosed herein, a primary power switching network for use with a vehicle is provided. The primary power switching network comprises a MEC for use within the vehicle and a primary power source configured to distribute three-phase primary power to the MEC. Equipment loads in the vehicle are serviced by the MEC. At least three primary power switching network devices (PPSNDs) within the MEC having a common configuration relative to one another such that each PPSND comprises a common power input source and common power outputs. Each PPSND within the MEC receives a different phase of the three-phase primary power generated from the primary power source.

According to yet another embodiment disclosed herein, a primary power switching network system is provided. The primary power switching network system includes a plurality of primary power switching buses configured for distributing primary power to a plurality of MECs. The primary power switching network system also includes at least one standalone solid state switch on the primary power switch network system. The solid state switch includes a self-contained control function configured to provide one or

more of localized protections, voltage sensing, and current sensing. Opening and closing of the solid state switch interrupts and routes primary power across one or more of the primary power switching buses to one or more of the plurality of MECs.

According to still yet another embodiment disclosed herein, a fast break power transfer system for switching between primary power sources to a vehicle is provided. The system comprises primary power sources having different output frequencies configured to provide high voltage AC power inputs to a high voltage primary power bus. A static inverter is configured for receiving a DC input and a solid state power breaker (SSPB) between the static inverter and a backup bus is coupled to the high voltage primary power bus. The static inverter is further configured to sync to the output frequency and phasing of the primary power source powering the high voltage primary power bus and the SSPB is configured to provide a control frequency output and a voltage from the static inverter to the backup bus. The high voltage primary power bus remains continuously powered during a power transfer to another of the available primary power sources.

According to another embodiment disclosed herein, a method for uninterrupted switching between primary power sources to a vehicle is provided. The method comprises providing first and second primary power sources having different output frequencies, providing a high voltage AC power input to a high voltage primary power bus from the first high voltage AC power source, synchronizing a static inverter to the output frequency of the first power source powering the high voltage primary power bus, interrupting the high voltage AC power from the first primary power to the high voltage primary power bus, in response to interrupting the high voltage AC power from the first primary power source, providing a control frequency output and a voltage from the static inverter to a backup bus coupled to the high voltage primary power bus, powering the high voltage primary power bus from the backup bus until the second primary power source powers the high voltage primary power bus, changing the output frequency of the static inverter to match the output frequency of the second primary power source, taking

the static inverter offline upon the occurrence of matching output frequencies; and powering the high voltage primary power bus from the second primary power source.

In one embodiment there is provided a primary power switching network for use with a vehicle. The power switching network includes a plurality of modular equipment centers (MECs) spatially distributed throughout the vehicle. Each of the plurality of MECs includes at least one primary power input configured for receiving primary power. The power switching network further includes a plurality of equipment loads throughout the vehicle. Each of the plurality of equipment loads is serviced by a nearest MEC of the plurality of MECs. The power switching network further includes a plurality of primary power switching network devices (PPSNDs) within one or more of the plurality of MECs. The plurality of PPSNDs have a common configuration relative to one another such that each PPSND includes at least one common power input source and a plurality of common power outputs.

Each PPSND within one of the plurality of MECs may further include a primary power bus configured for distributing primary power to one or more other ones of the plurality of MECs.

Each PPSND within one of the plurality of MECs may further include at least one first tie bus configured for distributing primary power to one or more other ones of the plurality of MECs.

Each PPSND within one of the plurality of MECs may further include at least one second tie bus configured for receiving primary power from one or more other ones of the plurality of MECs.

Each PPSND within one of the plurality of MECs may further include a plurality of common power output connections configured for distributing primary power.

At least one of the plurality of common power output connections may be configured for distributing primary power to a primary MEC.

At least one of the plurality of common power output connections may be configured for distributing primary power to a secondary MEC.

At least one of the plurality of common power output connections may be configured for distributing power to a high voltage AC load.

The primary power switching network may further include at least one power distribution module configured for receiving power from the plurality of PPSNDs within one of the plurality of MECs and distributing secondary power to equipment loads of the one of the plurality of MECs.

At least one PPSND within one of the plurality of MECs may be coupled to a multi-layered integrated truss system. The multi-layered integrated truss system may include at least one power transfer layer wherein the power transfer layer receives electrical power from a high power portion of the one of the plurality of MECs through the at least one PPSND and the power transfer layer includes a path for providing the electrical power to a low power portion of the one of the plurality of MECs.

Each PPSND of the plurality of PPSNDs may further include a plurality of contactors. At least a portion of the plurality of contactors on the each PPSND may be arranged in a common configuration relative one another for switching power from the at least one common power input source to the plurality of common power outputs.

The primary power switching network may further include at least one primary power source configured to distribute primary power to the plurality of MECs. The at least one primary power source may provide poly-phase primary power to the plurality of PPSNDs within the one or more of the plurality of MECs.

The primary power switching network may further include at least one primary power source configured to distribute primary power to the plurality of MECs. The at least one primary power source may provide three-phase primary power to the plurality of PPSNDs within the one or more of the plurality of MECs.

The one or more of the plurality of MECs may include at least three PPSNDs. Each of the at least three PPSNDs may receive a different phase of the three-phase primary power.

In another embodiment there is provided a solid state primary power switching network for use with a vehicle. The power switching network includes first and second modular equipment centers (MECs) spatially distributed throughout the vehicle, first and second primary power sources distributing poly-phase primary power to the first and second MECs, and a plurality of equipment loads throughout the vehicle. Each of the equipment loads serviced by a nearest one of the first and second MECs. The power switching network further includes a plurality of primary power switching network devices (PPSNDs) within each of the first and second MECs, the plurality of PPSNDs sharing a common configuration relative to one another such that each PPSND include at least one common power input source and a plurality of common power outputs. Each PPSND of the plurality of PPSNDs within the first MEC receives a different phase of the poly-phase primary power from the first primary power source and each PPSND of the plurality of PPSNDs within the second MEC receives a different phase of the poly-phase primary power from the second primary power source.

The first and second MECs may be primary MECs and the first and second primary power sources are generators.

In another embodiment there is provided a primary power switching network for use with a vehicle. The power switching network includes a modular equipment center (MEC) for use within the vehicle, at least one primary power source configured to distribute three-phase primary power to the MEC, a plurality of equipment loads in the vehicle serviced by the MEC, and at least three primary power switching network devices (PPSNDs) within the MEC, the at least three PPSNDs having a common configuration relative to one another such that each PPSND includes at least one common power input source and a plurality of common power outputs. Each PPSND receives a different phase of the three-phase primary power generated from the primary power source.

In another embodiment there is provided a primary power switching network system including a plurality of primary power switching buses configured for distributing primary power to a plurality of modular equipment centers (MECs) and at least one standalone solid state switch on the primary power switch network system. The at least one standalone solid state switch has a self-contained control function configured to provide one or more of localized protections, voltage sensing, and current sensing. Opening and closing of the at least one standalone solid state switch interrupts and routes primary power across one or more of the primary power switching buses to one or more of the plurality of MECs.

The standalone solid state switch may include pulse width modulation to limit current flow through the standalone solid state switch.

In another embodiment, there is provided a primary power switching network for use with a vehicle. The power switching network includes a plurality of modular equipment centers (MECs) spatially distributed throughout the vehicle. Each of the plurality of MECs includes at least one primary power input for receiving primary power from a primary power source. The primary power source is connected to the at least one primary power input by at least one primary power conductor. The power switching network further includes a plurality of equipment loads throughout the vehicle. Each of the plurality of equipment loads is serviced by a nearest MEC of the plurality of MECs. The power switching network further includes a plurality of primary power switching network devices (PPSNDs) within each MEC of the plurality of MECs. The plurality of PPSNDs have a common configuration relative to one another such that each PPSND of the plurality of PPSNDs includes a common power input and a plurality of common power outputs. Each PPSND receives a different phase of a power signal provided by the primary power source.

In another embodiment, there is provided a solid state primary power switching network for use with a vehicle. The power switching network includes first and second modular equipment centers (MECs) spatially distributed throughout the vehicle, and first and second primary power sources each connected to the first and second MECs by at least one respective primary power conductor. The first and second power sources are for distributing a respective

poly-phase primary power signal to the first and second MECs. The power switching network further includes a plurality of equipment loads throughout the vehicle. Each of the equipment loads is serviced by a nearest one of the first and second MECs. The power switching network further includes a plurality of primary power switching network devices (PPSNDs) within each of the first and second MECs. The plurality of PPSNDs share a common configuration relative to one another such that each PPSND includes at least one common power input and a plurality of common power outputs. Each PPSND of the plurality of PPSNDs within the first MEC receives a different phase of the respective poly-phase primary power signal from the first primary power source and each PPSND of the plurality of PPSNDs within the second MEC receives a different phase of the respective poly-phase primary power signal from the second primary power source.

In another embodiment, there is provided a primary power switching network for use with a vehicle. The power switching network includes a modular equipment center (MEC) for use within the vehicle, at least one primary power source connected to the MEC by at least one primary power conductor and configured to distribute a three-phase primary power signal to the MEC, a plurality of equipment loads in the vehicle serviced by the MEC, and at least three primary power switching network devices (PPSNDs) within the MEC. The at least three PPSNDs have a common configuration relative to one another such that each PPSND includes at least one common power input and a plurality of common power outputs. The each PPSND receives a different phase of the three-phase primary power signal generated from the at least one primary power source.

The features and functions 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 reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments presented herein will become more fully understood from the detailed description and the accompanying drawings, wherein:

FIG. **1** illustrates a top view of one configuration of an aircraft with spatially distributed modular equipment centers (MECs) wherein equipment loads are serviced by the nearest MEC according to at least one embodiment disclosed herein,

FIG. **2** illustrates the splitting of two generators per aircraft engine relative forward and aft of the aircraft according to at least one embodiment disclosed herein,

FIG. **3** illustrates one configuration of primary power feeders connected to generators energizing a power bus network according to at least one embodiment disclosed herein,

FIG. **4** illustrates one configuration of a primary MEC and a secondary MEC according to at least one embodiment disclosed herein,

FIGS. **5**A-**5**F illustrate one configuration of a fault tolerant combined primary and secondary power distribution network of primary MECs, secondary MECS, and a standby MEC according to at least one embodiment disclosed herein,

FIG. **6** illustrates one configuration of a secondary power busing network in a forward section of the aircraft according to at least one embodiment disclosed herein,

FIG. **7** illustrates one configuration of a MEC for servicing equipment loads and having a computing and network interface module for distributed computing functions and gateway routing of bi-directional data between MECs according to at least one embodiment disclosed herein,

FIG. **8** illustrates one configuration of a data network structure with communication bus interfaces between spatially distributed MECs separated by section breaks according to at least one embodiment disclosed herein,

FIG. **9** illustrates one configuration of the computing and interface module for distributed computing functions and gateway routing of bi-directional data according to at least one embodiment disclosed herein,

FIGS. **10**A-**10**D illustrate various configurations for high voltage primary power busing structures of primary MECs relative a particular power input source and a plurality of different power outputs according to at least one embodiment disclosed herein,

FIG. **11** illustrates a common structure and layout of a primary power switching network device having a common power input source and a plurality of common power outputs for use with the primary MECs according to at least one embodiment disclosed herein,

FIGS. **12**A-C illustrate one configuration of a set of primary power switching network devices for use with a primary MEC receiving three-phase power from a generator according to at least one embodiment disclosed herein,

FIG. **13** illustrates an exploded perspective view of a multi-layered integrated truss system of a MEC according to at least one embodiment disclosed herein,

FIG. **14** illustrates one configuration of a primary MEC with multiple power and communication transfer layers according to at least one embodiment disclosed herein,

FIG. **15** generally illustrates one configuration of three-phase primary power routed from main generators to multiple transformer rectifier units (TRUs) and autotransformer units (ATUs) resulting in zero direct current (DC) offset voltage according to at least one embodiment disclosed herein,

FIG. **16** illustrates one configuration of the distribution of either alternating current (AC) or DC power from the TRUs and ATUs to equipment loads utilizing twisted and shielded electrical conductor pairs according to at least one embodiment disclosed herein,

FIG. **17** illustrates one configuration of an integrated truss system of a MEC within the floor of an aircraft according to at least one embodiment disclosed herein,

FIG. **18** illustrates one configuration of a fast break power transfer system for rapid and transparent switching between primary power sources according to at least one embodiment disclosed herein, and

FIG. **19** illustrates one configuration of a routine for uninterrupted switching between power sources is provided according to at least one embodiment disclosed herein.

Each figure shown in this disclosure shows a variation of an aspect of the embodiments presented, and only differences will be discussed in detail.

DETAILED DESCRIPTION

The following detailed description is directed to vehicles having modular equipment centers to increase vehicle system redundancies while also distributing the modular equipment centers (MECs) throughout the vehicle in such a way that minimizes wire weight and the number of required wire connections to reduce overall vehicle weight and production time. The subject matter of the present specification is susceptible of embodiment in many different forms. There is no intent to limit the principles of the present subject matter to the particular disclosed embodiments. References hereinafter made to certain directions, such as, for example, "front", "rear", "left" and "right", are made as viewed from the rear of the vehicle looking forward. In the following detailed description, references are made to the accompanying drawings that form a part hereof and in which are shown by way of illustration specific embodiments or examples. Referring now to the drawings, in which like numerals represent like elements throughout the several figures, aspects of the present disclosure will be presented.

Aspects of this disclosure may be used in many types of vehicles such as, for example, aircraft, spacecraft, satellites, watercraft, submarines, and passenger, agricultural or construction vehicles. Aspects of this disclosure may also be used in different constructions of vehicles. While the immediate benefit is towards vehicles that have non-conducting frames, chassis or skin, the disclosure features may be suitable and beneficial of vehicles constructed of conductive materials. For the sake of simplicity in explaining aspects of the present disclosure, this specification will proceed utilizing a composite aircraft **10** as the primary example. However, as will be seen, many of aspects of the present disclosure are not limited to the composite aircraft **10**.

As well understood by those skilled in the art, the exemplary aircraft **10** depicted in FIG. **1** includes a fuselage made substantially of composite materials, or composites. The outer composite skin on the fuselage of the aircraft **10** conforms to the curvature of

fuselage frames. The fuselage includes a forward section **12**, a middle section **14**, and an aft section **16**. Section breaks **18**, **20**, **22** are defined between adjacent aircraft sections. The composite aircraft **10** may have any number of engines. As shown in FIG. **1**, left engine **30** is supported on the left wing and right engine **32** is supported on the right wing. Each of the engines **30**, **32** has a rotor which defines a rotor burst zone **38** (FIG. **5**A) in which damage to the fuselage and aircraft systems between the engines **30**, **32** may occur as a result of an event or an operational inconsistency with one of the engines **30**, **32**.

The composite aircraft **10** may have any number of sections and the position of the aircraft sections or systems within the composite aircraft **10** may sometimes be described as being forward or aft of the rotor burst zone **38**. Floor beams extend between fuselage frames to define a passenger compartment above the floor beams and a cargo area for holding cargo below the floor beams. Stanchions extending between the fuselage frames and the floor provide a fulcrum to assist in stiffening the floor of the composite aircraft **10**. The passenger area is pressurized and all or part of the cargo area may be pressurized. Ducts may be positioned through the crown run of the composite aircraft **10** above the passenger compartment or below the floor in the cargo area such as between the fuselage frame and the stanchions.

On each of the engines **30**, **32** are one or more main primary power sources such as high voltage AC left power generators **34**a, **34**b and high voltage AC right power generators **36**a, **36**b (hereinafter may be referred to collectively and/or generically as "left generators **34**", "right generators **36**" or "generators **34**, **36** "). Primary power feeders **40**a and **40**b extend from the left generators **34**a, **34**b and primary power feeders **42**a and **42**b extend from the right generator **36**a, **36**b. As shown in FIG. **1**, primary power is distributed throughout the composite aircraft **10** via the primary power feeders **40**a, **40**b, **42**a, **42**b (hereinafter may be referred to collectively and/or generically as "power feeders **40**, **42**"). The composite aircraft **10** may also have one or more high voltage AC auxiliary power unit generators **54** for redundancy in the event one or more of the

generators **34**, **36** fail, as well as to provide power when the engines **30**, **32** are not running. When the composite aircraft **10** is parked and the engines are not running, power may be provided to the aircraft by one or more power sources such as high voltage AC external power unit **56**.

For purposes of this disclosure, low voltage and high voltage are those voltages typically referred to as either low or high voltage within the aircraft industry and as may be described in DO-**160**, Environmental Conditions and Test Procedures for Airborne Equipment, a standard for environmental test of avionics hardware published by RTCA, Incorporated. Throughout this disclosure, **230** VAC is referred to as high voltage but another voltage within a range of voltages, higher or lower than **230** VAC, could also be referred to as high voltage. Also, **28** VDC and **115** VDC are referred to as low voltages but another voltage within a range of voltages, higher or lower than either of **28** VDC and **115** VDC, could also be referred to as low voltage.

The composite aircraft **10** in FIG. **1** does not have dedicated centralized equipment bays for housing power and communications equipment. The equipment is configured into modular power and communication equipment centers, referred to as MECs, that are spatially distributed throughout the composite aircraft **10**. For example, one or more MECs are spatially distributed in each of the forward, middle and aft sections **12**, **14**, **16**. Each of the MECs provide localized power conversion and may be either a primary MEC **44**, a secondary MEC **46**, or an auxiliary or standby MEC **48**, as described in greater detail below. Primary MEC **44**, secondary MEC **46** and standby MEC **48** may generally be referred to as "MEC" with one or more applicable reference numbers **44**, **46**, **48**. Primary power is distributed from the generators **34**, **36** via power feeders **40**, **42** across section breaks **18**, **20**, **22** to a primary power input of each of the MECs **44**, **46**, **48**.

For optimized fault tolerance, the aircraft **10** may include a standby MEC **48** positioned in the rear of the aircraft **10** and at least two MECs **44**, **46** positioned in each of the forward, middle, and aft sections **12**, **14**, **16** of the aircraft **10**. For example, in FIG. **1** redundancy may be achieved by having multiple MECs **44**, **46**, **48** in each aircraft section without having to cross section breaks **18**, **20**, **22**. Preferably, each section **12**, **14**, **16**

includes a primary MEC **44** and a corresponding secondary MEC **46** thereby defining a two by three configuration of MECs **44**, **46** plus a standby MEC **48**. If there are four separate aircraft sections then there is a two by four configuration of MECs **44**, **46**. Preferably, the MECS **44**, **46**, **48** are alternately spaced on the left and right sides relative to one another along the length of the aircraft **10**. It should be understood that the present disclosure is not limited to any particular number or configuration of MECs **44**, **46**, **48**.

Equipment loads **50** may be various electrical loads in an aircraft including, but not limited to, displays, fans, environmental units, and the like. Sometimes an equipment load **50** may be in the form of a line replaceable unit (LRU) **52** (FIG. **4**). The equipment loads **50** within each of the aircraft sections **12**, **14**, **16** are grouped into one or more zones of power and communication. Each zone of equipment loads **50** across multiple systems may be associated with and serviced by the nearest MEC **44**, **46**. Preferably, each zone of equipment loads **50** is located within a single section and associated with at least one MEC location in the same zone. Preferably, the connecting wires or lines do not cross section breaks **18**, **20**, **22**.

Generally, any equipment load **50** on the aircraft **10** requires both electrical power and communication data. Data is needed to tell the equipment load **50** what to do, or provide feedback about its current status, while electrical power is needed so the equipment load **50** can perform its intended function. If power and data are provided to an equipment load **50** from different equipment centers and if one of either the power or data is lost then the equipment load **50** then has an indeterminable state. To avoid indeterminate states each MEC **44**, **46**, **48** independently provides both the electrical power and communication data for servicing each of the localized equipment loads **50** within an associated zone. The electrical power and data communication to an equipment load **50** may be synced or grouped together in that both the power and the data communication provided to the equipment load **50** originate from a single source such as the nearest MEC **44**, **46**, **48**. Synced electrical power and communication data is sometimes referred to as a power channel. Each of the equipment loads **50** within a zone may receive power

from a particular MEC **44**, **46** and therefore the network communication switches providing data to those same equipment loads **50** are powered by that same MEC **44**, **46**.

The MECs **44**, **46**, **48** are configured to distribute power received from the main power sources. The MECs **44**, **46**, **48** may independently convert the primary power into secondary power. Secondary power may be distributed from the MECs **44**, **46**, **48** to then independently service each of the equipment loads **50** within each zone without a secondary branch power network extending across the section breaks **18**, **20**, **22**. In such case, control and conversion of the primary power may be distributed to each of the primary MECs **44** of each section of the aircraft **10** such that only primary power is distributed across the section breaks **18**, **20**, **22** amongst the primary MECs **44**. Ina preferred configuration, only high voltage power feeders and the data backbone cross production breaks.

Distributing only primary power across section breaks **18**, **20**, **22** reduces the amount of wire required for distributing secondary power across multiple sections of the aircraft **10**. This is because the distributed MEC architecture creates a separate secondary power distribution network within each section that allows for shorter runs of secondary wiring. Doing so reduces the overall weight of the wire utilized throughout the aircraft as well as the number of secondary connections required when joining adjacent fuselage sections. Also, because of the shorter secondary power runs, the total loop area of the power feeder run is reduced as compared to an implementation within a current return network. Moreover, aircraft production processes are improved because the secondary power network of wires extending across section breaks are limited or eliminated. The reduction of secondary power wires extending across section break are more readily tested and build quality verificd earlier due to reduced reliance on other sections before final assembly of the aircraft **10**.

As shown in FIG. **1**, primary power feeder **40**a extends from generator **34**b on the left engine **30** into the middle section **14** to a MEC **44** shown on the left side of the mid section **14**, across section break **20** to another MEC **44** shown on thc left side of forward section **12**, and then to another MEC **44** shown on the left side in front of forward section

12. Primary power feeder **40**b extends from generator **34**a on the left engine **30** into the middle section **14** to a MEC **44** on the left, across section break **22** to a left aft MEC **44**, and then to a left aft MEC **48**. Power feeder **42**a extends from generator **36**a on the right engine **32** into the middle section **14**, across section break **20** to a MEC **44** on the right in forward section **12**, and then to another MEC **44** on the right in front of the forward section **12**. Primary power feeder **42**b extends from generator **36**b on the right engine **32** into the middle section **14** to middle right MEC **44**, across section break **22** to right aft MEC **44**, and then to right aft MEC **44**. Alternatively, the power feeders **40**a, **40**b could instead provide primary power to the MECs **44** on the right side of one or more sections of the aircraft **10**. In such case, the power feeders **42**a, **42**b would provide primary power to the MECs **44** on the left side of one or more sections the aircraft **10**.

Also, one of the generators **34**a, **34**b on the left engine **30** could provide primary power to one side of the aircraft forward of a rotor burst zone **38** and the other of generators **34**a, **34**b on the left engine **30** could provide primary power to the other side of the aircraft **10** aft of the rotor burst zone **38**. In such case, one of the generators **36**a, **36**b on the right engine **32** could provide primary power forward of the rotor burst zone **38** to the opposite side that is powered by one of the left generators **34**a, **36**b. The other of generators **36**a, **36**b on the right engine **32** could provide primary power aft of the rotor burst zone **38** to the opposite side powered by the other one of the left generators **34**a, **36**b.

FIG. **2** illustrates splitting two generators per engine relative the rotor burst zone **38** of the aircraft **10** which increases the availability of primary power in the event of an operational issue with an engine **30**, **32**. If one of the engines **30**, **32** is lost, or a generator **34**, **36** within one of the engines **30**, **32** fail, the two remaining generators **34**a, **34**b, **36**a, **36**b on the remaining engine **30**, **32** distribute both forward and aft primary power to the aircraft **10**. Generator **34**a of the left engine **30** and generator **36**a of the right engine **32** power a pair of primary power switching buses **96**a forward of the rotor burst zone **38** that are connected to one another by a forward tie bus **76**. Generator **34**b of the left engine **30** and generator **36**b of the right engine **32** power another pair of

primary power switching buses **96**a aft of the rotor burst zone **38** that are connected by an aft tie bus **78**. A mid tie bus **80** connects at least one of the forward primary power switching buses **96**a with at least one of the aft primary power switching buses **96**a. Therefore, when an engine **30**, **32** experiences an operational inconsistency, the aircraft **10** continues to have power and control on one side along the entire length of the aircraft **10** due to the distribution of power from the remaining engine **30**, **32** in a forward and aft manner. The power and control is distributed from a single engine **30**, **32** both forward and aft of the rotor burst zone **38** without increasing the amount of wiring. FIG. **2** also illustrates the primary power switching buses **96**a distributing power to the secondary MECs **46** for power conversion and distribution to equipment loads **50** as explained in greater detail below. A standby MEC **48** may be coupled to the secondary MECs **46** to provide backup power when the primary main AC power sources are not available to the primary power switching buses **96**a as explained in greater detail below.

Unserviced equipment loads **50** in one or more zones occurs primarily for two reasons. Either all of the generators **34**, **36** failed and therefore primary power is no longer available to any of the MECS **44**, **46** or one or more of the buses **96** are physically damaged due to an event such as a rotor or tire burst. Rerouting of high voltage power from either of the four generators **34**, **36** or auxiliary power unit generator **54** based on failure of one or more main primary power sources occurs at the primary bus level via the tie buses **76**, **78**, **80** through opening and closing of combinations of switches as shown by the primary power busing network system **90** depicted in FIG. **3**. In one or more embodiments, one or more standalone solid state switches, for example contactors, are included on the primary power switch network system **90**. The solid state switches each have a self-contained control function configured to provide one or more of localized protections, voltage sensing, and current sensing, independent of the availability of other power system components. The standalone solid state switch can function without the need for data from other power system components. Opening and closing of the solid state switch interrupts and routes primary power across one or more of the primary power switching buses to one or more of the MECs **44**, **46**, **48**. Beginning

with FIG. **3**, contactors **216**, **218**, **220**, **222**, **250**, **260**, and **269** are depicted as either primarily closed or primarily open. The symbol for an open contactor is two parallel lines. The symbol for a normally closed contactor is the same with the exception that a diagonal line is drawn through the parallel lines. The standalone solid state switch may also include pulse width modulation to limit current flow through the standalone solid state switch. Rerouting of secondary power and low voltage DC between the MECs **44**, **46**, **48** based on failure of high voltage buses and conversion occur by the opening and closing of combinations of switches as shown by the primary power busing network **90** as depicted in FIG. **3**.

Each MEC **44**, **46**, **48** has both primary and standby power and is capable of independently performing closed loop processing and local control of sensors without being dependent on a central computer system. The distributed power system control architecture permits sharing of the overall vehicle power distribution status among the MECs **44**, **46**, **48** but each MEC **44**, **46**, **48** is only responsible for servicing equipment loads **50** in proximity of each MEC, with the exception of MEC **48** which also distributes standby power to all other MECs **44**, **46**. Each MEC **44**, **46**, **48** manages data associated with the zone of the nearest equipment loads **50** such that each MEC **44**, **46**, **48** independently performs operations within its own zone of equipment loads **50**.

Each MEC **44**, **46**, **48** also preferably has solid state switching for bus power control and also provides circuit protections. In FIG. **3** power from primary power feeders **40**, **42** connected to the generators **34**, **36** energizes primary power switching buses **96**a. Each primary power switching bus **96**a branches off to a primary power switching bus **96**b within MEC **44** and a primary power switching bus **96**c within MEC **46**. Each primary power switching bus **96**a connected with distribution feed **98** to a primary power switching bus **96**b corresponds with a single primary MEC **44** as shown in FIG. **4** and as described in greater detail below.

Referring to FIG. **4**, a portion of each primary MEC **44** with a primary power switching bus **96**a is a high power portion **120** and another portion of the primary MEC **44** with the primary power switching bus **96**b is a low power portion **122** of the primary MEC **44**. The high power portion **120** of a primary MEC **44** is configured to receive primary

power from any high power main source available to the aircraft **10** and is sometimes referred to as a primary power switching network device **302** (FIG. **12**A-**12**C). The network of high power portions **120** of the primary MECs **44** within the aircraft **10** define a high voltage primary power switching network.

The low power portion **122** is preferably configured to handle a fraction of the power from onboard power sources but still be able to handle the same voltages as the high power portions **120**. The primary power switching buses **96**c correspond with secondary MECs **46** shown in FIG. **4**. FIG. **4** best illustrates the similarity between a secondary MEC **46** and the low power portion **122** of a primary MEC **44**. Primary MECs **44** include the primary level power network busing structure of primary power switching buses **96**a to reroute primary sources across the aircraft **10** that the secondary MECs **46** do not have. During normal as well as abnormal operations, the primary and secondary MECs **44**, **46** both have primary and standby power. Secondary MECs **46** service the nearest equipment loads **50** just like a primary MEC **44**.

Referring back to FIG. **3**, distribution feeds **98** extend between primary power switching buses **96**a and **96**b of each primary MEC **44** and distribution feeds **100** extend between each bus **96**b of the primary MEC **44** and the primary power switching bus **96**c of a secondary MEC **46** that directly receives power from the same source. Also, a crosstie **102** extends between the bus primary power switching **96**b of the primary MEC **44** associated with left generator **34**a and the primary power switching bus **96**b of the primary MEC **44** associated with the right generator **36**a. A crosstie **104** extends between the primary power switching bus **96**c of the secondary MEC **46** associated with left generator **34**a and the primary power switching bus **96**c of the secondary MEC **48** associated with the right generator **36**a. A crosstie **106** extends between the primary power switching bus **96**b of the primary MEC **44** associated with left generator **34**b and the primary power switching bus **96**b of the primary MEC **44** associated with the right generator **36**b. A crosstie **108** extends between the primary power switching bus **96**b of the secondary MEC **46** associated with generator **34**b and the primary power switching

bus **96**b of the secondary MEC **46** associated with the right generator **36**b. Auxiliary power unit generator **54** is connected to the crossties **102**, **106**, respectively.

FIG. **5**A illustrates one configuration of the fault tolerant combined primary and secondary power distribution networks of primary, secondary and standby MECS **44**, **46**, **48** within the aircraft **10**. For purposes of illustrating greater detail, FIGS. **5**B-**5**E illustrate close-up partial views of four separate portions which can be positioned next to each other to assemble the complete system depicted in FIG. **5**A. Two dot-dash lines on each of FIGS. **5**B-**5**E denote the broken edges of each partial view. FIG. **5**B illustrates the top left portion of FIG. **5**A. FIG. **5**C illustrates the top right portion of FIG. **5**A. FIG. **5**D illustrates the bottom left portion of FIG. **5**A and FIG. **5**E illustrates the bottom right portion of FIG. **5**A. Also, FIG. **5**F illustrates one configuration of the standby MEC **48** of the system of FIG. **5**A. The contactors shown in FIG. **3** are also shown symbolically in FIGS. **5**A-**5**F, but without reference numbers to simply **5**A-**5**F, and may also be shown in other drawings without any reference numbers or having different reference numbers.

In FIG. **5**A the primary and secondary MECS **44**, **46** are arranged in such a way that there are a total of four in the forward sections of the aircraft **10** and another four in the aft sections of the aircraft **10**. Preferably, there is a primary MEC **44** and a secondary MEC **46** in each of a pair of forward sections and a primary MEC **44** and a secondary MEC **46** in each of a pair of aft sections. FIG. **5**A also shows a standby MEC **48** in an aft section of the aircraft **10**. The non-time limited power source for the standby MEC **48** can be a RAM air turbine (RAT) **128** or other suitable independent time limited standby power source such as a battery or fuel cell. In the event of an operational inconsistency with all the generators **34**, **36**, the RAT **128** is deployed to provide standby power to standby MEC **48** as well as to one or more of the MECs **44**, **46** in the event that all of the generators **34**a, **34**b, **36**a, **36**b have an operational inconsistency. The battery **598** provides temporary operational power to standby MEC **48** as well as to one or more of the MECs **44**, **46** while the non-time limited RAT **128** is being deployed.

If one of the generators **34**a, **34**b, **36**a, **36**b fails, power is not being received at the primary power switching bus **96**a of a primary MEC **46**. Therefore, the equipment loads

50 off of the lower power portion **122** of the primary power switching bus **96**b of the unpowered primary MEC **44** are unserviced and the equipment loads **50** off of the primary power switching bus **96**c of an unpowered adjacent secondary MEC **46** are unserviced. Power is then rerouted at the primary level from one of the other remaining operational sources by opening and closing of combinations of contactors to energize primary power switching bus **96**a of unpowered primary MEC **44** to power its equipment loads **50** and to energize primary power switching bus **96**c of any unpowered adjacent secondary MEC **46** to power its equipment loads **50**.

Alternatively, if a MEC **44**, **46**, **48** experiences a physical failure and as result its equipment loads **50** are unpowered, then power may be rerouted to power the equipment loads **50** of the unpowered MEC **44**, **46**, **48** by another powered MEC **44**, **46**, **48**. Depending on the amount of power available to be rerouted, all or only a portion of the equipment loads **50**, such as only the critical loads, may be repowered. Also, if all power sources are lost and the MECs **44**, **46**, **48** are unpowered, then the standby MEC **48** with the fuel cell or RAT **128** can power the critical equipment loads **50** of the other MECs **44**, **46**. Critical loads are those equipment loads **50** that the aircraft **10** must have powered to maintain continued safe flight and landing. Essential loads are those equipment loads **50** that are desirable to have such as radios and other communications equipment but operation is not required to fly the aircraft **10**. Non-essential loads are the lowest priority equipment loads **50** such as passenger comfort loads including food preparation devices, decorative lighting and cabin entertainment systems.

By way of example, the auxiliary power unit generator **54** could service the equipment loads **50** lost due to the failure of one of the main generators **34**, **36**. If generator **34**b fails then, through a combination of contactors in forward tie bus **76**, aft tie bus **78**, mid tie bus **80**, primary power is provided directly from the remaining main generators **34**, **36**. Alternatively, primary power may be provided from the auxiliary power unit generator **54** through another operational MEC **44**, **46** across one or more of the crossties **102**, **104**, **106**, **108**, to the primary power switching bus **96**a of an unpowered primary MEC **44** or to the primary power switching bus **96**c of an unpowered secondary MEC **46**.

In the event one or more of the MECs **44**, **46** has a physical operational inconsistency, all or part of the plurality equipment loads **50** within the zone associated with each operationally inconsistent MEC **44**, **46** can be associated with one or more other MECs **44**, **46** that are nearest in proximity. For example, if a primary MEC **44** physically fails, the equipment loads **50** once serviced by that failed MEC **44** may be serviced by another MEC **44**, **46** or a combination of MECs **44**, **46**. MECs **44**, **46** can determine the types of equipment loads **50** once serviced by the failed MEC **44** and then determine whether one or more of the combination of MECs **44**, **46** should service those unpowered equipment loads **50**. If it is determined that a secondary MEC **46** in closest proximity to the failed primary MEC **44** is to service the additional equipment loads **50** then the zone originally associated with that secondary MEC **46** is expanded to encompasses the zone formerly serviced by failed primary MEC **44**.

Alternatively, the additional equipment loads **50** may be divided between a secondary MEC **46** and another primary MEC **46** in proximity to the failed primary MEC **46**. In such case, the zone of equipment loads **50** associated with the nearest operational primary MEC **44** is expanded to include a portion of the zone formerly serviced by failed primary MEC **44** and the zone of equipment loads **50** associated with the nearest operational secondary MEC **46** is expanded to include the remaining portion of the zone formerly serviced by failed primary MEC **44**. In either case, one or more other MECs **44**, **46** in proximity of a failed MEC **44**, **46** are sourced to independently provide the services to the equipment loads **50** previously serviced by the failed MEC **44**, **46**.

Each secondary MEC **46** and each low power portion **122** of each primary MEC **44** includes contactors coupled to conversion equipment. The conversion equipment includes a transformer rectifier unit (TRU) **134**, which rectifies the **230** VAC and converts it to the main DC output such as **28** VDC for bus **136**, and an autotransformer or autostep down transformer unit (ATU) **138** to convert **230** VAC to **115** VAC for a low power AC output bus **140**. Each secondary MEC **44** and low power portion **122** of a primary MEC **44** further includes a second TRU **142**, not just for redundancy, but to provide power only to the critical loads absolutely necessary for continued safe flight and

landing. Limiting the second TRU **142** to only critical loads ensures that the standby power sources are not overloaded.

FIG. **6** illustrates the configuration of a secondary power busing configuration, in forward section **12** for example, where the primary power switching buses **96**b in the low power portions **122** of the primary MECs **44** and the primary power switching buses **96**c of the secondary MECs **46** are tied together. As described above, whether all or only a portion of the unpowered equipment loads **50** of a damaged MEC **44**, **46** are serviced by another MEC **44**, **46** depends on available power. In the event one of the TRUs **134** in one of the MECs **44**, **46** within an aircraft section fails, the most critical of equipment loads **50** from the operationally inconsistent TRU **134** may be serviced by another MEC **44**, **46** in that same aircraft section providing secondary power across the various contactors **220**, **222**, and **296** and backup buses **148**.

Preferably MECs **44**, **46** in the aft section **16**, have secondary power tie-ins from the auxiliary power unit generator **54** due to their proximity to one another which minimizes the power feeder wire weight. Also, the MECs **44**, **46** in the forward section **12** of the aircraft **10** tie in at lower voltage levels such as **115** VAC from the external power ground service equipment such as external power unit **56** as shown in FIGS. **2** and **6**. However, the **115** VAC from the ground to the low power AC output buses **140** in the MECs **48** in the forward section **12** could be converted to higher voltages such as **230** VAC by bi-directional ATUs **138** which then may be distributed to the other MECs **44**, **46** in other sections of the aircraft **10**. Also, a second TRU **142**, typically used for more critical loads as explained above, allows battery power from battery bus **294** via backup bus **148** to power those critical loads that were lost.

As shown in FIG. **7**, a computing (comprising hardware and software) and network interface (CNI) module **162** located inside each MEC **44**, **46**, **48** provides distribute computing functions and gateway routing of bi-directional data. Each CNI module **162** contains two failsafe computing systems that become a fault tolerant computing system. Each fail safe computing system is redundant to the other. This fault tolerant computing system responds gracefully to unexpected hardware and/or software failures to allow no

loss of service to system functions within the aircraft **10**. The CNI module **162** transmits/receives data to/from internal MEC computing functions and external MEC computing functions via an internal system communication bus (such as FlexRay, Controller Area Network (CAN), ARINC **664**, TTP or other bus technology). Other MECS **44**, **46**, **48** on the aircraft **10** will communicate with the CNI module **162** via a data networking specification, such as the ARINC **664**, across external data communication channel A and external data communication channel B as shown in FIG. **7** having reference numbers **188** and **190**, respectively.

The CNI module **162** is a distributed computing element that hosts specific software applications used within that localized zone of the aircraft **10**. Some examples of the system applications that can be hosted on the CNI module **162** are the AC and DC power systems, cargo door system, passenger entry door system, landing gear system, and passenger cabin system. The computing functions that communicate to the CNI module **162** are TRUs **134**, TRUs **142**, ATUs **138**, solid state switches of a breakers module **166**, a generator control unit GCU **168** associated with one of the generator **34**, **36**, solid state power distribution modules **170**, and remote data concentrators. The CNI module **162** communicates internally within the MEC **44**, **46**, **48** across internal data channel A **202** and internal data channel B **204** to the TRUs **134**, **142**, the ATUs **138**, the breaker modules **166**, the GCU **168**, and the power distribution modules **170** as described in greater detail below.

The CNI module **162** will transmit and receive data to/from these computing functions. The CNI module **162** will also transmit and receive the status and health from other MECs **44**, **46**, **48** and aircraft computing systems. Each CNI module **162** manages the workload of an individual MEC **44**, **46**, **48** with knowledge of what is going on in other MECs **44**, **46**, **48**. Once the information has been received by the CNI module **162** of a MEC **44**, **46**, **48**, its computing function will determine which system needs the data, interpret the health of the data, respond to any power system anomalies, supply time-critical information to computing functions that need it, perform system level logic

algorithms, report airplane level system faults, and control the distribution of AC and DC power for that zone.

FIG. **8** illustrates the data network structure with communication bus interfaces between the spatially distributed MECs **44**, **46**, **48** separated by section breaks **18**, **20**, **22**. This configuration allows each individual MEC **44**, **46**, **48** to communicate with other MECs **44**, **46**, **48** as well as provide the redundancy required to ensure continued communication across failures. Section break **20** defines forward and aft sections of the aircraft. The number of network communication switches needed is determined by the number of MECs **44**, **46**, **48** and the desired fault tolerance. FIG. **8** illustrates nine MECs **44**, **46**, **48** with three pairs of network switches **182**a-b, **184**a-b, **186**a-b (hereinafter may be referred to collectively and/or generically as "network switches **182**, **184**, **186**"). Each network switch **182**, **184**, **186** may be a multilayer network switch such as a layer-**3** network switch that can receive secondary electrical power from the CNI modules **162** of each of the interfacing MECs **44**, **46**, **48**. If there were more MECs **44**, **46**, **48** then more network switches would be required to achieve the same level of fault tolerance.

Each MEC **44**, **46**, **48** has A and B communication channels. Channels A and B of each primary MEC **44** connects to two corresponding A or B switches on either another primary MEC **44** or on a standby MEC **48**. Each primary MEC **44** includes one network switch **182**, **184**, **186** on either channel A or channel B, while standby MEC **48** in an aft section of the aircraft includes both switches of a pair of network switches **182**, **184**, **186** on both A and B channels. Switches **182**a, **184**a, **186**a correspond with channel A and switches **182**b, **184**b, **186**b correspond with channel B. External communication data lines **192** indicate switch to switch data lines.

Generally, a network switch on each primary MEC **44** on one side of the section break **20** is connected to two other network switches of other primary or standby MECs **44**, **48** where at least one of those MECs **44**, **48** is on the other side of the section break **20** and one is on the opposite side of the aircraft **10**. For example, network switch **182**a of the forward right primary MEC **44** that is forward of the section break **20** is connected on the other side of the section break **20** to both network switch **184**a on the aft left primary

MEC **44** and to network switch **186**a on the standby MEC **48**. Network switch **182**b on the forward left primary MEC **44** that is forward of the section break **20** is connected on the other side of the section break **20** to both network switch **184**b on the aft right primary MEC **44** and to network switch **186**b on the standby MEC **48**. Network switch **186**b on the standby MEC **48** is also connected to network switch **184**b on the opposite side of the aircraft **10**. Network switch **184**a is also connected to network switch **186**a of the standby MEC **48**.

Each of the secondary MECs **46** also has two data channels with two other primary or standby MECs **44**, **48**. External communication data lines **196** indicate data connections of a network switch of a primary MEC **44** directly to a secondary MEC **44**. One of the channels of each secondary MEC **48** is connected to a network switch on the same channel of a primary MEC **48** on the other side of the section break **20** and the other channel is connected to another secondary MEC **46**. Therefore, FIG. **8** shows eight data bus connections crossing section break **20** and four data bus connections crossing each of the section breaks **18**, **22**. This configuration minimizes the amount of communication wiring across section breaks as well as the overall weight of wiring in the aircraft. Separation is maintained between each data bus by utilizing the space in the crown and the floor of the aircraft **10**. Healthy CNI modules **162** can optimally respond to changing configurations of the power system in a coordinated fashion by utilizing local environment information and communications from other healthy CNI modules **162**.

If any two MECS **44**, **46**, **48** are powered then the communication network will be active and data will be present so that those two MECS **44**, **46**, **48** can fully communicate with each other. This communication network is a fault tolerant network in that any one connection between a pair of MECs may be lost without reducing any MEC **44**, **46**, **48** functionality. Moreover, loss of any two communication connections at the same time between the MECs **44**, **46**, **48** at most results in the loss of data communication with only one of the MECs **44**, **46**, **48**. Healthy CNI modules **162** can optimally respond to changing configurations of the power system in a coordinated fashion by utilizing local environment information and communications from other healthy CNI modules **162**.

For example, loss of the network switch **182**a on channel A of the forward right primary MEC **44** does not result in complete loss of communications to and from the forward right primary MEC **44** because communications to and from forward right primary MEC **44** may continue through channel B. Any other MECs **44**, **46**, **48** which had communicated via channel A with the forward right primary MEC **44** can directly communicate through channel B or via other MECs **44**, **46**, **48** that are connected to forward right primary MEC **44** via channel B. Also, if network switch **182**a on channel A of the forward right primary MEC **44** was lost in addition to the channel B connection to the forward right secondary MEC **44**, communications to and from the forward right primary MEC **44** would continue via channel B but then communications would be lost only with the forward right secondary MEC **44** because both channels A and B were lost.

One aspect of the present disclosure is distributed power control architecture. Power control is distributed to each MEC **44**, **46**, **48** as well as power itself. Based on the local data each individual MEC **44**, **46**, **48** collects, each MEC **44**, **46**, **48** performs its own power control of its associated zone to configure its own equipment loads **50** without having to rely on any other MECs **44**, **46**, **48**. Only the data that is really necessary, such as the need to reroute power, is sent to the CNI modules **162** of other MECs **44**, **46**, **48**.

Normal power up of an aircraft **10** on the ground is preferably a sequential power up of the MECs **44**, **46**, **48**. Normal power up is done via the battery **598** which powers all the standby buses in MECs **44**, **46** via the static inverter **290** and the backup bus **148**. Should the battery **598** not be available, a limited amount of exterior power from the external power unit **56** is sent first to power up the standby MEC **48**. Once the standby MEC **48** is powered up, power is then distributed from the standby MEC **48** to the each of the other primary and secondary MECs **44**, **46** to power up their CNI modules **162** and configure contactors within each MEC **44**, **46** as appropriate with the power sources that are available. On the other hand, a sequential power up is not utilized if a MEC **44**, **46** becomes unpowered during normal flight operations. If the CNI module **162** in one of

the MECs **44**, **46** has no primary power, the low power interconnection between two MECs **44**, **46**, such as a primary MEC **44** and a secondary MEC **44** with a distribution feed **100**, provides a means to still power the unpowered MEC **44**, **46** as explained above.

The CNI module **162** reads input/output communications from other systems or LRUs as well as configuration data from other MECs **44**, **46**, **48**. Broadcasting each MEC's **44**, **46**, **48** configuration data allows each of the other MECs **44**, **46**, **48** to determine what is going on elsewhere in the aircraft **10**. The CNI module **162** then uses this data to configure breakers and contactors within its MEC **44**, **46**, **48** and then writes configuration data onto channel A or B about the equipment loads **50** within its zone to broadcast to the other MECs **44**, **46**, **48** so that other MECs **44**, **46**, **48** can do the same. Each CNI module **162** checks the validity of the communications input/output and environmental data it receives and, if necessary, refines it to determine its own environment data and states of its breakers. Once the CNI module **162** figures out how it wants to command its breakers and contactors within its zone, it then sends its configuration data out to the other MECs **44**, **46**, **48**.

The CNI module **162** of each MEC **44**, **46**, **48** only controls the equipment loads **50** within the boundaries assigned to that MEC **44**, **46**, **48**. Each CNI module **162** of a particular MEC **44**, **46**, **48** does not set the equipment load **50** configuration of other MECs **44**, **46**, **48** or how to configure their breakers or contactors. However, all the MECs **44**, **46**, **48** still interact with one another to provide a coherent and unified power transfer function for the primary and secondary power systems of the aircraft **10**. The CNI modules **162** of MECs **44**, **46**, **48** that are functioning properly are able to react to a MEC **44**, **46**, **48** that has operational issues and reroute power across power tie buses **76**, **78**, **80**, distribution feeds **98**, **100** and crossties **102**, **104**, **106**, **108** even in conjunction with additional failures. The computing and networking architecture is both fail safe and fault tolerant. If a CNI module **162** has an operational issue, all of its connected load will enter a predefined default "fail-safe" state. Adjacent CNI modules **162** do not have the capacity or authority to control other equipment loads outside of their zone.

The CNI module **162** shown in FIG. **9** includes one network switch **182**, **184**, **186** on one side of the CNI module **162** corresponding with channel A and another network switch **182**, **184**, **186** on the other side corresponding with the channel B. Network switches**182**, **184**, **186** have one or more ports **206** for making external data communication connections. Each side of the CNI module **162** also has one or more ports **208** for making internal data communication connections within the MEC **44**, **46**, **48** as described in greater detail below. The CNI module **162** includes two multi-core processors **242**, **244** for running multiple instructions associatcd with processing channel A and channel B data communications. Each processor **242**, **244** can process instructions for receiving and transmitting communication data within a MEC **44**, **46**, **48** at ports **208** or for receiving and transmitting communication data outside of the MEC **44**, **46**, **48** with either network switch **182**, **184**, **186** through the ports **206**. One of the processors **242**, **244** on one side of the CNI module **162** corresponds with one communication channel and the other processor **244** on the other side of the CNI module **162** corresponds with the other communication channel. However, each processor **242**, **244** has a crossover to the other network switch **182**, **184**, **186** for the other communication channel so that each processor **242**, **244** can read and process both channel A and B communications.

Each component or LRU **52** placed on a truss system of a MEC **44**, **46**, **48** such as the CNI module **162** may include a barcode reader **248** for optically reading labels. The barcode reader **248** may bc a quick response (QR) code reader for reading QR codes. Barcodes (not shown) may be placed in the MEC, **44**, **46**, **48** or elsewhere in the aircraft **10** in proximity of the barcode reader **248**. The barcode rcadcr **248** reading barcodes allows the MEC **44**, **46**, **48** to input information such as identification, position, time tracking and other conſiguration information to set software parameters of the CNI module **162** of the MEC **44**, **46**, **48**. For example, the barcode reader **248** may read the position of the CNI module **162** so that the MEC **44**, **46**, **48** knows which section or which side of the aircraft **10** it is located in. Also, determining the location of the CNI module **162** allows the MEC **44**, **46**, **48** to determine the nearest equipment loads **50**. The conſiguration information may also be transmitted to other MECs **44**, **46**, **48**,

elsewhere in the aircraft **10**, or a central facility outside of the aircraft **10** such as a maintenance facility.

Based on how much power is distributed from the MEC **44**, **46**, **48**, the CNI module **162** may require one or more additional power inputs **288**, such as **28** VDC or **115** VAC, and power regulators **238**, from one or more transfer layers of a truss system as explained below. For example, **28** VDC is input to point of use regulator **280** for the barcode reader **248**. Each CNI module **162** also receives one or more DC power inputs **284** from power outputs **286** of the CNI modules **162** of one or more other MECs **44**, **46**, **48** to power one or both network switches **182**, **184**, **186**. Power inputs **284** and power regulators **246** provide redundancy to prevent a single power failure resulting in failure of any of the processing or communication channels.

If there is a complete loss of power to a MEC **44**, **46**, **48** at inputs **288** from a transfer layer of the truss system, then the MEC **44**, **46**, **48** with the CNI module **162**, network switches **182**, **184**, **186**, the power regulators **246**, and the barcode reader **248**, may still be powered. Because of the one or more DC power inputs **284** routed from redundant power outputs **286** of other CNI modules **162** of other MECs **44**, **46**, **48**, the CNI module of the unpowered MEC **44**, **46**, **48** never loses power and is able to reroute power from an adjacent MEC and then powers up one or more transfer layers of its own MEC **44**, **46**, **48**. The MEC **44**, **46**, **48** can then still service some or all of its equipment loads **50** and the CNI module **162** remains fully functional and can communicate with other CNI modules **162** thereby keeping truss system of the MEC **44**, **46**, **48** and the communications network active.

FIGS. **10**A-**10**D illustrate different configurations of the high voltage primary power switching bus structure of each of the primary MECs **44** shown in FIGS. **5**A-**5**E. Each may be designated as R**1**, R**2**, L**1** or L**2** based on which generator **34**, **34**b, **36**a, **36**b directly powers each of the four primary MECs **44** and whether the four primary MECs **44** are forward or aft and whether they are on the left or on the right side of the aircraft **10**. R1 corresponds with the forward right primary MEC **44** that receives primary power

from generator **36**a. R**2** corresponds with the aft right primary MEC **44** that receives primary power from generator **36**b. L**1** corresponds with the forward left primary MEC **44** that receives primary power from generator **34**a. L**2** corresponds with the aft left primary MEC **44** that receives primary power from generator **34**b.

FIG. **10**A illustrates the high power portion **120** with primary power switching bus **96**a and solid state switching devices of the forward right primary MEC **44** (R**1**) of FIGS. **5**A and **5**B. FIG. **10**B illustrates the high power portion **120** with primary power switching bus **96**a and solid state switching devices of the aft right primary MEC **44** (R**2**) of FIGS. **5**A and **5**C. FIG. **10**C illustrates the high power portion **120** with primary power switching bus **96**a and solid state switching devices of the forward left primary MEC **44** (L**1**) of FIGS. **5**A and **5**D. FIG. **10**D illustrates the high power portion **120** with primary power switching bus **96**a and solid state switching devices of the aft left right primary MEC **44** (L**2**) of FIGS. **5**A and **5**E. Together, FIGS. **10**A-**10**D depict a common architecture and layout of solid state switching devices that can provide connectivity for each primary MEC **44**.

FIG. **10**A best illustrates the primary busing structure, solid state elements, and connections for the forward right primary MEC **44** (R**1**) which has the least number of solid state elements in comparison to the other primary MECs **44** positioned elsewhere. However, the minimal structure depicted in FIG. **10**A may be expanded to include the additional solid state elements (shown in phantom) in order to include the required functionality for any of the other primary MECs **44**. The additional solid state elements may or may not be populated in all slots in all installed MECs **44**, **46**, **48**.

Each of the four configurations of FIGS. **10**A-**10**D for the four primary MECs **44** have a primary power connection **210** from one of the main generators **34**, **36** and a connection **212** to either the forward or aft tie buses **76**, **78**. Each configuration also includes an output connection **214** to an associated secondary MEC **46**. Each also includes two high current solid state contactors **216**, **218** and two low current solid state contactors **220**, **222**. The two **100** amp contactors **216**, **218** are connected together at connection **224**.

One of the high current contactors **216** is also connected at connection **210** for turning on and off main primary power and the other high current contactor **218** is also connected at the connection **212** for the forward or aft tie buses **76**, **78** depending on whether the primary MEC **44** is in a forward or aft section of the aircraft **10**. The low current contactor **220** is connected to a connection **214** for the associated secondary MEC **46**. The other low current contactor **222**, in combination with the distribution feed **98** as described in greater detail below, is for turning on and off power between the high power portion **120** and the low power portion **122** of each primary MEC **44**.

The left forward primary MEC **44** (L**1**) depicted in FIG. **10**C includes another high current contactor **250** between a connection **252** from the mid tie **80** and the connection **212** for the forward tie bus **76**. The aft left primary MEC **44** (L**2**) depicted in FIG. **10**D includes the additional high current contactor **250** that the left forward primary MEC **44** (L**1**) includes as well as another high current contactor **260** between the connection **252** for the mid tie **80** and an input connection **262** for one of the auxiliary power unit generator **54**. The aft left primary MEC **44** (L**2**) also includes the same low current contactor **232** to the standby MEC **48** where high voltage AC power is sent across tie **270** and to a power converter, such as another TRU or an auto-transformer rectifier unit (ATRU) **272**, and to bus **274**.

The aft right primary MEC **44** (R**2**) depicted in FIG. **10**B also includes a low current contactor **232** for connecting the standby MEC **48** with high voltage AC power across tie **234** to ATRU **236** and to bus **240**. All four configurations also have the option of having additional contactors such as a low current contactor **278** for turning on and off power requiring **230** VAC as shown in each of the FIGS. **10**A-**10**D.

The varying architectures shown in each of the FIGS. **10**A-**10**D can be rearranged into a single common structure and layout of a primary power switching network device (PPSND) **302**, as shown in FIG. **11**, with optional contactors **232**, **250**, **260**, **278** for various loads based on the primary power switching configuration and where the MEC **44** is within an aircraft **10** as explained above. Each PPSND **302** corresponds with the

high power portion **120** of each primary MEC **44** and is configured to share common sources and outputs with options for additional contactors **232**, **250**, **260**, **278** for receiving primary power directly from a standby MEC **48** or for receiving primary power from auxiliary power unit generator **54** which are connected via the forward, aft and mid tie buses **76**, **78**, **80** as needed. The PPSNDs **302** each have at least one common power input source connection and a plurality of common power output connections for distributing primary power.

As shown in FIG. **5**C the high power primary power switching bus **96**a of aft right primary MEC **44** is connected to the standby MEC **48** with tie **234**. In FIG. **5**D the forward left primary MEC **44** is connected by the forward tie bus **76** with contactor **218**a-c to the forward right primary MEC **44** and connected by the mid tie bus **80** with contactors **250**a-c to the aft left primary MEC **44**. The aft left primary MEC **44** as shown in FIG. **10**D has the most contactors as a result of being connected to other primary MECs **44** with the aft and mid tie buses **78**, **80** as well as the standby MEC **48** with contactors **232**a-c by the tie **270**.

A set of substantially identical PPSNDs **302**a-c as shown in FIGS. **12**A-**12**C, can be used with a primary MEC **44** to receive poly-phase primary power such as three-phase primary power from one of the generators **34**, **36**. Although the PPSNDs **302**a-c shown are labeled for use in combination with the forward right primary MEC **44** (R**1**), the three PPSNDs **302**a-c may also be used to receive three-phase power for either of the other primary MECs **44**. Each of the primary power feeders **40**, **42** preferably is a four conductor power wire connected to each of the primary MECs **44** where three of the conductors carry either of phases A, B or C of the three-phase power. The forth conductor can be a neutral wire connected to a fourth PPSND.

Still referring to FIG. **11** and FIGS. **12**A-**12**C, phase A power is received at connection **210**a to power the primary power switching bus **96**a of the PPSND **302**a of FIG. **12**A, phase B power is received at connection **210**b to power the primary power switching bus **96**b of the PPSND **302**b of FIG. **12**B, and phase C power is received at connection **210**c

to power the primary power switching bus **96**c of the PPSND **302**c of FIG. **12**C. Solid state elements are depicted by squares in each of FIGS. **12**A-**12**C and sets of the solid state elements constitute the contactors **216**, **218**, **220**, **222**, **232**, **250**, **260** and **278** as depicted in FIG. **11**.

In FIGS. **12**A-**12**C, reference numbers ending with "a", "b" or "c" may refer to components utilizing phase A power, phase B power or phase C power, respectively. However, such reference numbers themselves may also refer collectively and/or generically to the same components without specifically referencing a particular phase of power. Contactors **210**a-c power the high power primary power switching buses **96**a-c, respectively. Primary power comes from each of the primary power switching buses **96**a-c across contactors **218**a-c to the forward tie buses **76**a-c (or the aft tie **78**a-c depending on whether the primary MEC **44** is in a forward or aft section of the aircraft **10**). Alternatively, power could come from the forward tie buses **76**a-c to the primary power switching bus **96**a-c across contactors **218**a-c. Primary power could also be provided to and from the mid tie bus **80**a-c at connections **252**a-c and across contactors **250**a-c in association with the primary power switching buses **96**a-c. Primary power could also be provided from auxiliary power unit generator **54** with a power tie **130** connected to connection **262**a-c and across contactors **260**a-c to the primary power switching buses **96**a-c.

Primary power is provided from the primary power switching buses **96**a-c across contactors **220**a-c to the output connections **214**a-c for the secondary MEC **46**. Primary power is also provided from the primary power switching buses **96**a-c across contactors **222**a-c to output connections **390**a-c and across distribution feed **98** to power the low power portion **122** of the primary MEC **44**. Three-phase primary power from the output connections **390**a-c of the PPSNDs **302**a-c may be sent through a truss system to other components within the same MEC **44**, **48** as the PPSNDs **302**a-c. Distribution feed **98** is preferably a four wire conductor with a first wire for phase A power connected to output

connection **390**a, a second wire connected to output connection **390**b, and a third wire connected to output connection **390**c.

Three-phase power may be distributed directly from the high power portion **120** of a primary MEC **44** to optional or auxiliary high voltage AC loads by utilizing output connections **340**a-c or output connections **342**a-c on the PPSNDs **302**a-c shown in FIGS. **12**A-**12**C. Contactor **232** and contactor **278**, shown in FIG. **11**, correspond with output connections **340**a-c and output connections **342**a-c shown in FIGS. **12**A-**12**C. Power of **230**VAC to and from the auxiliary loads is controlled by the contactors **232**a-c, **278**a-c of the PPSNDs **302**a-c. If the PPSNDs **302**a-c were being utilized in the left aft primary MEC **44** (L**2**) as shown in FIGS. **5**A and **5**E, one of the auxiliary three-phase loads connected to output connections **340**a-c of the PPSNDs **302**a-c would be the standby MEC **48**. In such case, the tie **270** providing three-phase power from the standby MEC **48** would be a four wire conductor with a separate wire connected to each of the three PPSNDs **302**a-c and the fourth wire as a neutral connected to a fourth PPSND **302**. Although FIGS. **12**A-**12**C depict direct connections for a total of two different three-phase loads, many other three-phase loads may be serviced by a particular primary MEC **44** with additional connections.

One or more of the MECS **44**, **46**, **48** may also include an integrated truss system having a mounting structure of one or more data and/or power transfer layers separated by one or more insulation layers. The truss is configured to facilitate easy installation or replacement within an aircraft **10** and may be constructed of rigid or flexible materials such as sheet metal, thermoplastics, composites or some other suitable material. In an aircraft, power or data could be transferred to various locations on the mounting structure of the truss system or to various locations in the aircraft. In some configurations, a via or a mechanism such as a truss interconnect can electrically connect one or more power or data lines in one layer to one or more power or data lines in one or more different layers of the integrated truss system, as described in U.S. Pat. Application Publication No. **2015-0004834**, entitled TRUSS INTERCONNECT, published January **1**, **2015**. The

interconnect can also be used to electrically interconnect a LRU mounted to the top surface layer of the integrated truss system and to send power into the truss or from the truss into the LRU. An LRU with the PPSNDs **302**a-c has a conductive boss (projection) and as the interconnect passes through the LRU and into the truss system the interconnect expands into the boss as well as the transfer layers of the truss system to make electrical connections between the LRU and the truss system.

In some configurations, the integrated truss system may electrically connect both power and data systems. In further configurations, the truss interconnect can also provide a mechanical connection between one or more layers of the integrated truss system. In additional configurations, the truss interconnect may be configured for multiple insertions and extractions, allowing the reuse of the truss interconnect.

FIG. **13** illustrates an exploded, perspective view of a multi-layered integrated truss system **500** of a MEC **44**, **46**, **48**. The integrated truss system **500** may include insulation layers **502**a-**502**b (hereinafter referred to collectively and/or generically as "insulation layers **502**") and transfer layers **504**a-**504**c (hereinafter referred to collectively and/or generically as "transfer layers **504**"). In some configurations, the insulation layers **502** and the transfer **504** layers are alternately arranged among each other such that the insulation layers at least partially electrically separate the transfer layers **504** from one another. In further configurations, the insulation layers **502** are configured to, at least partially, physically separate one or more of the transfer layers **504** from one or more other transfer layers **504**. Also, in some configurations one or more of the insulation layers may act as a smoke or water drip barrier between the passenger and cargo compartments.

Components of a MEC **44**, **46**, **48** may be detachably secured to the truss system **500**. A portion of the power busing network system **90** of FIG. **3**, for example corresponding with the high power portion **120** of a primary MEC **44**, with the PPSNDs **302**a-c, is housed in an LRU **52** mounted to the top surface insulation layer **502**a of the truss system **500**. Also inside the LRU **52** with the power busing network system **90** is a

microprocessor that receives channel A and B data inputs from the CNI module **162** to control all the contactors **216**, **218**, **220**, **222**, **232**, **250**, **260** and **278**.

Three-phase primary power **506**a-d (hereinafter may be referred to collectively and/or generically as "three-phase primary power **506**") is provided from one of the main generators **34**, **36** to the PPSNDs **302**a-c inside the power busing network system **90**. Phase A power **506**a, phase B power **506**b, or phase C power **506**c, or all three, may be routed from the output connections **390**a-c through the insulation layers **502** to one or more transfer layers **504** of the truss system **500**. The neutral **506**d of the three phase primary power **506** also may be routed through the insulation layers **502** to one or more transfer layers **504** of the truss system **500**. Communication data is sent from one MEC **44**, **46**, **48** to any other MEC **44**, **46**, **48** across two data channels **188**, **190** (commonly referred to as channels A and B). As shown in FIG. **13**, the mounting structure of the truss system **500** provides separate layers configured to provide separate communication channels to system components mounted to the truss system **500**. Both data channels **188**, **190** may be routed through the insulation layers **502** to one or more transfer layers **504** of the truss system **500**. For example, the transfer layer **504**a includes data transfer path **536** and transfer layer **504**b includes data transfer path **538**. The data transfer paths **536**, **538** may be separated from one another by one or more layers **502**, **504** such as transfer layer **504**c. Data communications back and forth between the power busing network system **90** with PPSNDs **302** and the CNI module **162** are sent back and forth across the data channels **188**, **190**. Data channel **188** passes through the transfer path **536** of transfer layer **504**a and data channel **190** passes through the transfer path **538** of transfer layer **504**b.

In some configurations, the transfer layers **504** are configured to include one or more power or data transfer paths, or both. For example, the transfer layer **504**c may include power transfer paths **512**a and **512**b which correspond with phase B power **506**b and neutral **506**d of the three phase primary power **506**. The power transfer path **512**a receives phase B power, of **230** VAC for example, and transfers it to another LRU **52**

mounted to the truss system **500** such as the CNI module **162** shown in FIG. **13**. Transfer path **512**b is the current return path across the neutral **506**d from the CNI module **162** back to one of the PPSNDs **302**.

Each MEC **44**, **46**, **48** also includes at least one power distribution module **170** for distributing secondary power from the MECs **44**, **46**, **48**. Each distribution module **170** may be configured as one or more LRUs **52**. Each distribution module **170** preferably receives all three phases but distributes them to single phase leads in a balanced manner. As shown in FIG. **13**, phase A **506**a and phase B **506**b are provided through two different transfer layers **504** of the truss system **500** and then can be provided to distribution modules **170**. Each distribution module **170** then distributes single phase secondary power to the low power equipment loads **50** within the assigned zone of each particular MEC **44**, **46**, **48**. The equipment loads **50** associated with each MEC **44**, **46**, **48** are preferably distributed evenly across all three power phases. Preferably, each of the low power equipment loads **50** is connected to a distribution module **170** with a twisted electrical conductor pair. Although the present application depicts a particular number of connections in one or more of the Figures, any number of equipment loads **50** may be serviced by a MEC **44**, **46**, **48** subject to the amount of secondary power available.

FIG. **14** illustrates a primary MEC **44** with several layers of a truss system. The primary MEC **44** includes TRUs **134**, **142**, the ATU **138**, the CNI module **162**, distribution modules **170** and a PPSND **302**. Primary MECs **44** include a PPSND **302** and MECs **46**, **48** do not. A secondary MEC **46** could be depicted in a manner similar to the MEC **44** in FIG. **10**B except without a PPSND **302**. The two TRUs **134**, **142**, the ATU **138**, the CNI module **162**, distribution modules **170** and the PPSND **302** are electrically interconnected to the traces or metalized interconnects in the transfer layers **504** by inserting interconnector mechanisms **562**. The interconnection mechanisms **562** are inserted through each of the TRUs **134**, **142**, the ATU **138**, the CNI module **162**, distribution modules **170** and the PPSND **302** and into vias **566** in each of the transfer layers **504**.

The truss system includes transfer layer **504**a with trace **536** for channel A and transfer layer **504**b with trace **538** for channel B. Each of the TRUs **134**, **142**, the ATU **138**, distribution modules **170** and the PPSND **302** are connected to a dedicated channel A trace **536** and to a dedicated channel B trace **538**. However, the number of traces, **536**, **538** on each transfer layer **504** depends on the protocol. In other embodiments, the TRUs **134**, **142**, the ATU **138**, the distribution modules **170** and the PPSND **302** could all be connected to the same channel A trace **536** and to the same channel B trace **538**.

The truss system in FIG. **14** also includes transfer layers **504**c, **504**d, **504**e and **504**f. Transfer layer **504**c includes traces **570** with three-phase primary power **506**, such as **230**VAC, for powering the truss system of the MEC **44**, **46**, **48** and the systems connected to it. A respective trace **570** corresponds with phase A power **506**a, phase B power **506**b, phase C power **506**c, and neutral **506**d. The two TRUs **134**, **142**, the ATU **138**, the CNI module **162**, and the PPSND **302** are connected to the traces **570** of transfer layer **504**c with interconnector mechanisms **562** through vias **566**. The three-phase primary power **506** is provided from the generators **34**, **36** through the PPSND **302** to the transfer layer **504**c. The two TRUs **134**, **142**, the ATU **138**, and the CNI module **162** are then powered by receiving the three-phase primary power **506** from the traces **570** of the transfer layer **504**c.

Secondary power is distributed from the TRUs **134**, **142** and the ATU **138** to transfer layers **504**d, **504**e, **504**f. Transfer layers **504**d, **504**e are low voltage layers, such as **28** VDC, and each includes a positive trace **574**, a negative trace **576**, and a neutral trace **578**. One of these transfer layers **504**, such as transfer layer **504**e, may provide standby power from the fuel cell or RAT **128** via the second TRU **142**. **28** VDC power from the traces **574**, **576**, **578** of transfer layers **504**d, **504**e is distributed to the distribution module **170**. Transfer layer **504**f is a low voltage three-phase layer, such as **115**VAC, that includes phase A power **580**, phase B power **582**, phase C power **584** and a neutral **586**. **115** VAC power from the traces of transfer layer **504**f is also distributed to the distribution module **170**.

The distribution module **170** is connected to the traces of transfer layers **504**d, **504**c, **504**f for secondary power and also to the traces **536**, **538** for channels A and B **202**, **204** in order to distribute the secondary power to equipment loads **50** with the twisted and shielded electrical conductor pairs **314**. The distribution module **170** is not connected to transfer layer **504**b with three-phase primary power **506** because primary power is not distributed from the distribution module **170**. Communication data from channels A and B **202**, **204** of truss transfer layers **504**a, **504**b controls when the distribution module **170** turns on and off secondary power to the twisted and shielded electrical conductor pairs **314** to service the equipment loads **50**.

As shown in FIG. **14**, the CNI module **162** is connected to every trace in every layer **504** of the truss system of the MEC **44**, **46**, **48**. Because there are multiple voltage inputs to the CNI module **162**, power regulators perform conversions to the needed voltages. If any of the traces on one or more of the layers **504** become powered, the CNI module **162** becomes active. For example, if all the MECs **44**, **46** lose primary power, power could be provided to the standby MEC **48** with the fuel cell RAT **128** thereby providing power to traces **574**, **576**, **578** of the standby layer **504**e. Power in the traces **574**, **576**, **578** of the transfer layer **504**e would activate the CNI module **162**. The CNI module **162** also receives communication data for use with the network switches **182**, **184**, **186** from both channels A and B **202**, **204** from each of the traces **536**, **538** of the transfer layers **504**a, **504**b.

FIG. **14** also depicts a barrier **588** preferably positioned above the transfer layers **504** of the truss system of a MEC **44**, **46**, **48**. If the truss system were positioned within the floor structure as shown in FIG. **17**, the barrier serves as a smoke barrier for obstructing smoke from the cargo compartment from entering the passenger compartment and/or as a water drip barrier for obstructing dripping water anywhere with the aircraft **10**. For example, the barrier **588** could obstruct water from dripping onto electrical components of a MEC **44**, **46**, **48**. Alternatively, or in addition to the barrier **588**, one or more of the insulation layers **502** could be the smoke and/or water drip barrier. For example, the

uppermost insulation layer **502** of the truss system could be configured to act as a barrier to water and smoke.

In existing composite aircraft, the current return network provides a fault current return path, a personal safety protection path, and lightning protection path for the aircraft. However, as explained above, the current return network also provides a significant amount of wire weight to an aircraft which is undesirable.

The current return networks of these known aircraft are also susceptible to large voltage offsets. Both AC and DC voltages may be measured on the current return network. The return currents of all the equipment loads throughout the aircraft on the current return network are cumulative and therefore a voltage drop is created along the current return network as measured from the power source grounding point to the load grounding points. The voltage drop at different points along the current return network increases from the power source grounding points toward the back of the aircraft proportional to the impedance of the current return network and the current passing through it.

FIG. **15** generally illustrates three-phase (**3ϕ**) primary power **506** is routed from one or more of the main generators **34**, **36** to multiple isolated TRUs **134** and non-isolated ATUs **138**. The TRUs **134** and ATUs **138** are distributed throughout the aircraft **10** as part of the distributed architecture as shown in FIG. **15**. At least one TRU **134** and at least one ATU **138** corresponds with one of the MECs **44**, **46**, **48**. Because the TRUs **134** are isolated they can be grounded wherever it is convenient. Also, because the TRUs **134** are distributed, the TRUs **134** can be grounded at different locations and, therefore, their DC return currents remain local to each respective MEC **44**, **46**, **48**. However, the return currents are no longer cumulative which results in a DC offset voltage of zero.

FIG. **16** also generally illustrates the distribution of either AC or DC power from an ATU **138** or a TRU **134**, respectively. However, more specifically as described above, the primary power **506** is first distributed to the power conversion equipment and then to the

distribution modules **170** connected to each of the low power equipment loads **50** with multiple twisted and shielded electrical conductors where the conductors carry essentially equal but opposite currents. In application there may be small differences in current carried by the conductors. For example, twisted and shielded electrical conductor pair **314** includes an electrical power conductor **310** and a neutral or return conductor **312**. The neutral conductor may be routed with a three-phase power feeder.

After converting the primary power **506**, AC power is distributed from each ATU **138** to AC equipment loads **50**a with an electrical power conductor **310** and current is returned from each AC equipment load **50**a on a corresponding return conductor **312** of the twisted and shielded electrical conductor pair **314**. DC power is provided from each TRU **134** to the DC equipment loads **50**b with electrical power conductor **310**. Current is returned from each DC equipment load **50**b on the corresponding return conductor **312** of the twisted electrical conductors.

Phase A power **506**a, phase B power **506**b, and phase C power **506**c are distributed from the generators **34**, **36**. A fourth wire from the generators **34**, **36** for the three-phase power **506** is also depicted that is the neutral conductor **506**d. Each of the AC equipment loads **50**a includes a shield termination wire **590** depicted by a broken line connected to the neutral conductor **506**d and each of the DC equipment loads **50**b includes a shield termination wire **592** also depicted by a broken line connected to the neutral conductor **506**d. Although each of the equipment loads **50**a and **50**b are connected to the neutral conductor **506**d with shield termination wires **590** and **592**, respectively, the load return currents are no longer cumulative. In FIG. **16**, part of the neutral conductor **506**d is configured to appear as a current return network (CRN) merely to illustrate that the voltage differential is zero as a result of using small loops of twisted wire conductors for localized secondary power distribution. The neutral conductor **506**d of the distributed three-phase power **506** between MECs **44**, **46**, **48** of the aircraft **10**, which is much smaller than conductors that would typically be utilized as part of a CRN, may simply be referred to as a safety ground bus (SGB). Therefore, a CRN is no longer needed in the

composite aircraft **10** with localized secondary power distribution provided by twisted wire conductors. The twisted wire conductor pairs now provide current return. Also, the cross-sectional area of the loops created by twisted conductors such as a twisted conductor pair is much smaller than the cross-sectional area created by the larger wire loop of the CRN which reduces the lighting threat to the composite aircraft **10**. For comparison, the conductors of the twisted pair may be about **16** to about **20** American wire gauge (AWG) whereas the conductors of the CRN are about **2** AWG or larger diameter.

FIG. **16** also illustrates the distribution of primary power from generators **34**, **36** among primary MECs **44** distributed within the forward, mid and aft sections of the aircraft **10**. Each primary MEC **44** includes a TRU **134** and an ATU **138** for servicing equipment loads **50**b and equipment loads **50**a, respectively, as described above. Power is distributed from each MEC **44** to each equipment load **50** with a twisted and shielded electrical conductor pair **314**. FIG. **16** also depicts a pair of MECs **44** providing **230**VAC for auxiliary loads **520**. As referenced in FIGS. **12**A-**12**C and the accompanying text, **230**VAC power to and from the auxiliary loads is controlled by the contactors **232**, **278** of the PPSNDs **302** of the primary MEC **44**.

FIG. **16** also illustrates a plurality of LRUs **52**, such as avionics, serviced by the forward most primary MEC **44**. FIG. **16** also illustrates a battery **598** for providing standby power. Although FIG. **16** depicts the battery **598** providing standby power to only the forward most primary MEC **44**, battery standby power is preferably provided to all primary MECs **44**.

FIG.**17** illustrates an integrated truss system **600** which may be used in aircraft manufacturing for providing one or more power and data transfer paths as explained above. One or more MECs **44**, **46**, **48** may include the truss system **600** as a support or mounting structure for attaching all or part of vehicle systems, components of a MEC **44**, **46**, **48**, equipment loads **50**, LRUs **52**, or other equipment.

The mounting structure of the truss system **600** may be a multi-part or modular assembly of separate structural elements that stack, detachably connect or lock together to create an integrated mounting structure that may be installed in an aircraft **10** as a single unitary piece. Each structural element may have one or more transfer layers and one or more insulation layers as described above. Each structural element of the multi-part truss system **600** may be detachable from one another to allow repair or replacement of damaged structural elements without removing undamaged structural elements from the aircraft **10**. One or more layers of each structural element may also be replaced. One element of the truss system **600** could be swapped out without having to remove the entire truss system **600**. Also, all or at least a portion of the truss system **600** may also be detachable from the support structure of the aircraft **10** such as the floor beams or fuselage frame members. Alternatively, the truss system **600** may be manufactured as a single monolithic structure which may be installed or replaced in it's entirely.

The truss system **600** is configured to extend within a thin structural volume defined in the sidewall of the fuselage between frame members, and by the depth of the frame members, or in the space in the floor between the passenger and cargo compartments of the aircraft **10**, and by the depth of the floor beams. Alternately, the truss system could have a physical form configured to be implemented within a traditional equipment bay. The truss system **600** mounted in the sidewall of the aircraft **10** preferably corresponds with the curvature of the fuselage of the aircraft **10**. FIG. **17** is a bottom view looking upward toward the truss system **600** configured to extend from sidewall to sidewall of the aircraft **10**, under seat rails **610**, and between transverse floor beams **608**. A MEC **44**, **46**, **48** positioned in the floor or in the sidewall of the aircraft **10** with a truss system such as truss system **600** can service the equipment loads **50** within the passenger compartment and in the cargo compartment of the aircraft **10** that are in proximity of the MEC **44**, **46**, **48**.

The truss system **600** is configured to have a narrow middle portion that extends over the top of two inner adjacent floor beams **608** and opposite end portions that extend further

outward from both sides of the two inner adjacent floor beam **608** to the next floor beams **608** to provide a wide surface for mounting components such as the power distribution modules **170**. In one or more embodiments, the truss system is configured to have a width and length between adjacent floor beams **608**, or between floor beams **608** that are displaced from one another, that is suitable for serving as a smoke barrier for obstructing smoke from the cargo compartment from entering the passenger compartment and/or as a water drip barrier for obstructing water dripping onto electrical components within the MEC **44**, **46**, **48**.

FIG. **17** also shows the CNI module **162**, power distribution modules **170**, TRUs **134**, **142**, the ATU **138**, and the PPSNDs **302** mounted to the truss system **600** of a primary MEC **44**. The TRU **134** receives **230** VAC from the output connections **390** of the PPSNDs **302**. The TRUs **134** connect to a power bus with **28** VDC to power the distribution modules **170**. Each power distribution module **170** has connections **596** for interfacing with the equipment loads **50** associated with the primary MEC **44**.

Each structural element of the truss system **600** has one or more transfer and insulation layers as explained above. One of the transfer layers may be configured to transfer high voltage power from one portion of a MEC **44**, **46**, **48** to another portion of that same MEC **44**, **46**, **48**. For example, high voltage power may be provided inside the truss system **600** across a transfer layer to the PPSNDs **302**, configured as an LRU **52**, mounted to the surface of truss system **600**. Low voltage secondary power may also be provided through another transfer layer of the truss system **600** to low power equipment loads **50** mounted to the surface of the truss system **600**. Also, communication data can be provided across a transfer layer of the truss **600** to an aircraft system component mounted to the surface of the truss system **600**. One transfer layer of the truss system **600** could provide channel A to a system component mounted to the surface of the truss system **600** and another transfer layer could provide channel B to that same system.

FIG. **18** illustrates a fast break power transfer system for seamlessly switching on the low power portion **122** of the primary MEC **44** or the secondary MECs **46** between primary

power sources such as high voltage AC main power generators **34**, **36**, high voltage AC auxiliary power unit generator **54**, or high voltage AC external power unit **56**, in a manner that is transparent to any downstream loads and so that functioning of equipment loads **50** is not disrupted and power users see no visible break in power. Solid state switching devices enable transparent power transfers because the solid state devices can be switched within milliseconds (less than **1**ms for example) whereas traditional mechanical devices are on the order of tens of milliseconds (**20**ms-**50**ms typically). For example, primary power sources can be switched without the momentary break, such as about **50**ms, in the power that causes the lights and video system to visibly blink just before the aircraft backs away from an airport gate. The main generators **34**, **36** may be variable frequency starter generators where their frequencies vary with the speed of the engines **30**, **32**. Therefore, the outputs of the generators **34**, **36** are difficult to synchronize with the outputs of either of the other primary AC power sources that could provide power to the high voltage AC primary power switching bus **96**a.

Each of the main generators **34**, **36**, the auxiliary power unit generator **54**, and the external power unit **56** provides high voltage AC power to the high power AC primary power switching bus **96**a of a primary MEC **44**. High voltage AC power is then provided from the primary power switching bus **96**a through a solid state power breaker (SSPB) **222** to the high voltage AC distribution primary power switching bus **96**b of the low power portion **122** of the primary MEC **44**.

To switch primary power sources and overcome the difficulties of synchronizing their variable frequencies, two separate high voltage DC inputs are provided to a static inverter **290** of the standby MEC **48**. One of the inputs is from one of the ATRUs **236**, **272** of the standby MEC **48** which provides a non-time limited power source to the static inverter **290**. An example of a non-time-limited power sources are the generators **34**, **36**, the auxiliary power unit generator **54**, the external power unit **56**, or a secondary primary power source not coupled to either of the high voltage primary power switching buses **96**a, **96**b. A high voltage AC power source is rectified and converted by the ATRU **236**,

272 into high voltage DC power. The high voltage DC power is then provided to the static inverter **290** through the high voltage battery bus **294**. If these non-time-limited primary power sources are not available, the time-limited battery **598** becomes the secondary backup source of power to the static inverter **290**.

Therefore, the other input to the static inverter **290** is the high voltage DC input from the high voltage DC battery **598** that provides high voltage DC power in the absence of the high voltage DC input from the ATRU **236**, **272**. This high voltage source could be a flywheel, capacitor bank or any other suitable energy storage device. The battery **598** could be of any voltage so long as the output is suitable to power the static inverter **290**. High voltage is not necessarily required. However, the battery **598** is a time-limited power sources in that it is only able to provide sufficient power for a limited amount of time. The static inverter **290** is configured to take the high voltage DC input and create a controlled frequency with high voltage AC output, such as **230** VAC, that is provided through a SSPB **296** to the backup and standby buses **148**, **160** of one or more of the primary MECs **44**.

To utilize one of the generators **34**, **36** during normal operations, contactor **216** closes to power high voltage primary power switching bus **96**a, and when the SSPBs **222**, **298** are closed, power is provided to the primary power switching bus **96**b, backup bus **148**, the standby bus **160**. However, during normal operations, the SSPB **296** between the static inverter **290** and the standby bus **148** is open and the static inverter voltage, frequency, and phase angle are kept in sync with whichever power source is powering the high voltage AC primary power switching bus **96**a. When it is desirable to do a power transfer, such as switch from one of the generators **34**, **36** to the external power unit **56**, the external power unit **56** is coupled to the aircraft **10** and external power is available but contactor **94** between the external power unit **56** and the high voltage primary power switching bus **96**a remains open until commanded power transfer is initiated as explained below.

The static inverter **290** is preferably powered from a secondary source not coupled to either of the high voltage primary power switching buses **96**a, **96**b. The static inverter **290** is synchronized to the frequency of the high voltage primary power switching bus **96**a and when a transfer is initiated the contactor **216** to the generator **34**, **36** opens so that the generator **34**, **36** no longer provides power to the high voltage primary power switching bus **96**a. At substantially the same time that the contactor **216** to the generator **34**, **36** is opened, the SSPB **222** opens and closes when the loss of power to the backup bus **148** is sensed (less than **1**ms). The static inverter **290**, previously synchronized to the main generator **34**, **36**, provides a controlled frequency output as well as the required voltage to the backup bus **148**. The static inverter **290** powers the backup bus **148** through the closed SSPB **296** and, through the network of closed SSPBs **296**, **298**, also may hold up the low power bus **96**b with power for a short duration of time. This occurs for about **50** milliseconds when the high voltage primary power switching bus **96**a is restored with a second power source such as the auxiliary power unit generator **54** or the external power unit **56** to energized high voltage primary power switching bus **96**a.

When external power sources powers the high voltage primary power switching bus **96**a (less than about **50**ms) the static inverter **290** syncs to the external power unit **56**'s frequency. When the static inverter **290** is in sync with the high voltage primary power switching bus **96**a, SSPBs **222**, **290** close and the SSPB **296** next to the static inverter **290** opens completing the fast break power transfer on buses **96**b, **96**c for MEC **48**. In order to take off one primary power source and bring on another primary power source, the high voltage primary power switching bus **96**b is always powered because of the power received from the static inverter **290** to bridge the gap of time in which the output frequencies are being matched up. This occurs in just a few milliseconds or less transparently to any downstream loads.

When switching between one of the primary sources of the main generator **34**, **36**, the auxiliary power unit generator **54**, or the external power unit **56**, to a subsequent one of either the main generator **34**, **36**, the auxiliary power unit generator **54**, or the external

power unit generator **56**, the **230** VAC output from the static inverter **290** through SSPB **296** to the backup bus **148** is controlled and synchronized with the primary **230** VAC input through the SSPB **222** and the primary power switching bus **96**b to the backup bus **148**. The CNI module **162** orchestrates state changes to SSPBs **222**, **296**, **298**. It also controls the opening and closing of the contactors **94**, **216**, **218** and the SSPBs **222**, **296**, **298** to provide a constant control frequency output to the high voltage bus **96**b and the backup and standby buses **148**, **160** of the primary MEC **44**. The **115** VAC and the **28** VDC loads off of the high voltage primary power switching bus **96**b continue to be powered by the backup bus **148** during the transfer because the backup bus **148** powers the high voltage primary power switching bus **96**b through the SSPB **298**.

The static inverter **290** is preferably connected to the backup bus **148** rather than the high voltage primary power switching bus **96**b because in the event the engines **30**, **32** and generators **34**, **36** are lost it is desirable to power only the critical loads for continued safe flight and landing and to shed all non-critical loads to conserve time-limited power sources. As soon as main AC power is lost, SSPB **296** closes to provide power from the time-limited battery **598** through the battery bus **294** and the static inverter **290** to the backup bus **148** as well as the standby bus **160** for powering the critical loads. Some equipment loads may be turned off when the backup bus **148** is powered by the static inverter **290**.

The time-limited battery **598** lasts longer if the loads placed on the battery **598** are limited to only the critical loads. The SSPB **298** above the backup bus **148** opens to isolate the backup bus **148** from the high voltage primary power switching bus **96**b and its non-critical loads such that only the critical loads for safe flight and landing are powered from the standby bus **160**. The RAT **128** also provides DC power to the battery bus **294** but only after the time required to detect, command, deploy and stabilized power generation. A significant amount of time of up to one minute may be required for the RAT **128** to deploy and begin generating electricity before beginning to provide power to the battery bus **294**.

FIG. **19** illustrates routine **700** for seemingly uninterrupted switching between power sources is provided herein. Unless otherwise indicated, more or fewer operations may be performed than shown in the figures and described herein. Additionally, unless otherwise indicated, these operations may also be performed in a different order than those described herein.

The routine **700** starts at operation **702**, where first and second power sources are provided having different output frequencies. In operation **704** a high voltage AC power input from one of the power sources is provided to a high voltage primary power switching bus **96**a. Operation **706** includes synchronizing a static inverter **290** to the high voltage primary power switching bus **96**a. At operation **708** the high voltage AC power from the first power source to the high voltage primary power bus is interrupted. When the first source is not connected to high voltage primary power switching bus **96**a, a break power transfer is performed to bring the second source on the high voltage primary power switching bus **96**a. A control frequency output and voltage from the static inverter **290** is provided to a backup bus **148** in operation **710**. At operation **712**, the high voltage power bus **96**b is powered from the backup bus **148**. Operation **714** includes changing the output frequency of the static inverter **290** to match the output frequency of the second power source now powering the high voltage primary power switching bus **96**a. Operation **716** determines whether the output frequencies match. If the output frequencies do not match, the routine **700** returns to operation **714**. If the output frequencies match then the routine continues to operation **718** where the SSPB **222** is closed and SSPB **296** is opened to remove the static inverter **290** from the backup bus **148**. The fast power transfer in completed on the power portion **122** of the MECs **44**, **46** in operation **720**, after which the routine **700** ends.

The subject matter described above is provided by way of illustration only and should not be construed as limiting. Various modifications and changes may be made to the subject matter described herein without following the example embodiments and applications

illustrated and described, and without departing from the true spirit and scope of the present disclosure, which is set forth in the following claims.

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

1. A primary power switching network for use with a vehicle, the power switching network comprising:

a plurality of modular equipment centers (MECs) spatially distributed throughout the vehicle, each of the plurality of MECs comprising at least one primary power input for receiving primary power from a primary power source, the primary power source connected to the at least one primary power input by at least one primary power conductor;

a plurality of equipment loads throughout the vehicle, each of the plurality of equipment loads serviced by a nearest MEC of the plurality of MECs; and

a plurality of primary power switching network devices (PPSNDs) within each MEC of the plurality of MECs, the plurality of PPSNDs having a common configuration relative to one another such that each PPSND of the plurality of PPSNDs comprises a common power input and a plurality of common power outputs, wherein the each PPSND receives a different phase of a power signal provided by the primary power source.

2. The primary power switching network of claim **1**, wherein each PPSND within one of the plurality of MECs further comprises a primary power bus configured for distributing primary power to one or more other ones of the plurality of MECs.

3. The primary power switching network of claim **1** or **2**, wherein each PPSND within one of the plurality of MECs further comprises at least one first tie bus

configured for distributing primary power to one or more other ones of the plurality of MECs.

4. The primary power switching network of any one of claims **1** to **3**, wherein each PPSND within one of the plurality of MECs further comprises at least one second tie bus configured for receiving primary power from one or more other ones of the plurality of MECs.

5. The primary power switching network of any one of claims **1** to **4**, wherein each PPSND within one of the plurality of MECs further comprises a plurality of common power output connections configured for distributing primary power.

6. The primary power switching network of claim **5**, wherein at least one of the plurality of common power output connections is configured for distributing primary power to a primary MEC.

7. The primary power switching network of claim **5** or **6**, wherein at least one of the plurality of common power output connections is configured for distributing primary power to a secondary MEC.

8. The primary power switching network of any one of claims **5** to **7**, wherein at least one of the plurality of common power output connections is configured for distributing power to a high voltage AC load.

9. The primary power switching network of any one of claims **1** to **8**, further comprising at least one power distribution module configured for receiving power from the plurality of PPSNDs within one of the plurality of MECs and distributing secondary power to equipment loads of the one of the plurality of MECs.

10. The primary power switching network of any one of claims **1** to **9**, wherein at least one PPSND within one of the plurality of MECs is coupled to a multi-layered integrated truss system, the multi-layered integrated truss system comprising at least one power transfer layer, wherein the at least one power transfer layer receives electrical power from a high power portion of the one of the plurality of MECs through the at least one PPSND and the power transfer layer includes a path for providing the electrical power to a low power portion of the one of the plurality of MECs.

11. The primary power switching network of any one of claims **1** to **10**, wherein the each PPSND further comprises a plurality of contactors, wherein at least a portion of the plurality of contactors on the each PPSND are arranged in a common configuration relative one another for switching power from the common power input to the plurality of common power outputs.

12. The primary power switching network of any one of claims **1** to **11**, wherein the primary power source is configured to distribute poly-phase primary power to the plurality of MECs and wherein the power signal comprises a poly-phase primary power signal.

13. The primary power switching network of any one of claims **1** to **11**, wherein the primary power source provides three-phase primary power to the each PPSNDs within the each MEC.

14. The primary power switching network of claim **13**, wherein the plurality of PPSNDs within the each MEC comprise at least three PPSNDs within the each MEC, and wherein each of the at least three PPSNDs receives a different phase of the three-phase primary power.

15. A solid state primary power switching network for use with a vehicle, the power switching network comprising:

first and second modular equipment centers (MECs) spatially distributed throughout the vehicle;

first and second primary power sources each connected to the first and second MECs by at least one respective primary power conductor, the first and second primary power source for distributing a respective poly-phase primary power signal to the first and second MECs;

a plurality of equipment loads throughout the vehicle, each of the equipment loads serviced by a nearest one of the first and second MECs; and

a plurality of primary power switching network devices (PPSNDs) within each of the first and second MECs, the plurality of PPSNDs sharing a common configuration relative to one another such that each PPSND comprise at least one common power input and a plurality of common power outputs,

wherein each PPSND of the plurality of PPSNDs within the first MEC receives a different phase of the respective poly-phase primary power signal from the first primary power source and each PPSND of the plurality of PPSNDs within the second MEC receives a different phase of the respective poly-phase primary power signal from the second primary power source.

16. The solid state primary power switching network of claim **15**, wherein the first and second MECs are primary MECs and the first and second primary power sources are generators.

17. A primary power switching network for use with a vehicle, the power switching network comprising:

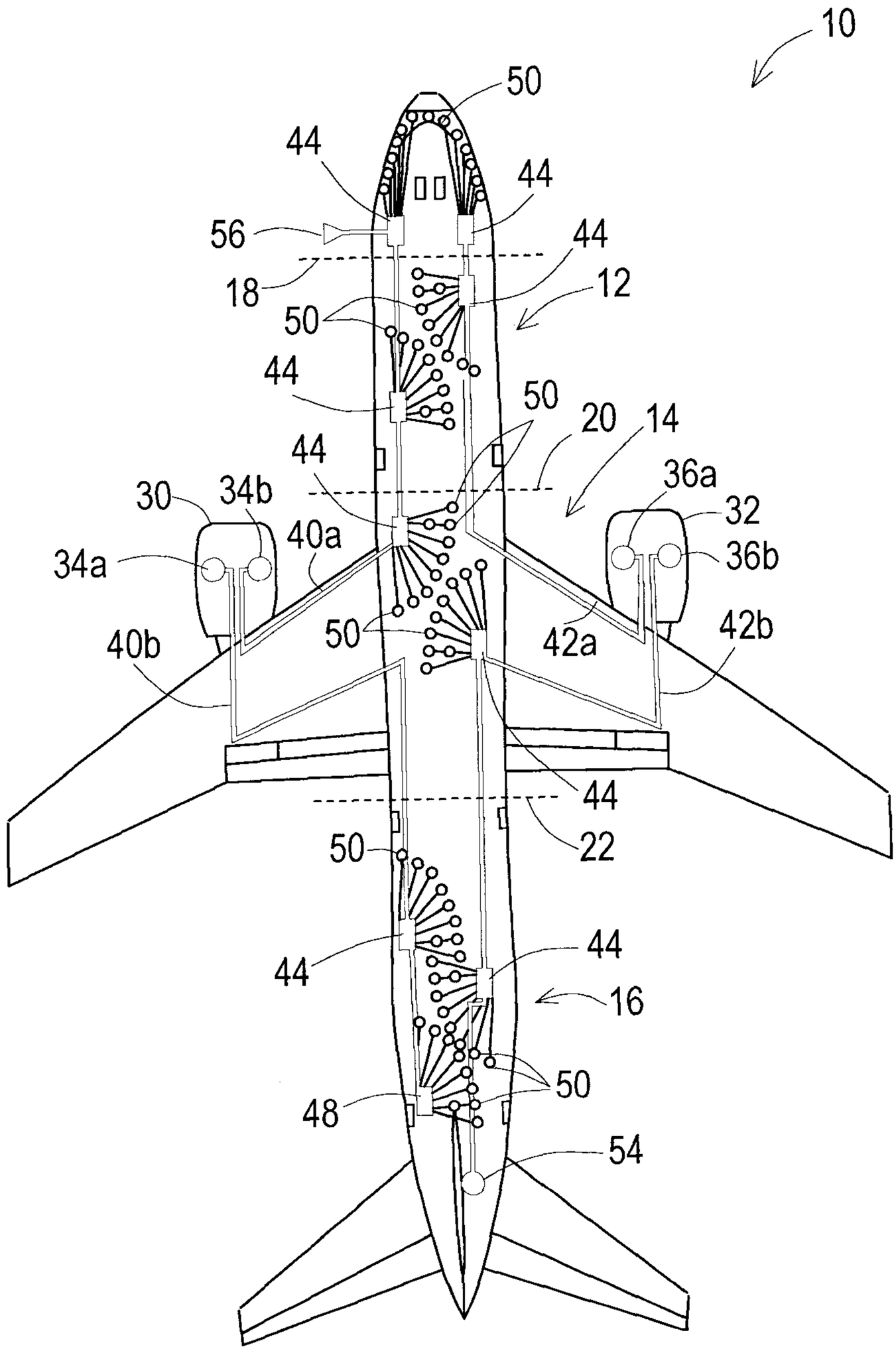
a modular equipment center (MEC) for use within the vehicle;

at least one primary power source connected to the MEC by at least one primary power conductor and configured to distribute a three-phase primary power signal to the MEC;

a plurality of equipment loads in the vehicle serviced by the MEC; and

at least three primary power switching network devices (PPSNDs) within the MEC, the at least three PPSNDs having a common configuration relative to one another such that each PPSND comprises at least one common power input and a plurality of common power outputs,

wherein the each PPSND receives a different phase of the three-phase primary power signal generated from the at least one primary power source.


10
50
44
44
56
44
18
12
50
44
50
20
14
44
36a
30
34b
32
40a
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42a
42b
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44
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22
44
44
16
50
48
54

FIG. 1

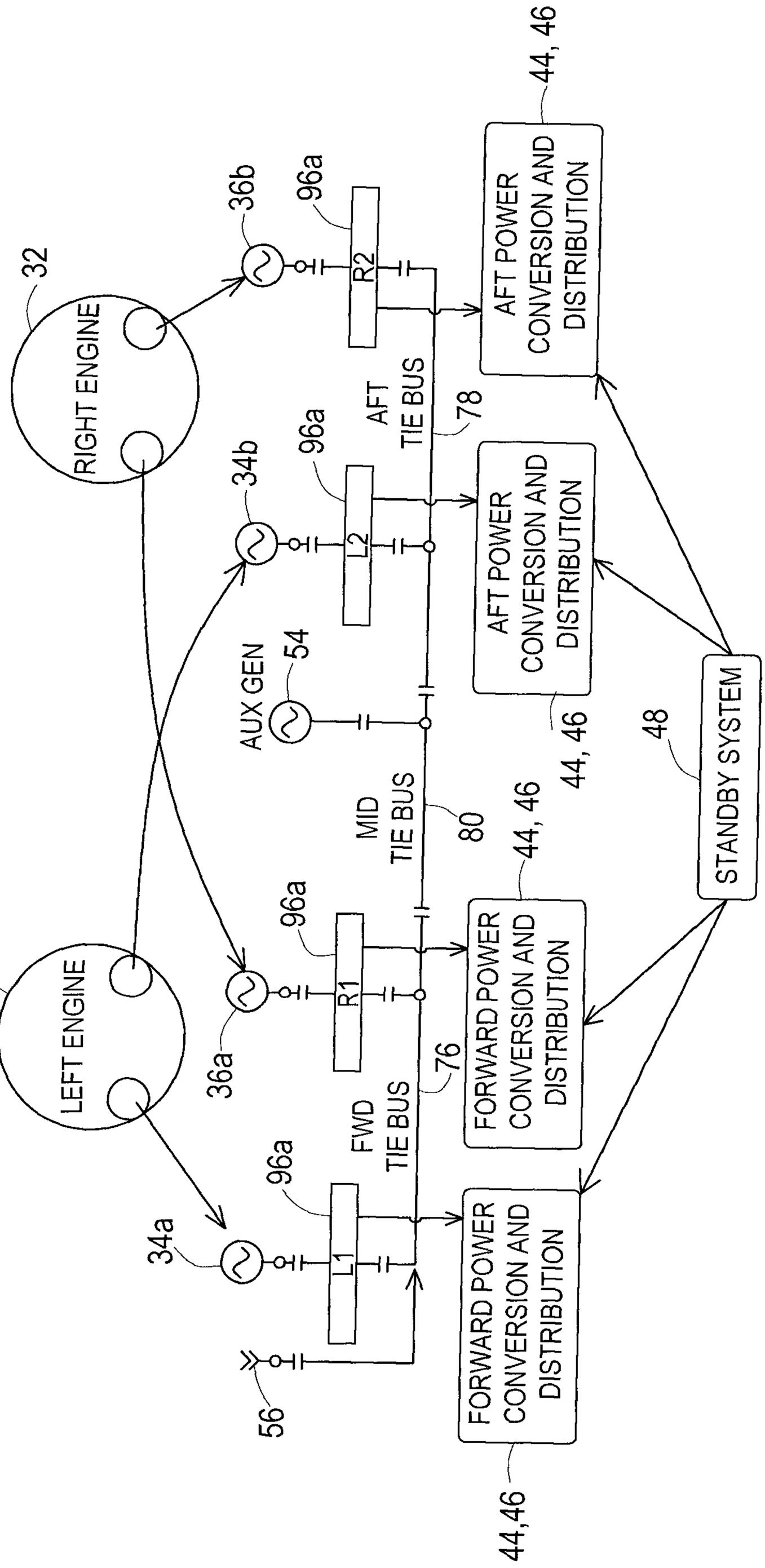

32
RIGHT ENGINE
36b
96a
R2
AFT POWER CONVERSION AND DISTRIBUTION
44, 46
34b
96a
L2
AFT TIE BUS
78
AUX GEN
54
AFT POWER CONVERSION AND DISTRIBUTION
44, 46
48
STANDBY SYSTEM
MID TIE BUS
80
44, 46
30
LEFT ENGINE
36a
96a
R1
FWD TIE BUS
76
FORWARD POWER CONVERSION AND DISTRIBUTION
34a
96a
L1
56
FORWARD POWER CONVERSION AND DISTRIBUTION
44,46

FIG. 2

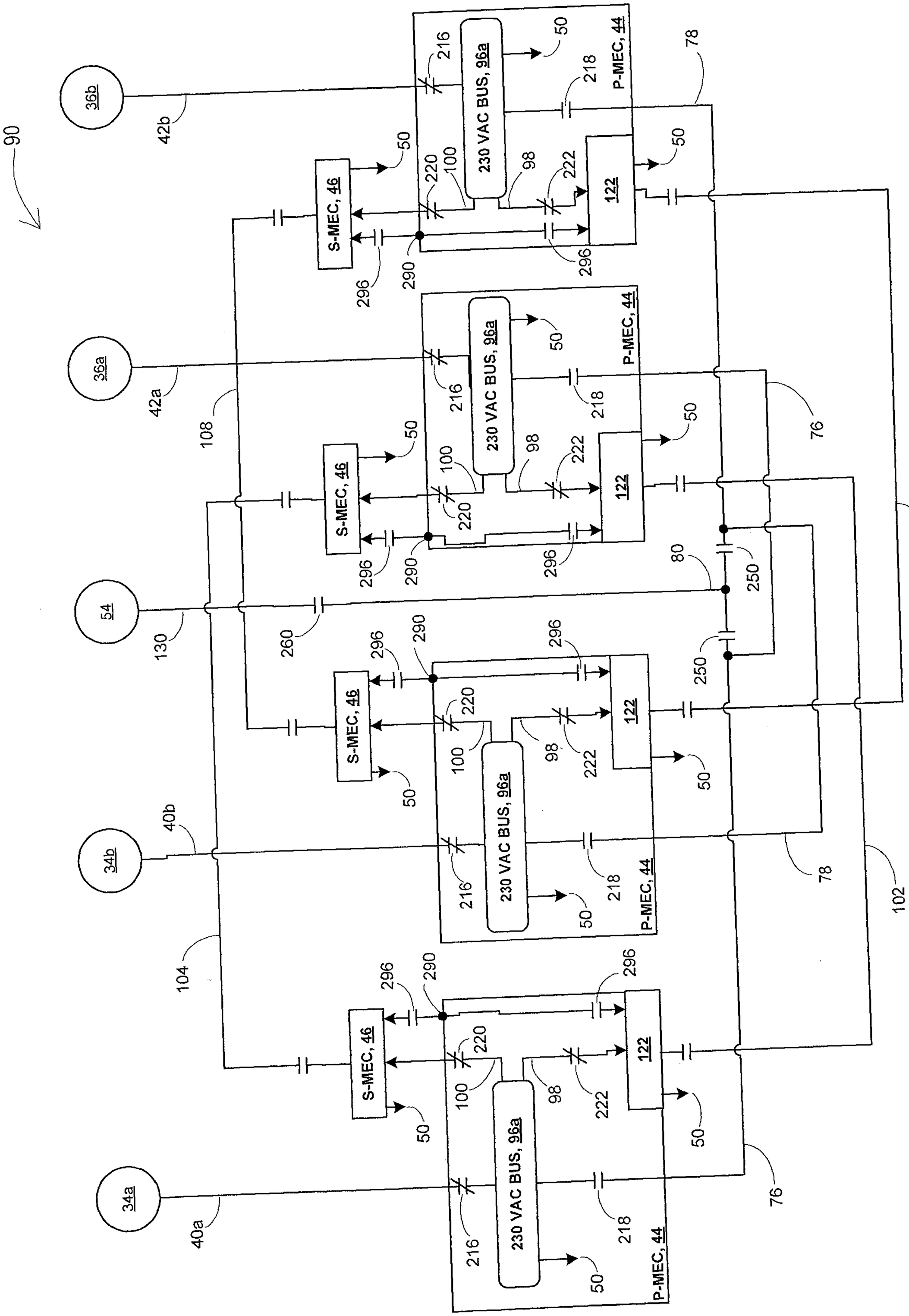

90
36b
42b
S-MEC, 46
230 VAC BUS, 96a
P-MEC, 44
122
50
216
218
220
222
100
98
296
290
78
76
106
36a
42a
108
54
130
260
80
250
34b
40b
104
102
34a
40a

FIG. 3

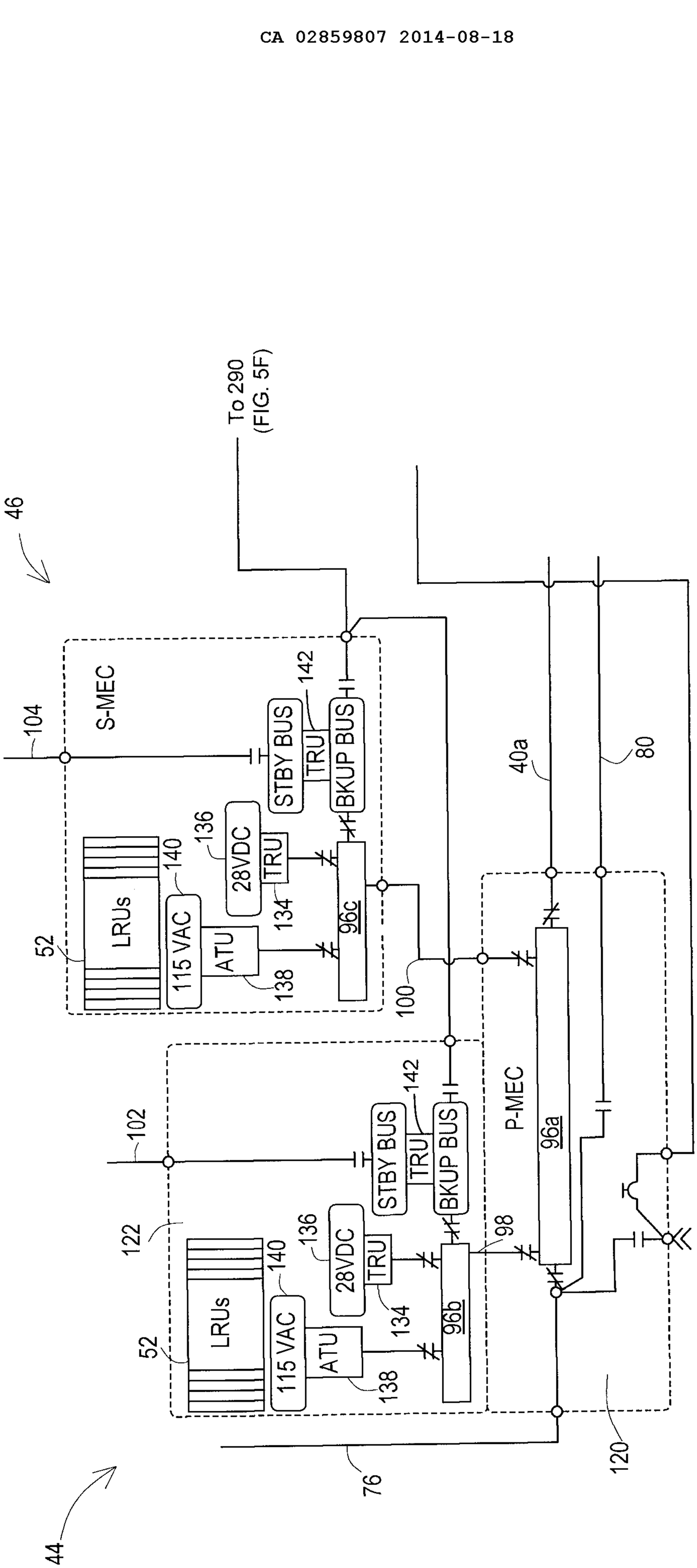

To 290
(FIG. 5F)
46
104
S-MEC
142
STBY BUS
TRU
BKUP BUS
136
28VDC
TRU
134
96c
52
LRUs
140
115 VAC
ATU
138
100
40a
80
102
122
P-MEC
96a
98
96b
120
76
44

FIG. 4

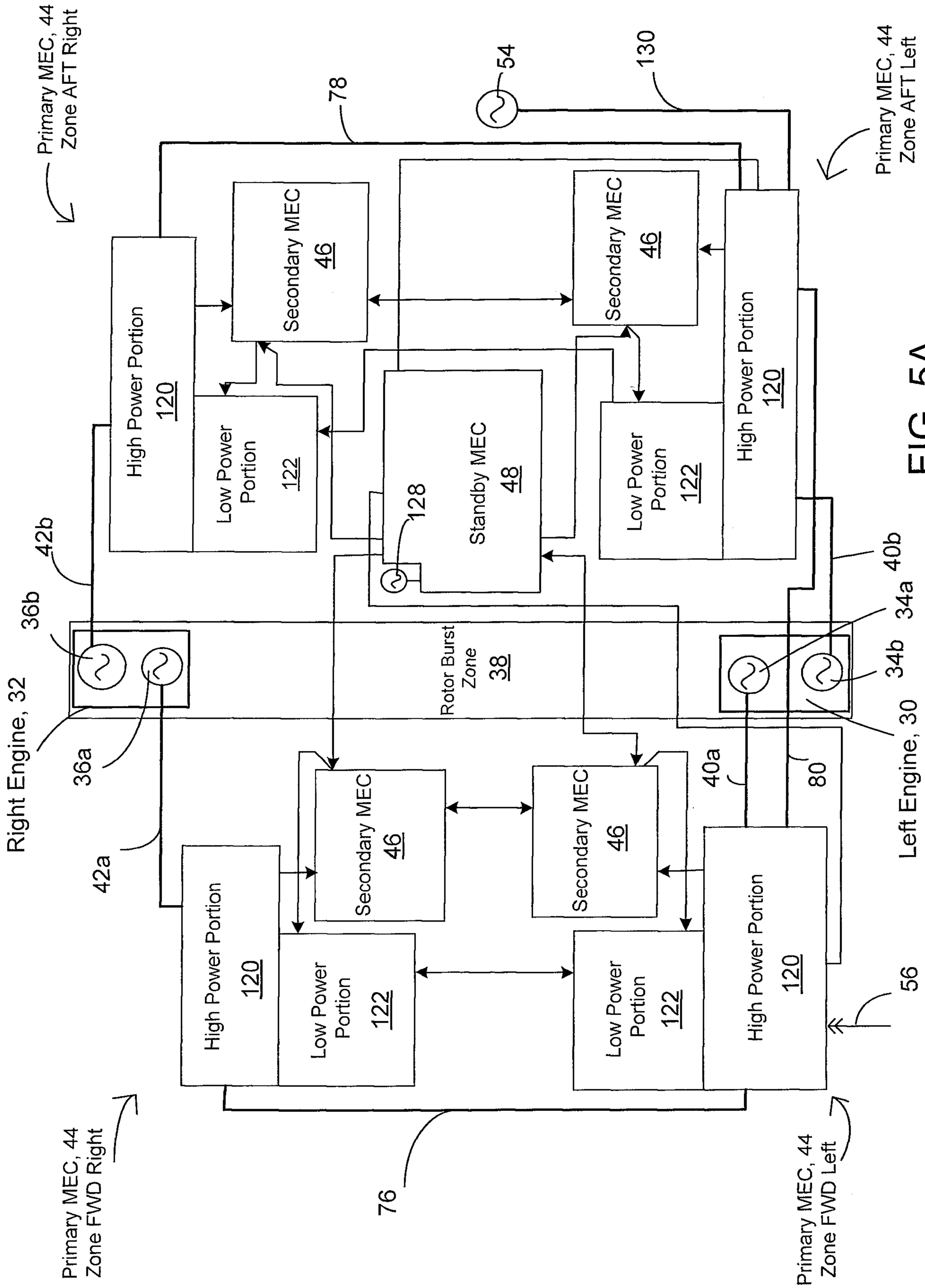

Primary MEC, 44
Zone AFT Right
78
54
130
Primary MEC, 44
Zone AFT Left
High Power Portion
120
Secondary MEC
46
Low Power
Portion
122
Standby MEC
48
128
42b
36b
Right Engine, 32
36a
Rotor Burst
Zone
38
34a
34b
Left Engine, 30
40b
42a
40a
80
56
Primary MEC, 44
Zone FWD Right
76
Primary MEC, 44
Zone FWD Left

FIG. 5A

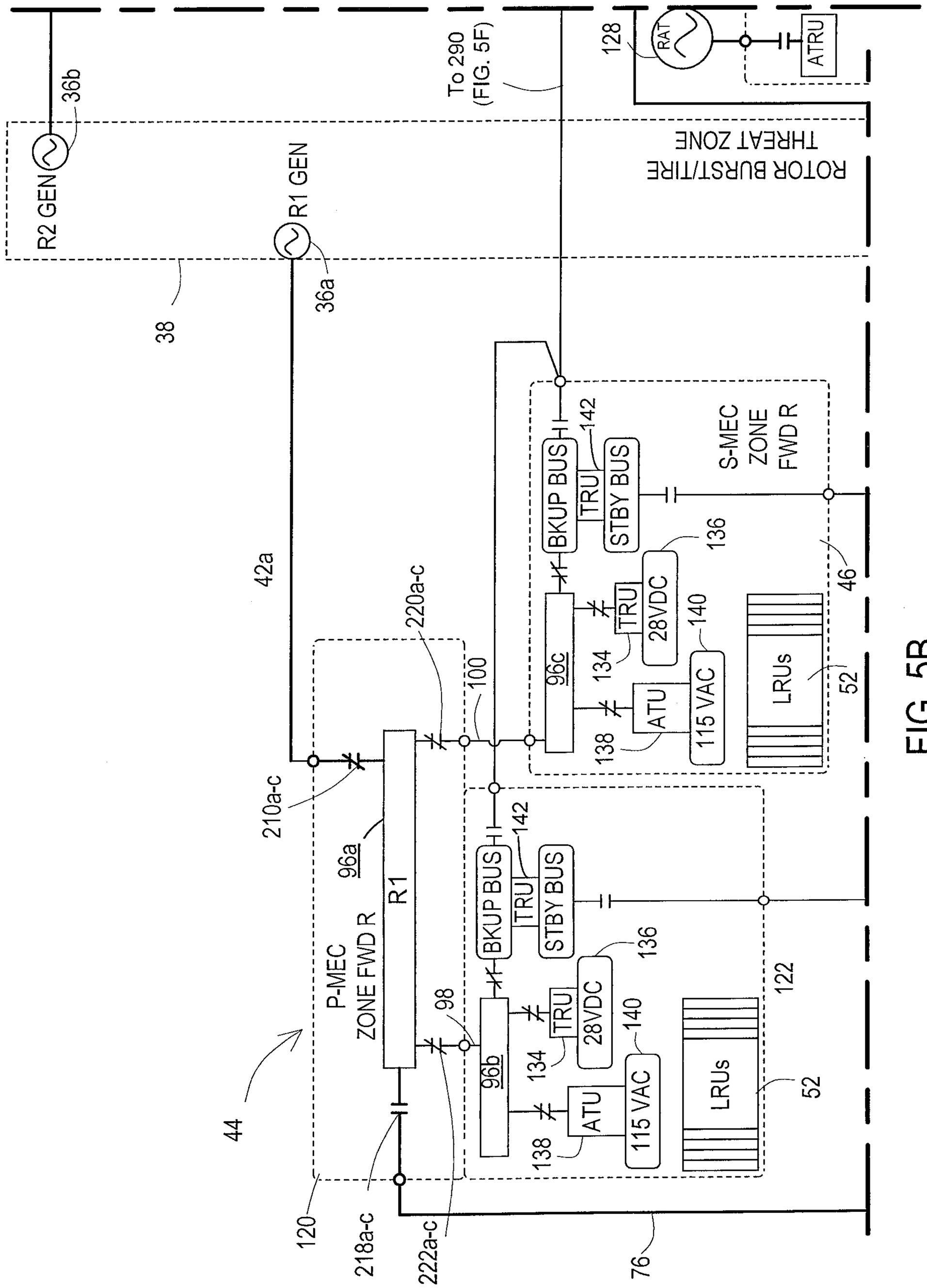

To 290
(FIG. 5F)
128
RAT
ATRU
ROTOR BURST/TIRE
THREAT ZONE
36b
R2 GEN
38
R1 GEN
36a
42a
220a-c
100
46
S-MEC
ZONE
FWD R
142
BKUP BUS
TRU
STBY BUS
136
28VDC
140
134
ATU
115 VAC
138
96c
LRUs
52
210a-c
96a
R1
P-MEC
ZONE FWD R
98
96b
122
44
120
218a-c
222a-c
76

FIG. 5B

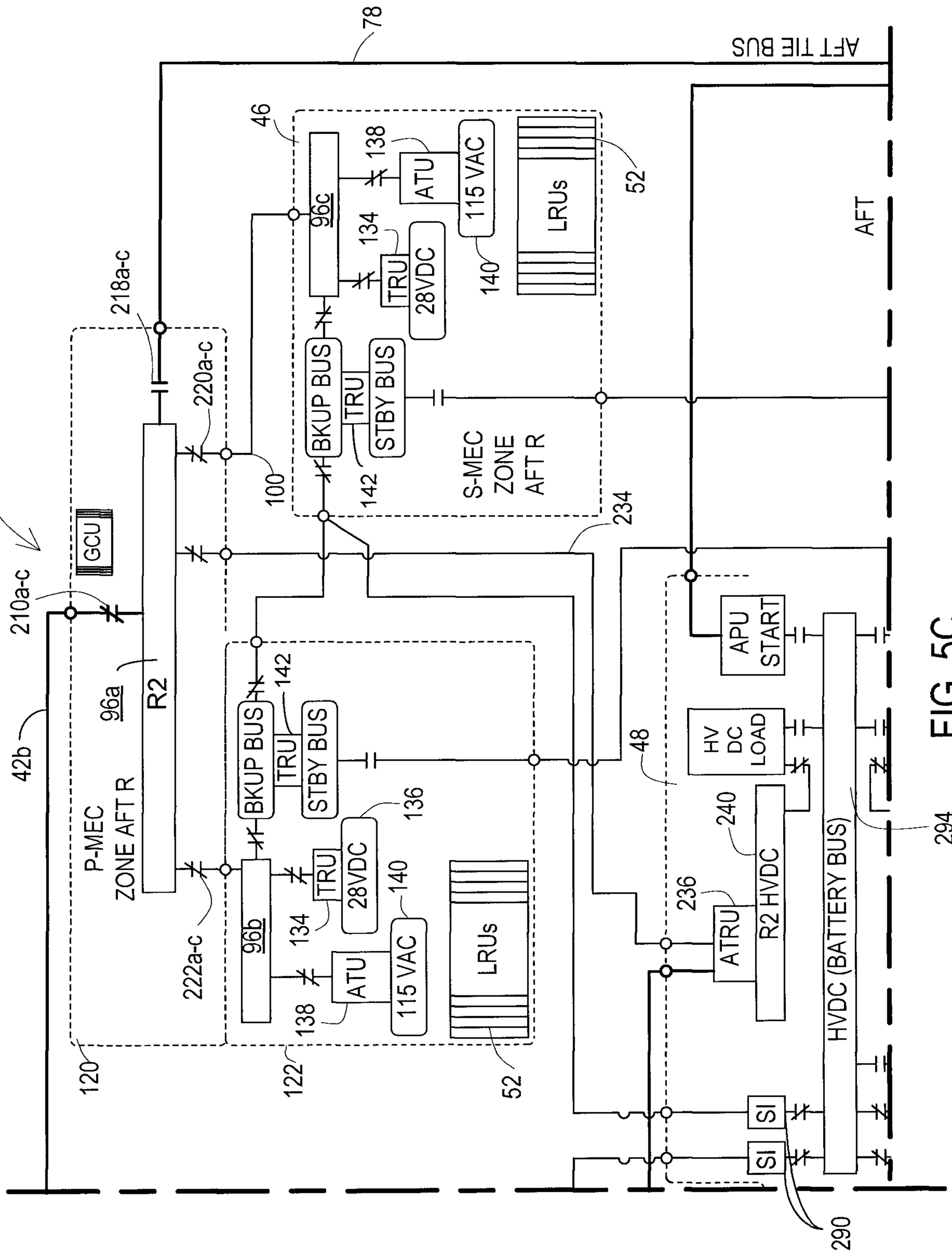

78
AFT TIE BUS
46
96c
138
ATU
115 VAC
134
TRU
28VDC
140
LRUs
52
AFT
218a-c
220a-c
BKUP BUS
TRU
STBY BUS
142
100
S-MEC
ZONE
AFT R
234
44
210a-c
GCU
42b
96a
R2
P-MEC
ZONE AFT R
222a-c
96b
136
48
APU
START
HV
DC
LOAD
240
236
ATRU
R2 HVDC
294
HVDC (BATTERY BUS)
120
122
52
SI
SI
290

FIG. 5C

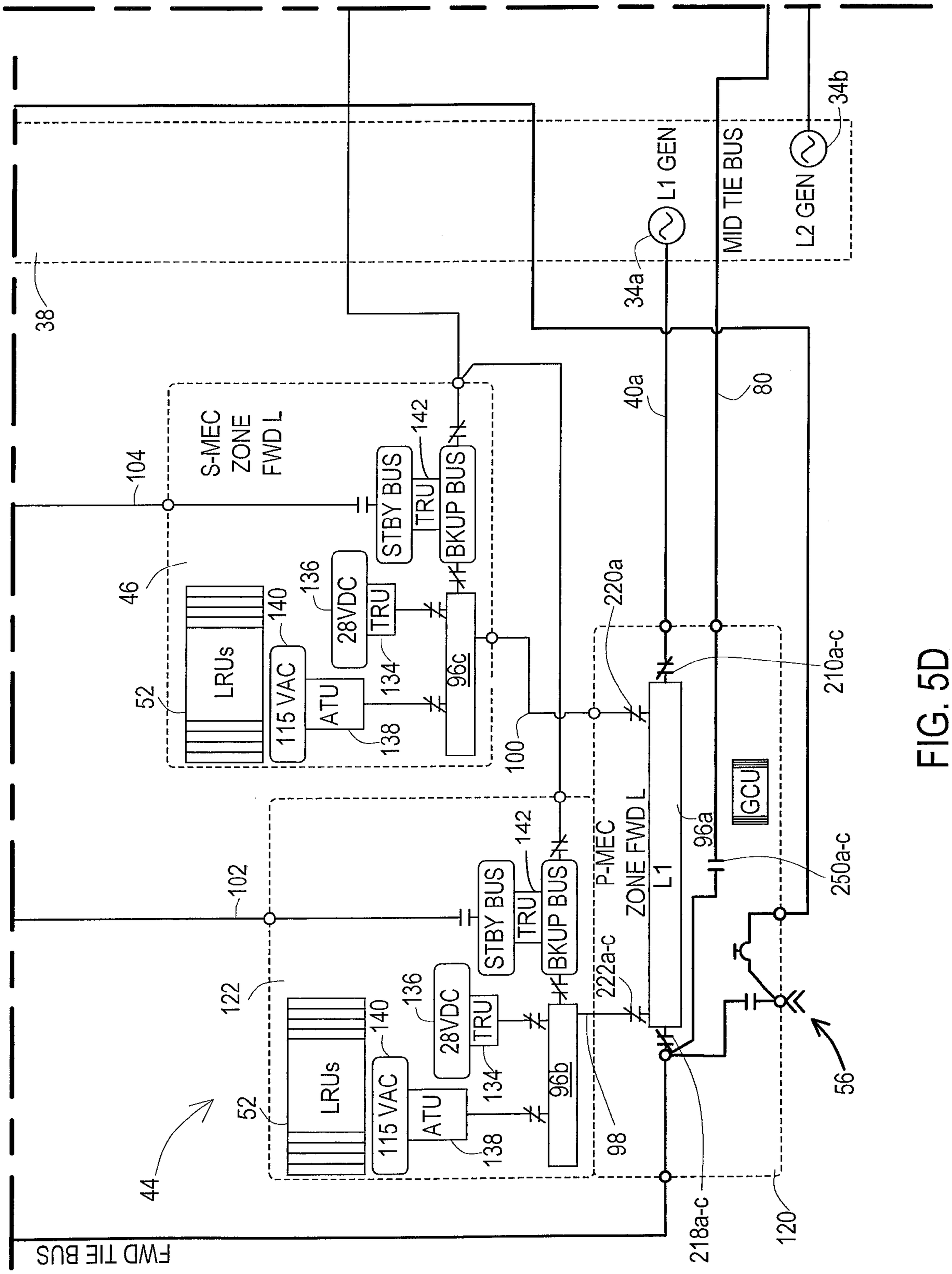

FWD TIE BUS
MID TIE BUS
L1 GEN
L2 GEN
34b
34a
38
40a
80
220a
104
S-MEC ZONE FWD L
142
STBY BUS
TRU
BKUP BUS
136
28VDC
TRU
134
96c
46
52
LRUs
140
115 VAC
ATU
138
100
102
P-MEC ZONE FWD L
222a-c
96a
GCU
210a-c
250a-c
122
96b
98
56
44
218a-c
120

FIG. 5D

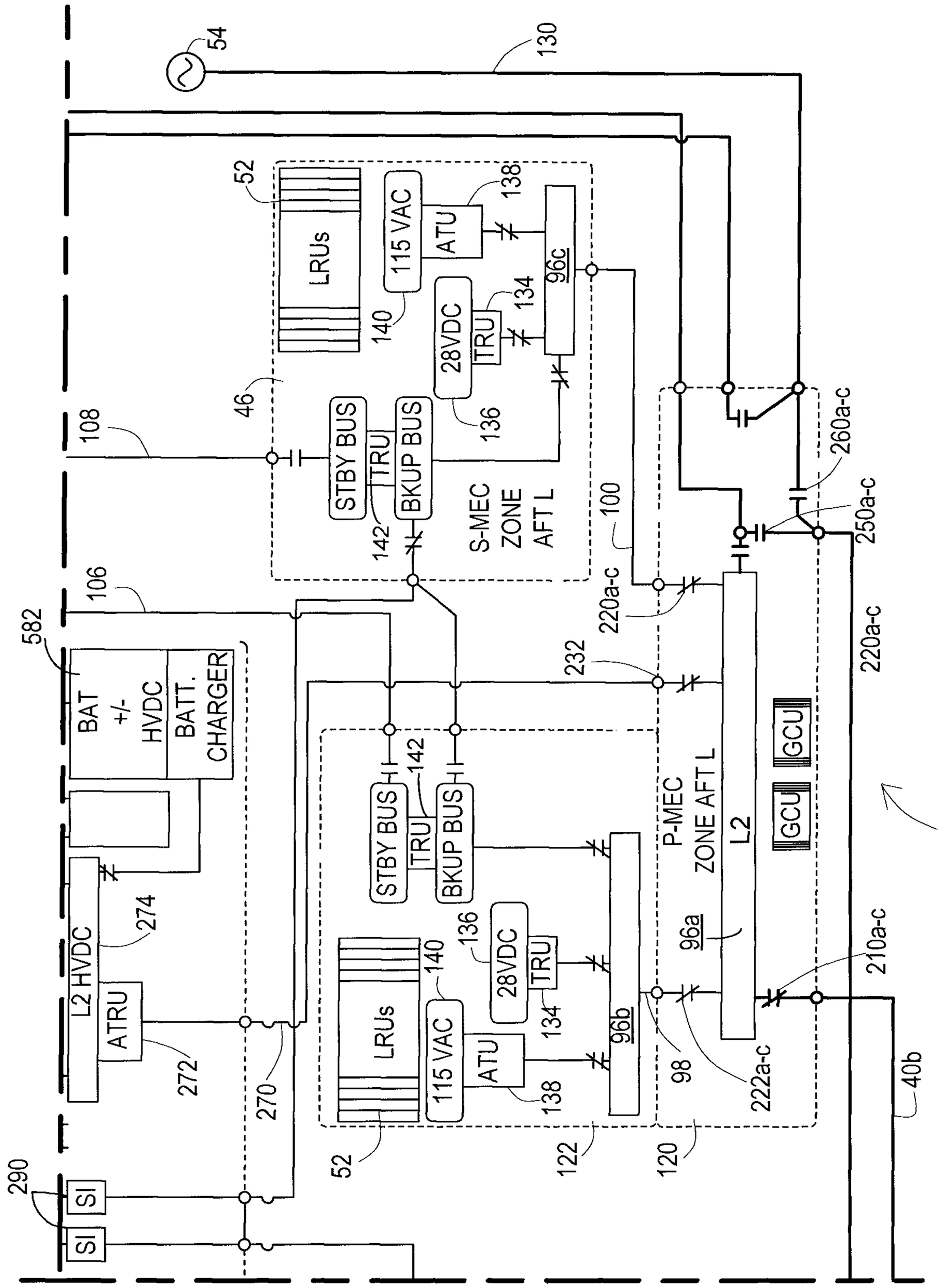

54
130
52
LRUs
115 VAC
ATU
138
140
28VDC
TRU
134
96c
46
108
STBY BUS
TRU
BKUP BUS
142
136
S-MEC
ZONE
AFT L
100
260a-c
250a-c
220a-c
106
582
BAT
+/-
HVDC
BATT.
CHARGER
232
P-MEC
ZONE AFT L
L2
GCU
GCU
44
L2 HVDC
ATRU
274
272
270
96a
210a-c
96b
98
222a-c
40b
122
120
290
SI
SI

FIG. 5E

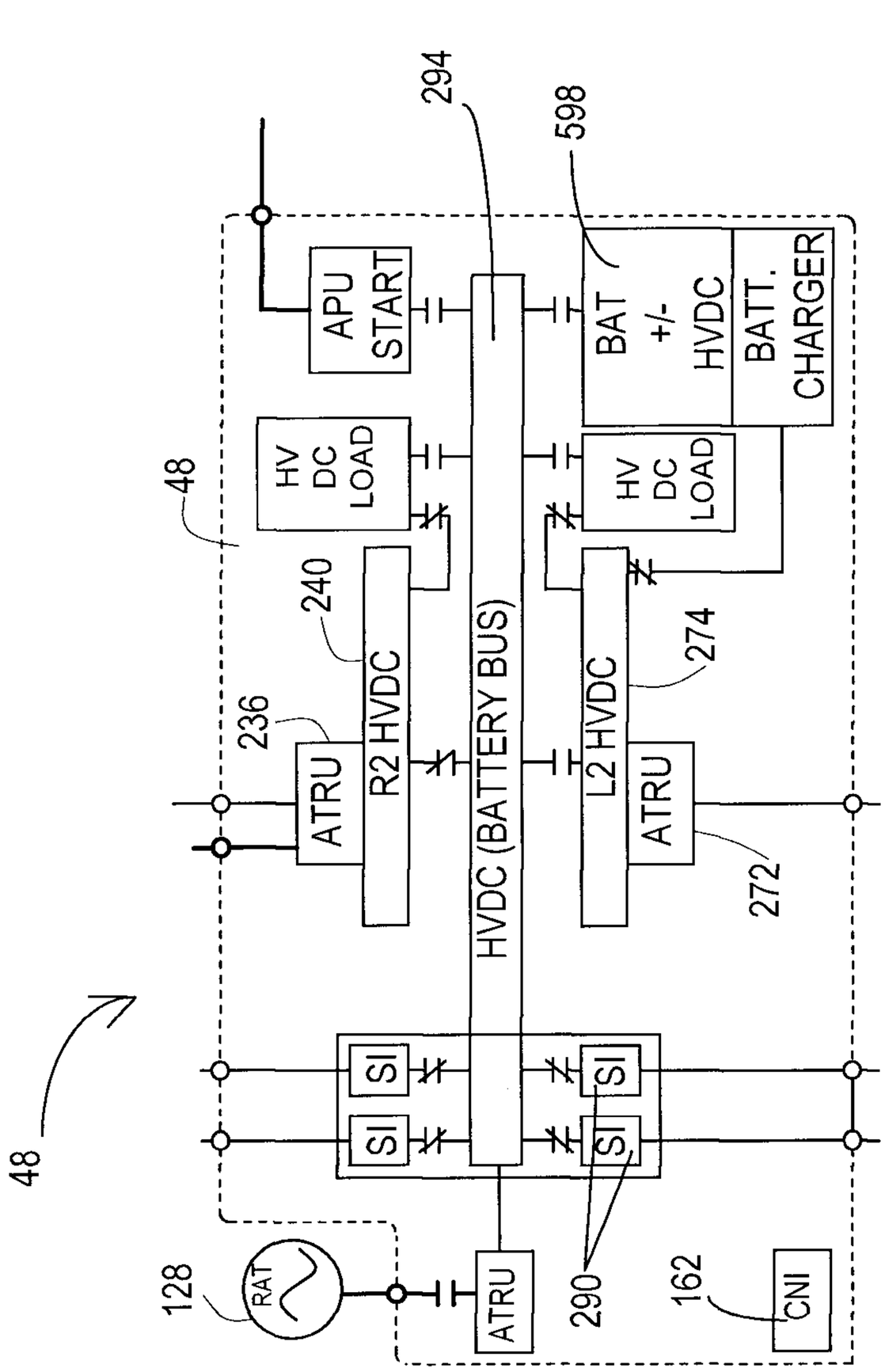

48
294
598
APU START
HV DC LOAD
BAT +/- HVDC
BATT. CHARGER
HV DC LOAD
240
236
ATRU
R2 HVDC
HVDC (BATTERY BUS)
L2 HVDC
274
ATRU
272
SI
SI
SI
SI
128
RAT
ATRU
290
162
CNI

FIG. 5F

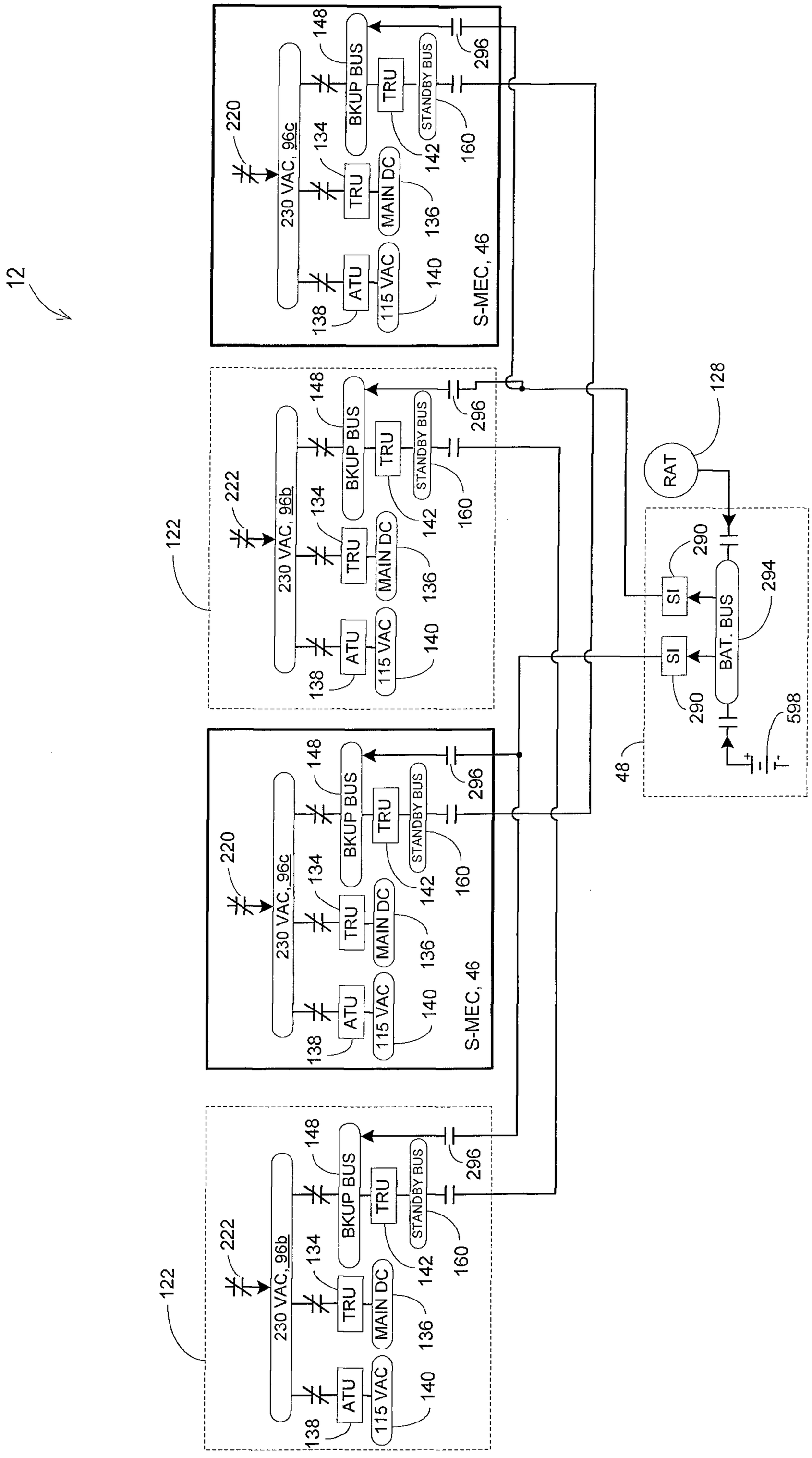

12
220
230 VAC, 96c
134
148
BKUP BUS
TRU
STANDBY BUS
296
142
160
TRU
MAIN DC
136
ATU
115 VAC
140
138
S-MEC, 46
122
222
230 VAC, 96b
RAT
128
SI
290
294
BAT. BUS
598
48
T-

FIG. 6

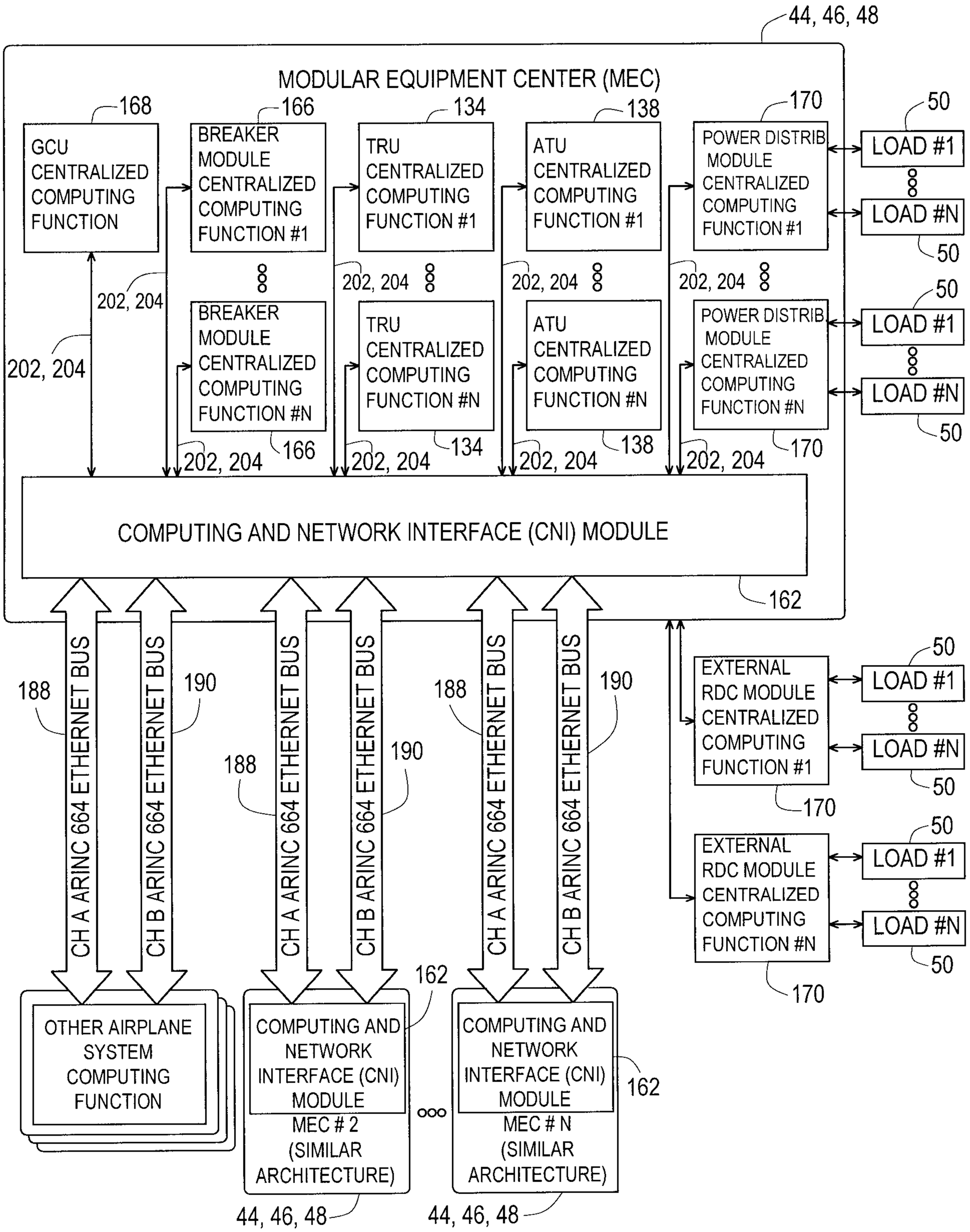

44, 46, 48
MODULAR EQUIPMENT CENTER (MEC)
168
GCU CENTRALIZED COMPUTING FUNCTION
166
BREAKER MODULE CENTRALIZED COMPUTING FUNCTION #1
134
TRU CENTRALIZED COMPUTING FUNCTION #1
138
ATU CENTRALIZED COMPUTING FUNCTION #1
170
POWER DISTRIB MODULE CENTRALIZED COMPUTING FUNCTION #1
50
LOAD #1
LOAD #N
202, 204
BREAKER MODULE CENTRALIZED COMPUTING FUNCTION #N
TRU CENTRALIZED COMPUTING FUNCTION #N
ATU CENTRALIZED COMPUTING FUNCTION #N
POWER DISTRIB MODULE CENTRALIZED COMPUTING FUNCTION #N
COMPUTING AND NETWORK INTERFACE (CNI) MODULE
162
188
190
CH A ARINC 664 ETHERNET BUS
CH B ARINC 664 ETHERNET BUS
EXTERNAL RDC MODULE CENTRALIZED COMPUTING FUNCTION #1
EXTERNAL RDC MODULE CENTRALIZED COMPUTING FUNCTION #N
OTHER AIRPLANE SYSTEM COMPUTING FUNCTION
COMPUTING AND NETWORK INTERFACE (CNI) MODULE
MEC # 2 (SIMILAR ARCHITECTURE)
MEC # N (SIMILAR ARCHITECTURE)

FIG. 7

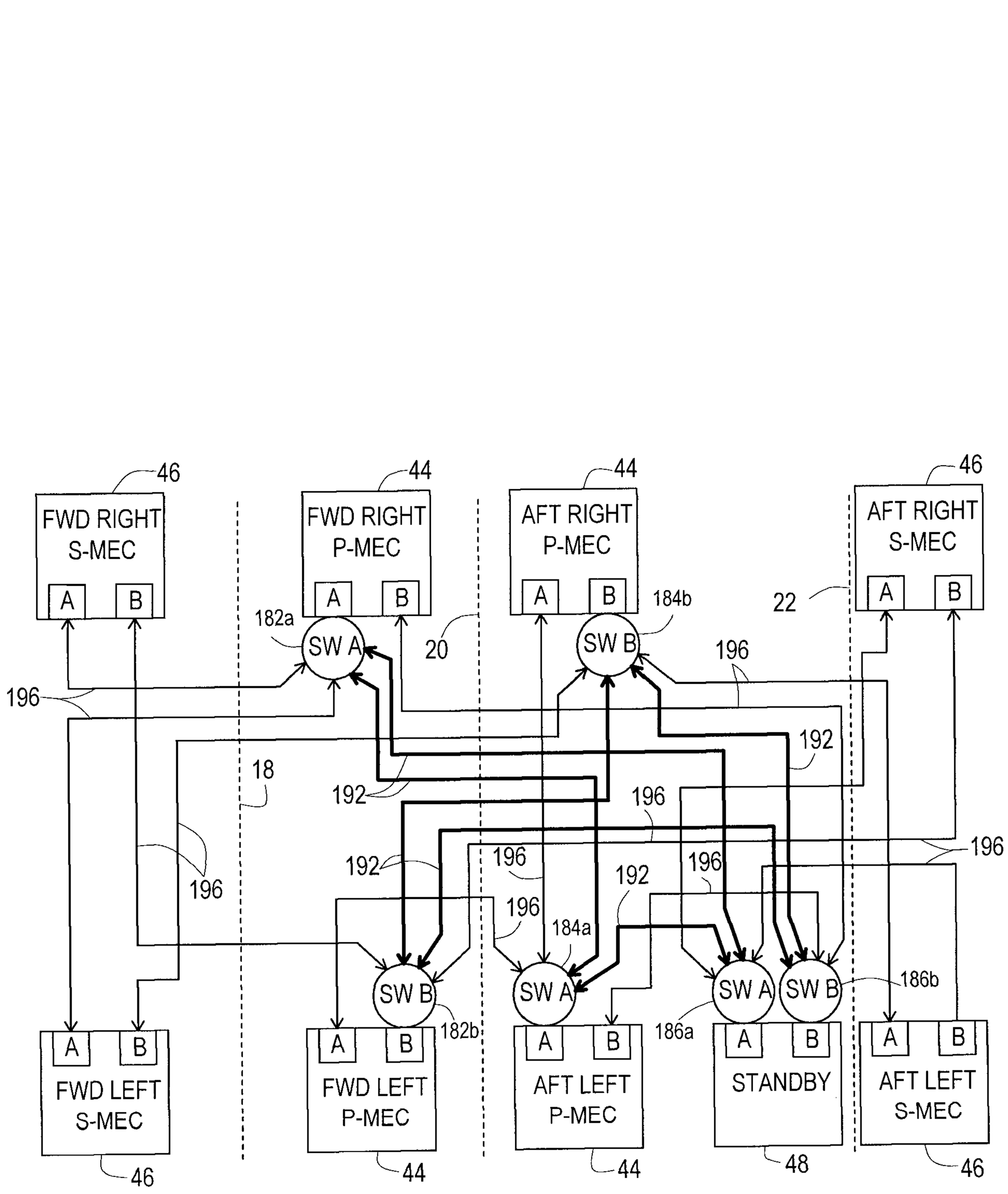

46
FWD RIGHT S-MEC
A
B
44
FWD RIGHT P-MEC
A
B
182a
SW A
20
44
AFT RIGHT P-MEC
A
B
184b
SW B
22
46
AFT RIGHT S-MEC
A
B
196
196
18
192
192
196
196
196
196
196
192
196
196
196
184a
SW B
SW A
SW A
SW B
186b
182b
186a
A
B
FWD LEFT S-MEC
46
A
B
FWD LEFT P-MEC
44
A
B
AFT LEFT P-MEC
44
A
B
STANDBY
48
A
B
AFT LEFT S-MEC
46

FIG. 8

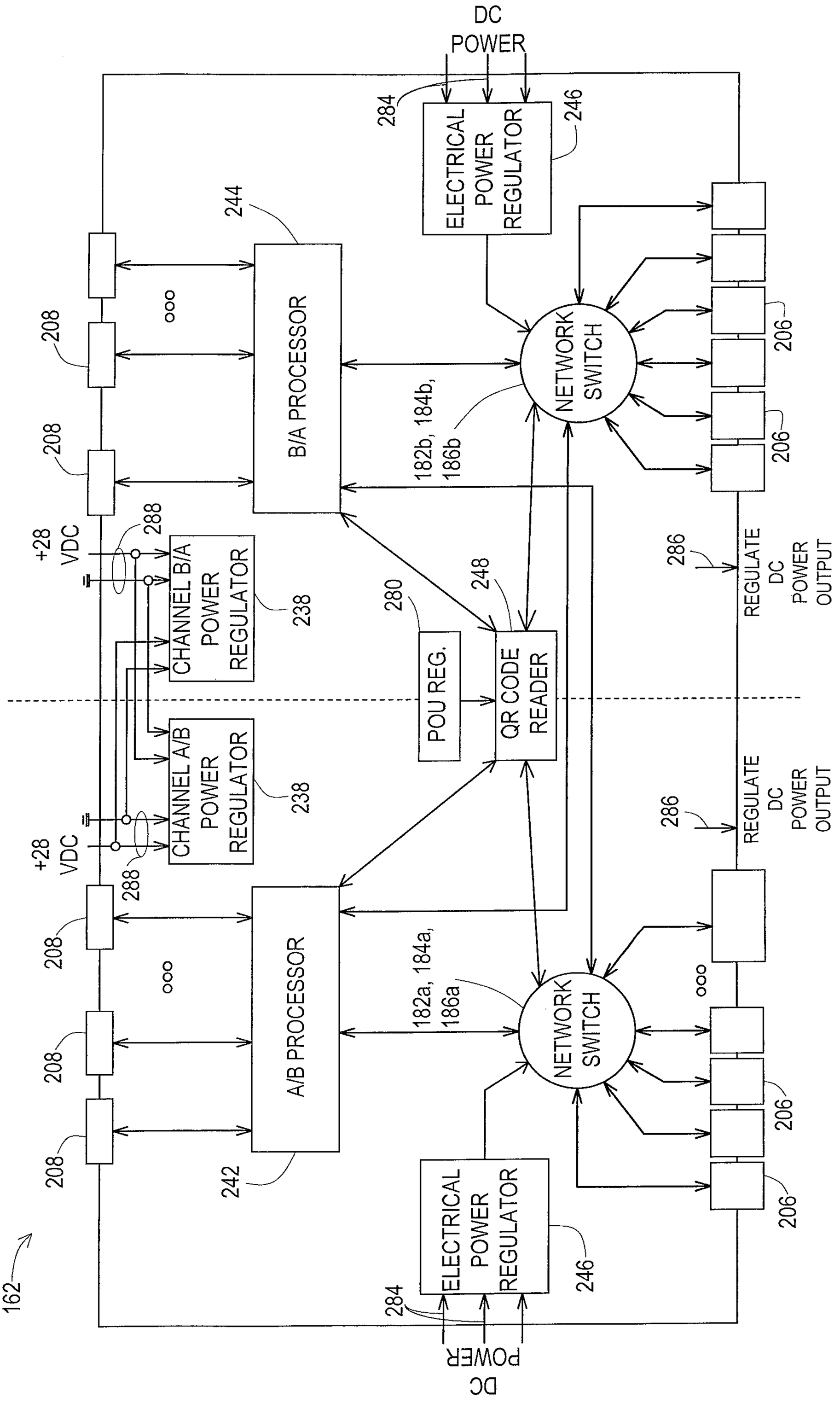

DC POWER
284
ELECTRICAL POWER REGULATOR
246
244
208
208
208
B/A PROCESSOR
182b, 184b, 186b
NETWORK SWITCH
206
206
206
+28 VDC
288
CHANNEL B/A POWER REGULATOR
238
280
POU REG.
248
QR CODE READER
286
REGULATE DC POWER OUTPUT
+28 VDC
288
CHANNEL A/B POWER REGULATOR
238
208
208
208
A/B PROCESSOR
182a, 184a, 186a
NETWORK SWITCH
206
206
242
ELECTRICAL POWER REGULATOR
246
284
DC POWER
162

FIG. 9

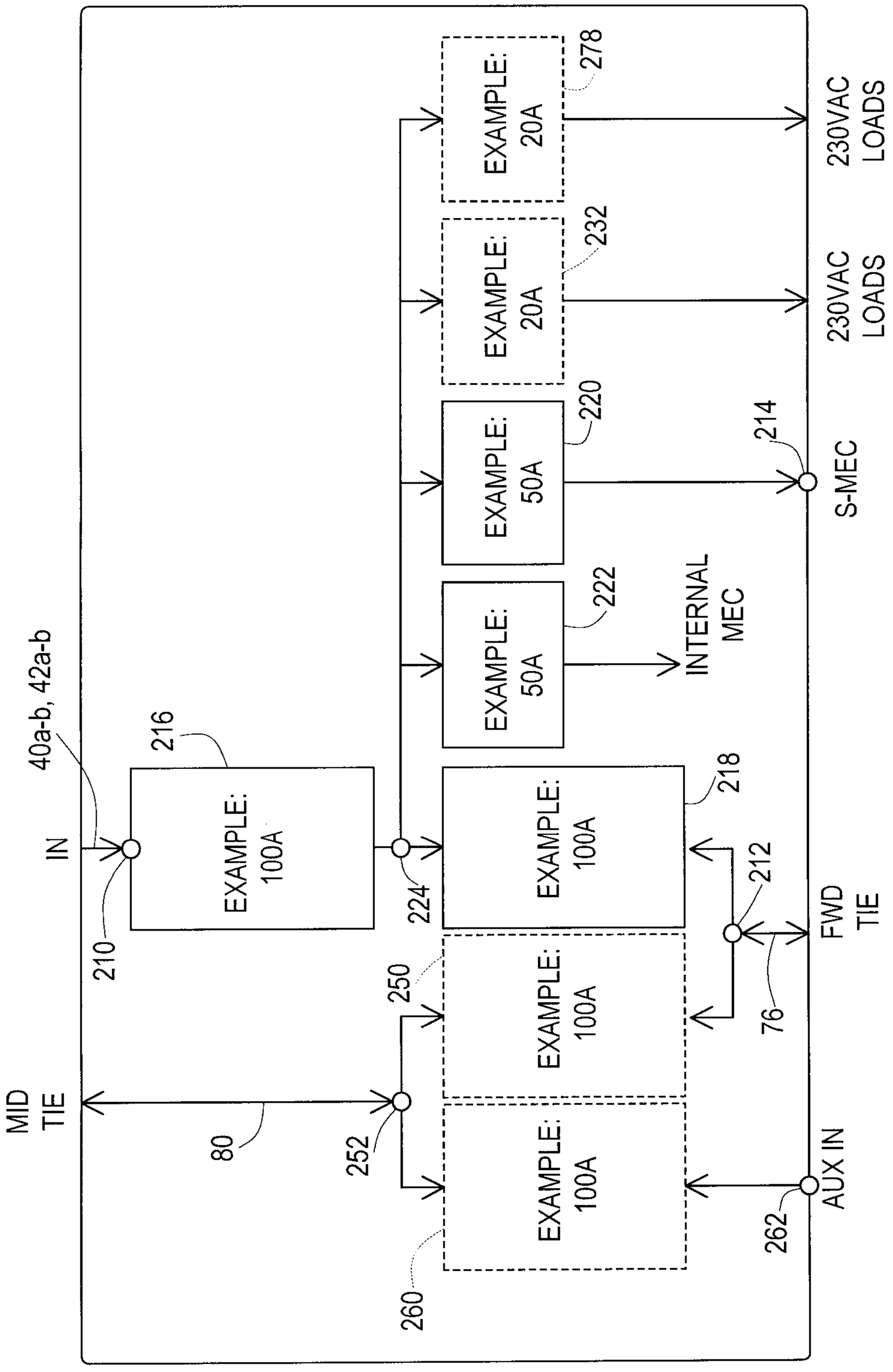

EXAMPLE: 20A
278
EXAMPLE: 20A
232
EXAMPLE: 50A
220
214
222
INTERNAL MEC
S-MEC
230VAC LOADS
230VAC LOADS
40a-b, 42a-b
IN
216
EXAMPLE: 100A
210
224
EXAMPLE: 100A
218
250
EXAMPLE: 100A
212
FWD TIE
76
MID TIE
80
252
EXAMPLE: 100A
260
262
AUX IN

FIG. 10A

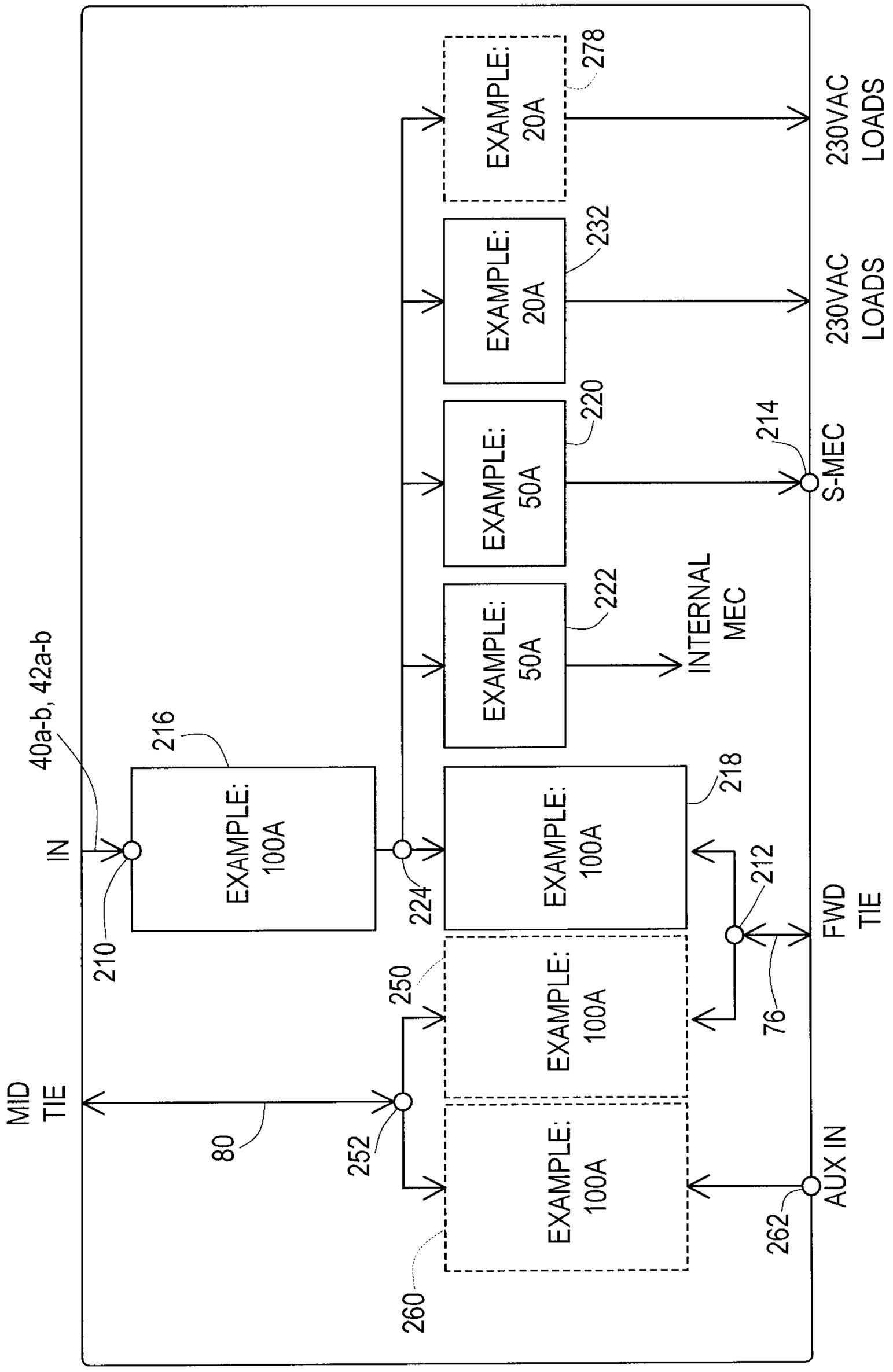

IN
40a-b, 42a-b
210
216
EXAMPLE: 100A
224
EXAMPLE: 100A
218
212
FWD TIE
76
EXAMPLE: 100A
250
EXAMPLE: 100A
260
MID TIE
80
252
EXAMPLE: 50A
222
INTERNAL MEC
EXAMPLE: 50A
220
214
S-MEC
EXAMPLE: 20A
232
EXAMPLE: 20A
278
230VAC LOADS
230VAC LOADS
262
AUX IN

FIG. 10B

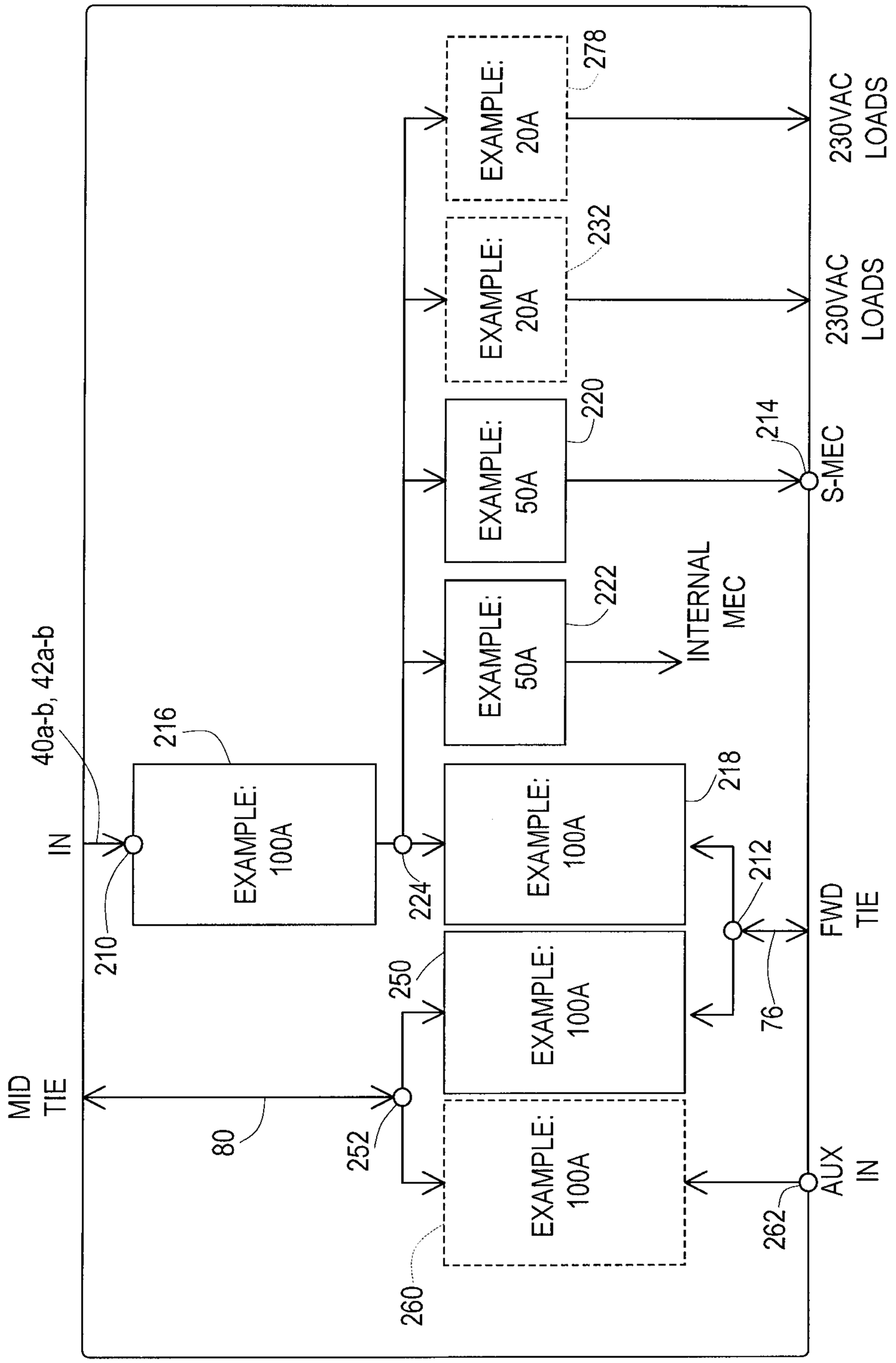

EXAMPLE: 20A
278
EXAMPLE: 20A
232
EXAMPLE: 50A
220
EXAMPLE: 50A
222
EXAMPLE: 100A
216
EXAMPLE: 100A
218
EXAMPLE: 100A
250
EXAMPLE: 100A
260
230VAC LOADS
230VAC LOADS
S-MEC
214
INTERNAL MEC
40a-b, 42a-b
IN
210
224
212
FWD TIE
76
MID TIE
80
252
AUX IN
262

FIG. 10C

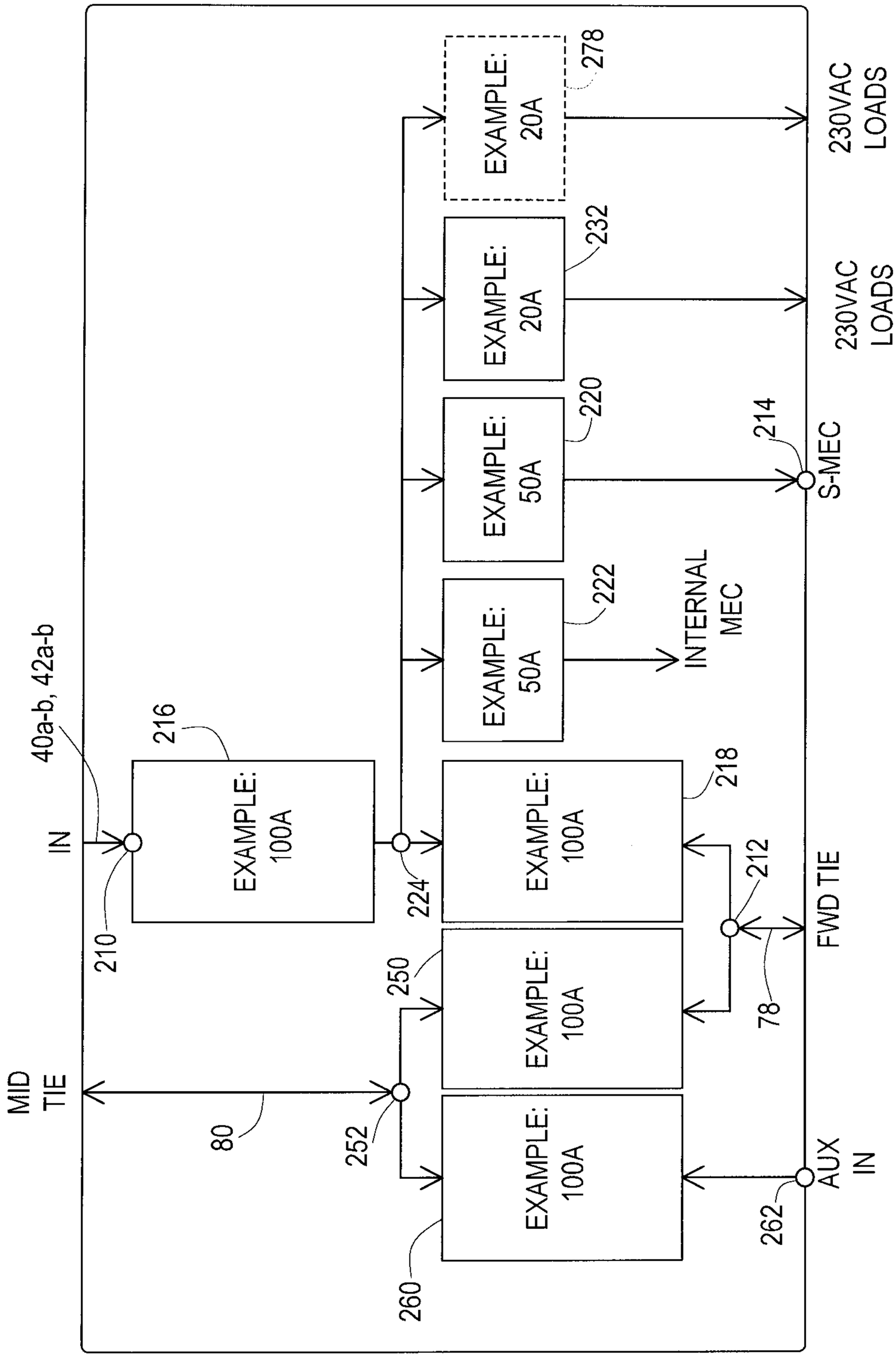

IN
40a-b, 42a-b
MID TIE
FWD TIE
AUX IN
INTERNAL MEC
S-MEC
230VAC LOADS
230VAC LOADS
EXAMPLE: 100A
EXAMPLE: 100A
EXAMPLE: 100A
EXAMPLE: 100A
EXAMPLE: 50A
EXAMPLE: 50A
EXAMPLE: 20A
EXAMPLE: 20A
210
216
224
218
250
260
252
80
212
78
262
214
220
222
232
278

FIG. 10D

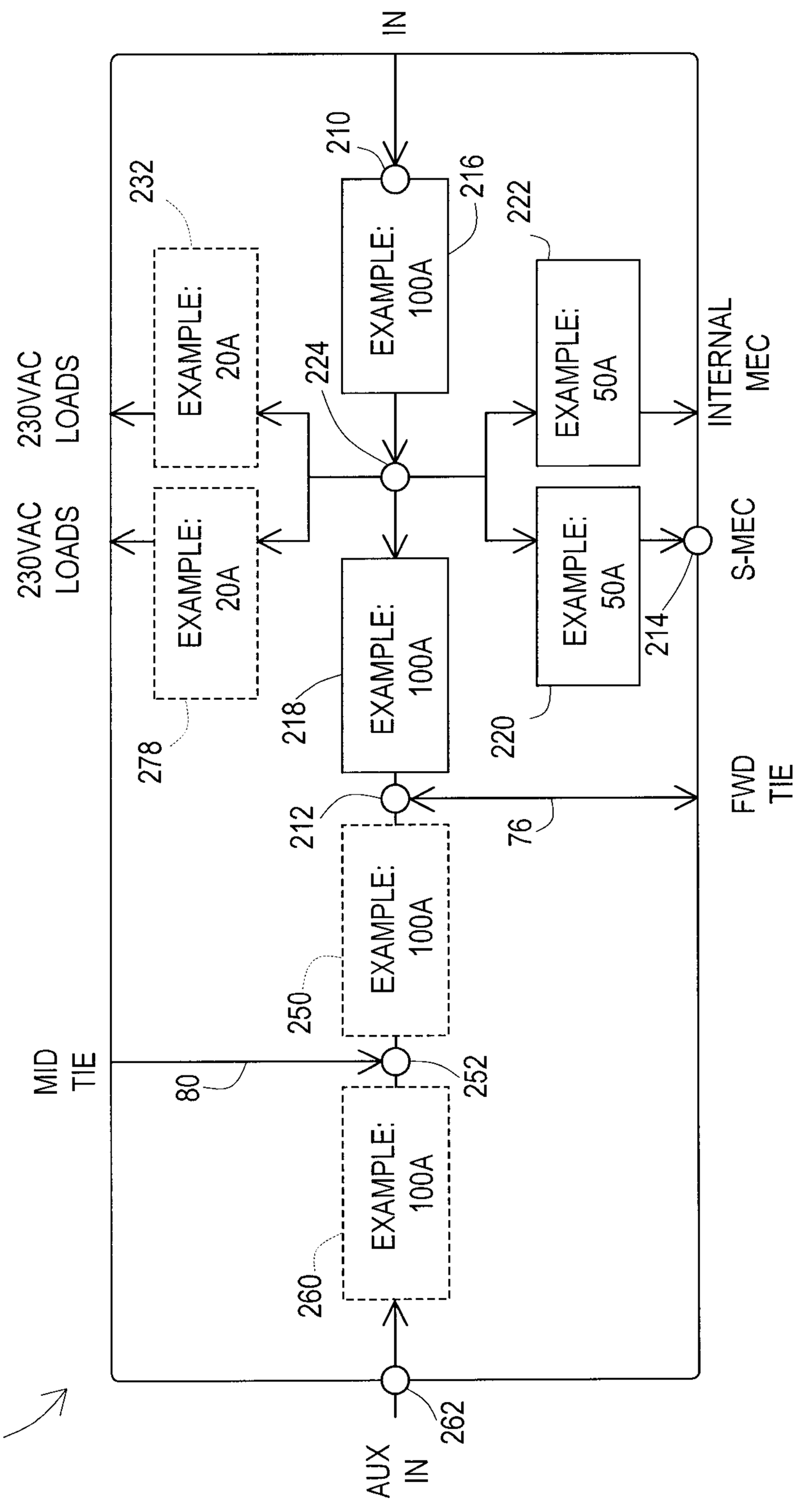

230VAC LOADS
230VAC LOADS
MID TIE
AUX IN
S-MEC
INTERNAL MEC
FWD TIE
EXAMPLE: 20A
EXAMPLE: 20A
EXAMPLE: 100A
EXAMPLE: 100A
EXAMPLE: 100A
EXAMPLE: 100A
EXAMPLE: 50A
EXAMPLE: 50A
210
212
214
216
218
220
222
224
232
250
252
260
262
278
80
76
302

FIG. 11

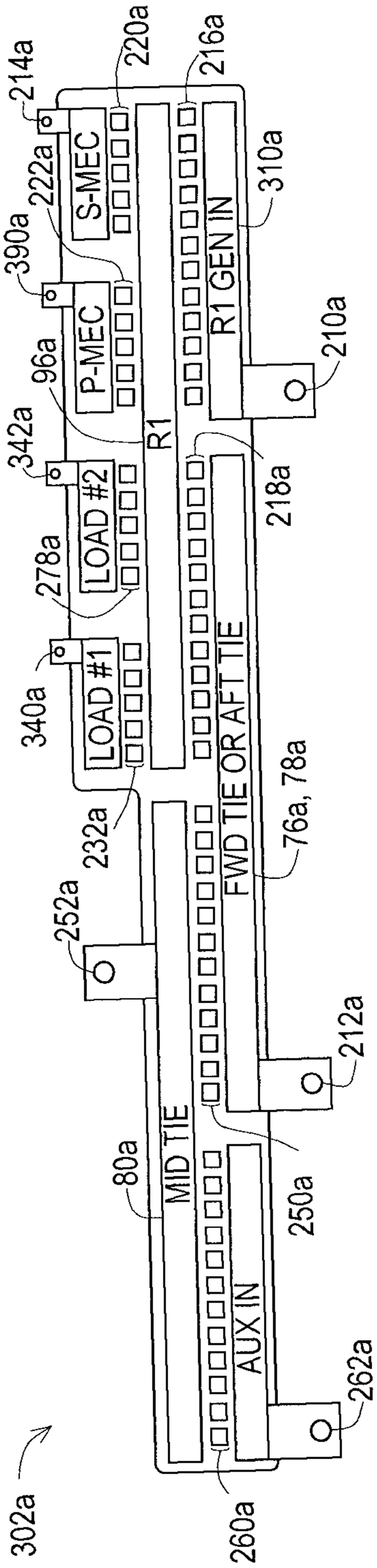

214a
220a
216a
222a
S-MEC
390a
P-MEC
96a
342a
R1
LOAD #2
278a
R1 GEN IN
310a
210a
218a
340a
LOAD #1
232a
FWD TIE OR AFT TIE
76a, 78a
252a
212a
MID TIE
80a
250a
AUX IN
262a
260a
302a

FIG. 12A

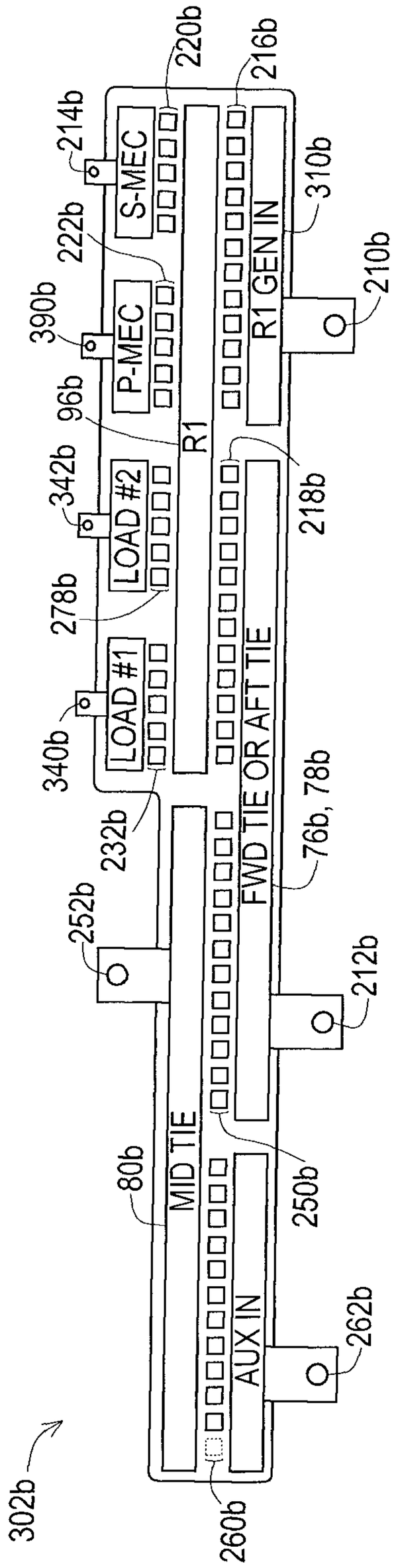

220b
216b
214b
S-MEC
222b
310b
R1 GEN IN
390b
P-MEC
210b
96b
R1
342b
LOAD #2
278b
218b
340b
LOAD #1
FWD TIE OR AFT TIE
78b
232b
76b,
252b
212b
MID TIE
80b
250b
AUX IN
262b
302b
260b

FIG. 12B

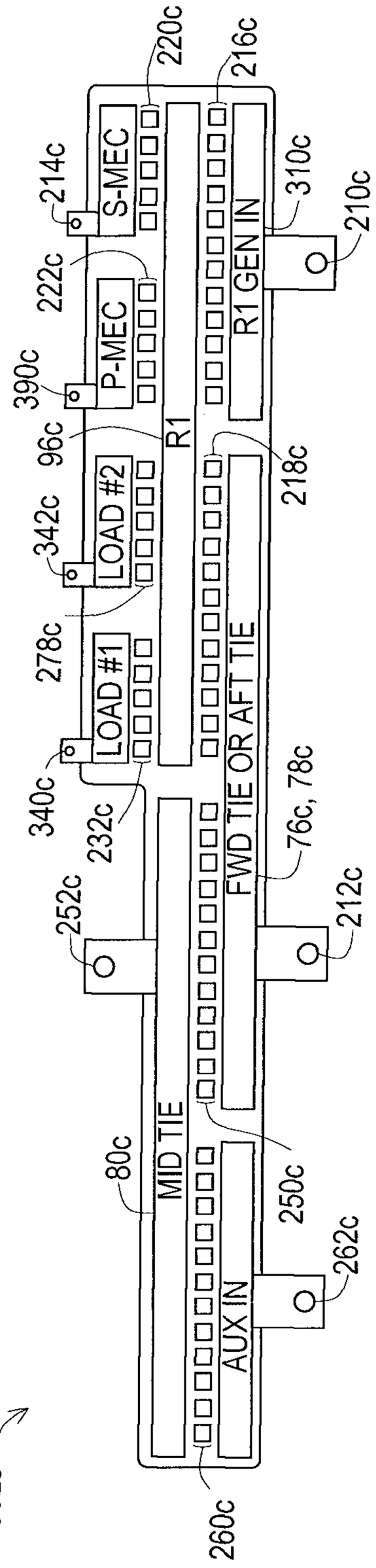

220c
216c
214c
S-MEC
222c
310c
R1 GEN IN
210c
390c
P-MEC
96c
R1
342c
LOAD #2
218c
278c
LOAD #1
78c
340c
232c
252c
76c, 78c
FWD TIE
212c
80c
MID TIE
250c
AUX IN
262c
302c
260c

FIG. 12C

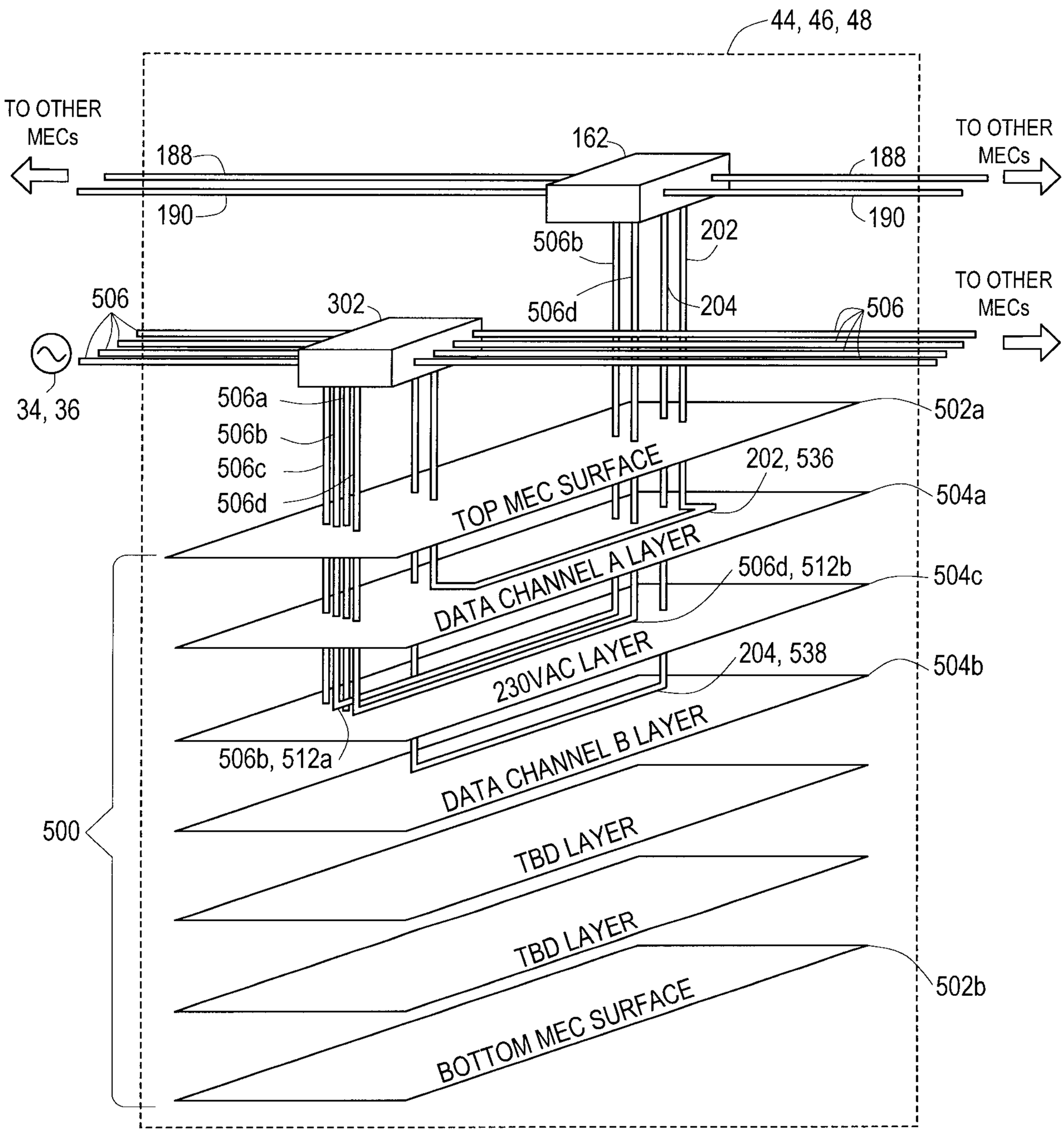

44, 46, 48
TO OTHER MECs
188
190
162
188
190
TO OTHER MECs
506b
202
506d
204
506
302
506
TO OTHER MECs
34, 36
506a
506b
506c
506d
502a
TOP MEC SURFACE
202, 536
504a
DATA CHANNEL A LAYER
506d, 512b
504c
230VAC LAYER
204, 538
504b
506b, 512a
DATA CHANNEL B LAYER
TBD LAYER
TBD LAYER
BOTTOM MEC SURFACE
502b
500

FIG. 13

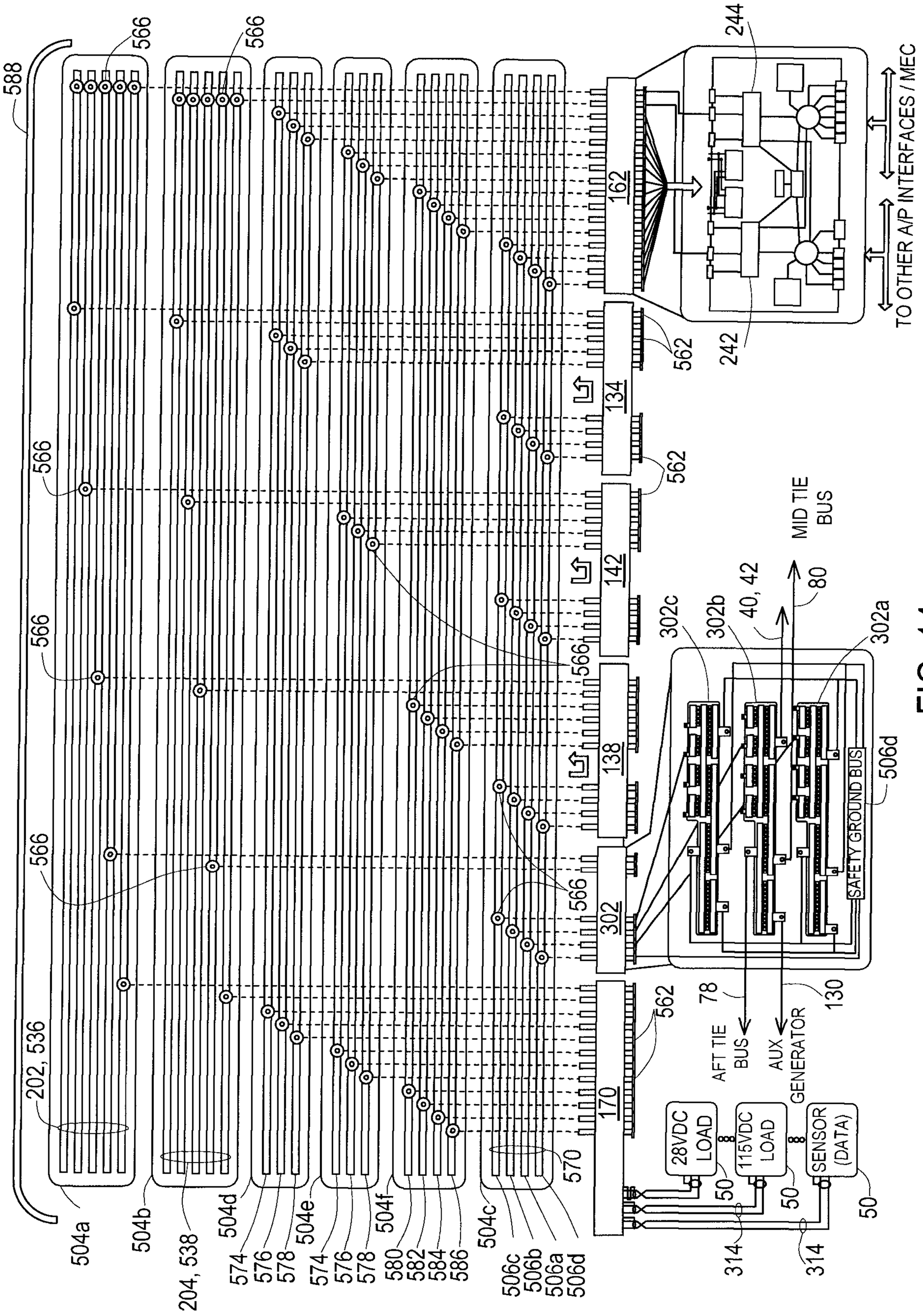

588
566
566
244
TO OTHER A/P INTERFACES / MEC
162
562
242
134
562
566
142
566
MID TIE BUS
80
302c
302b
40, 42
302a
566
138
506d
SAFETY GROUND BUS
566
302
562
78
130
AFT TIE BUS
AUX GENERATOR
202, 536
28VDC LOAD
115VDC LOAD
SENSOR (DATA)
50
50
50
50
314
314
504a
504b
204, 538
504d
504e
504f
504c
574
576
578
574
576
578
580
582
584
586
570
506c
506b
506a
506d

FIG. 14

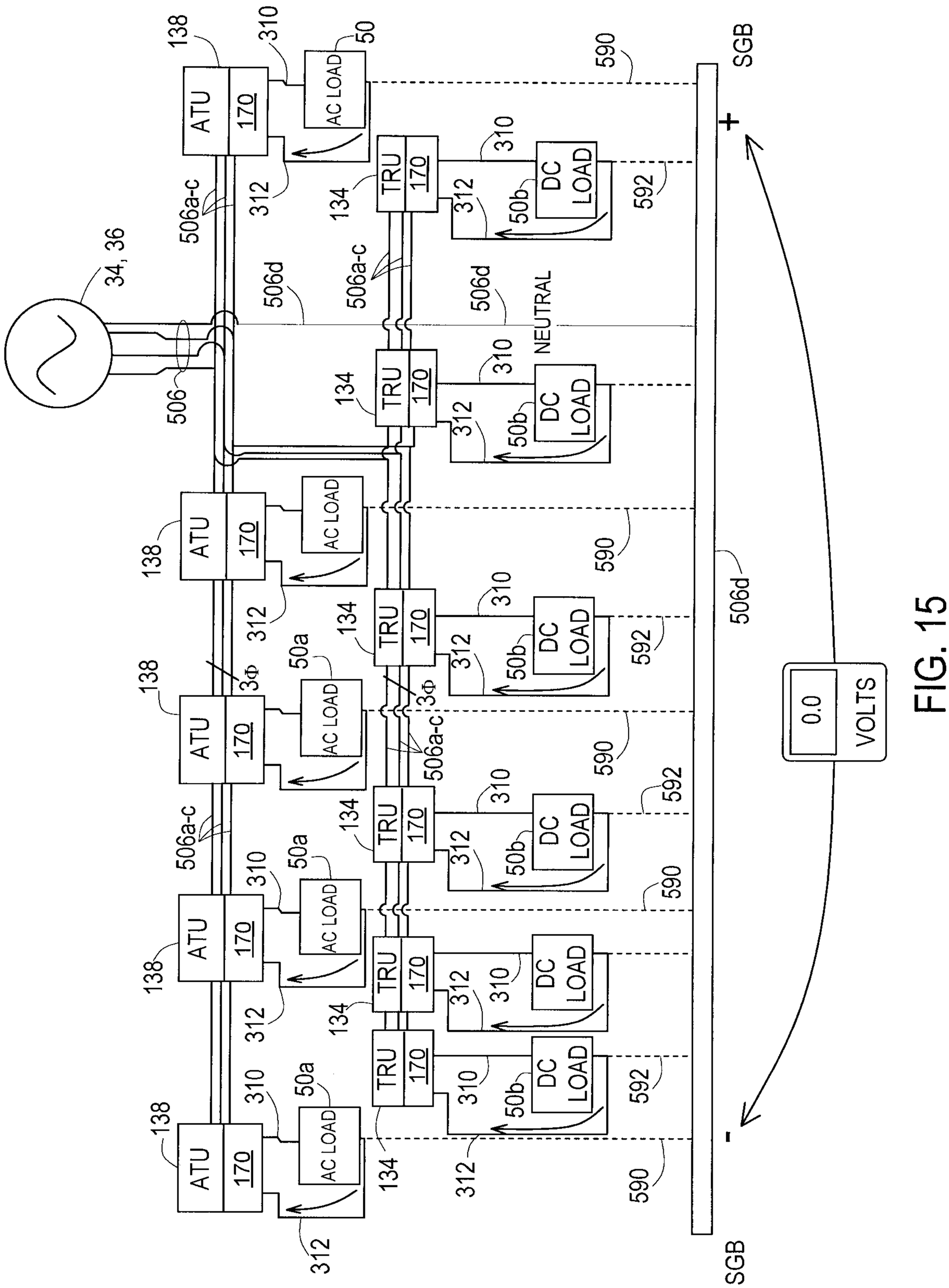

138
310
50
590
SGB
ATU
170
AC LOAD
TRU
DC LOAD
506a-c
312
134
50b
592
34, 36
506d
NEUTRAL
506
50a
3Φ
0.0
VOLTS
+
-

FIG. 15

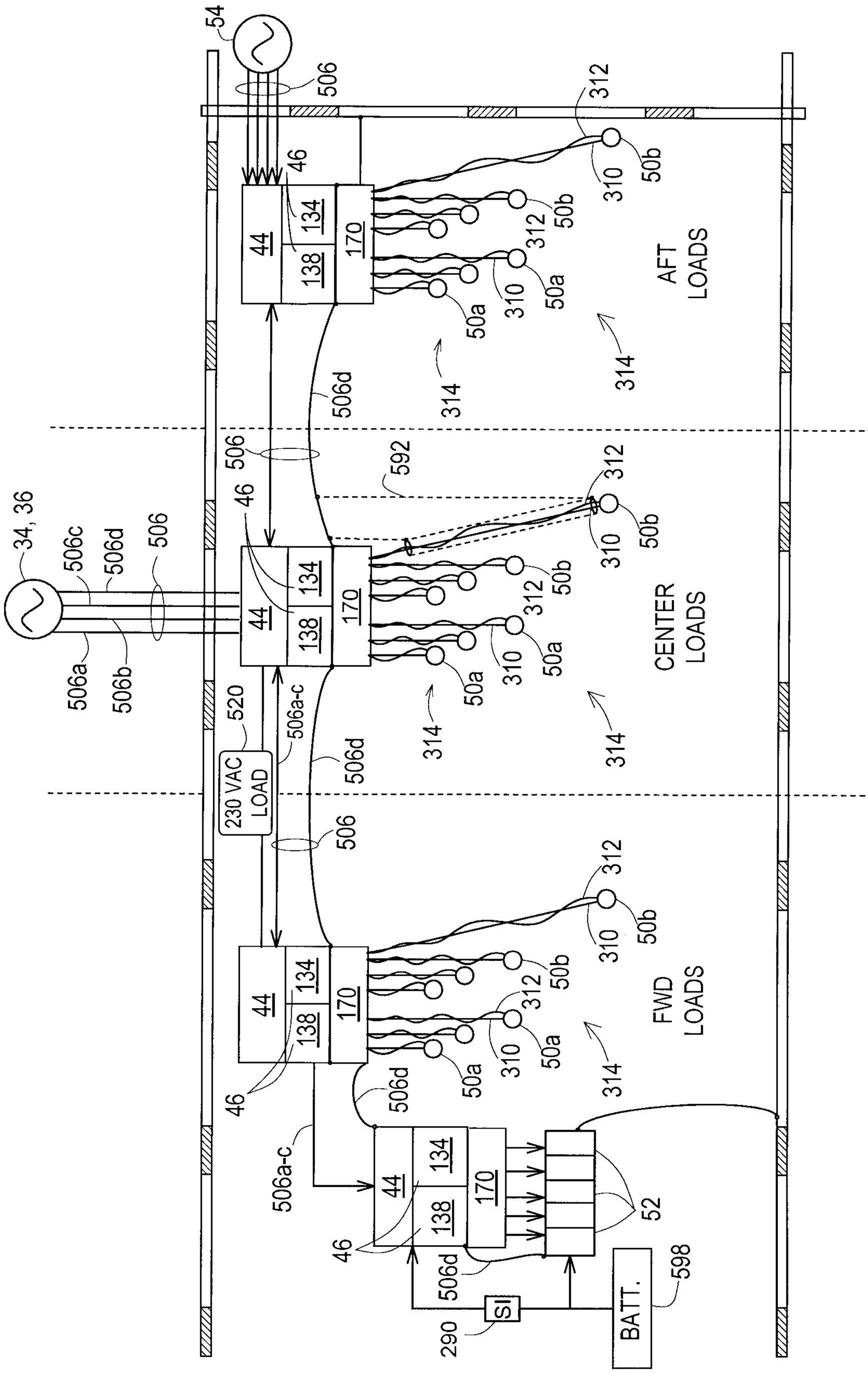

54
506
312
46
44
134
138
170
310
50b
50a
AFT
LOADS
314
506d
592
34, 36
506c
506a
506b
520
506a-c
230 VAC
LOAD
CENTER
LOADS
FWD
LOADS
52
SI
290
BATT.
598

FIG. 16

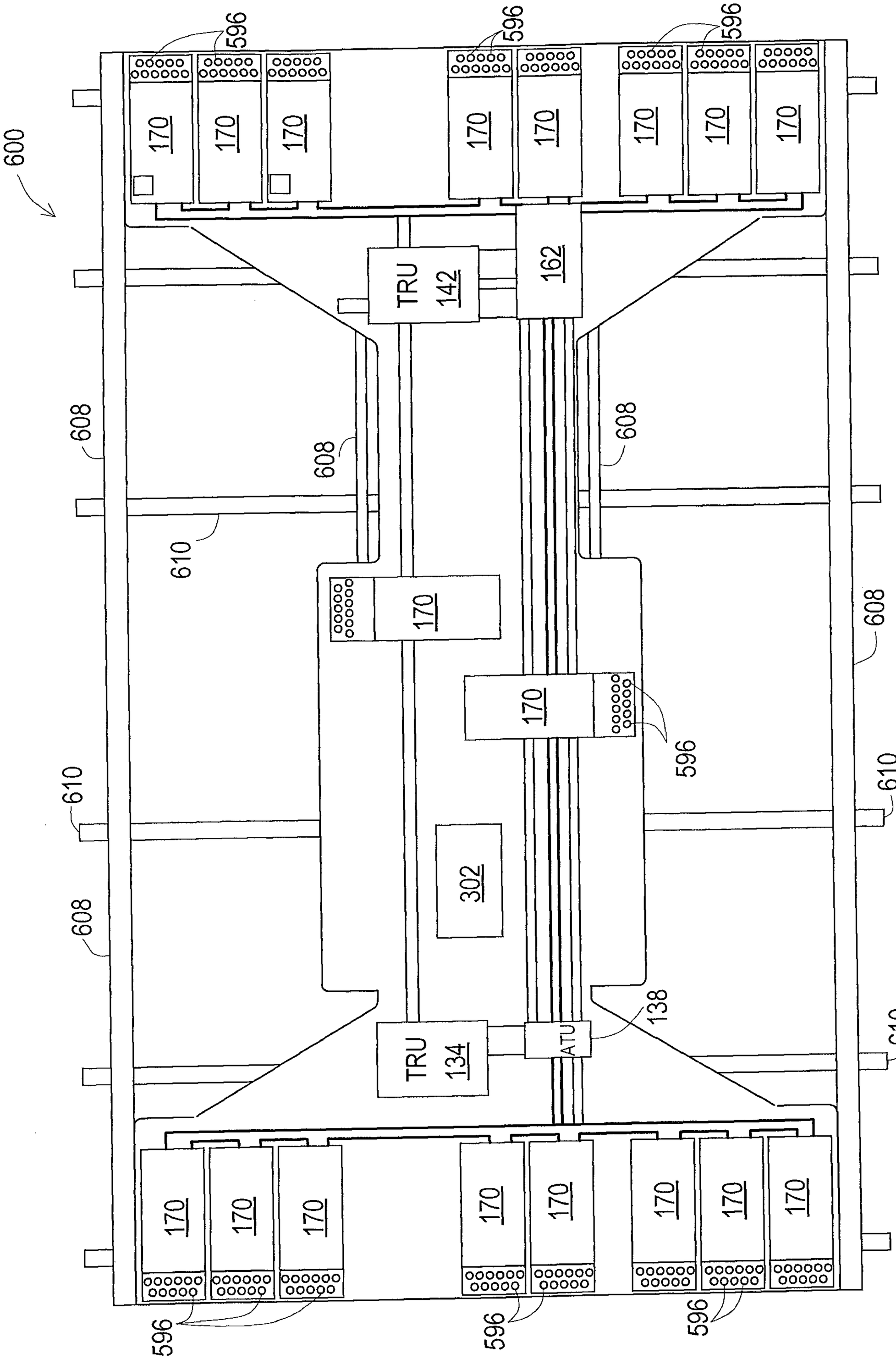


FIG. 17

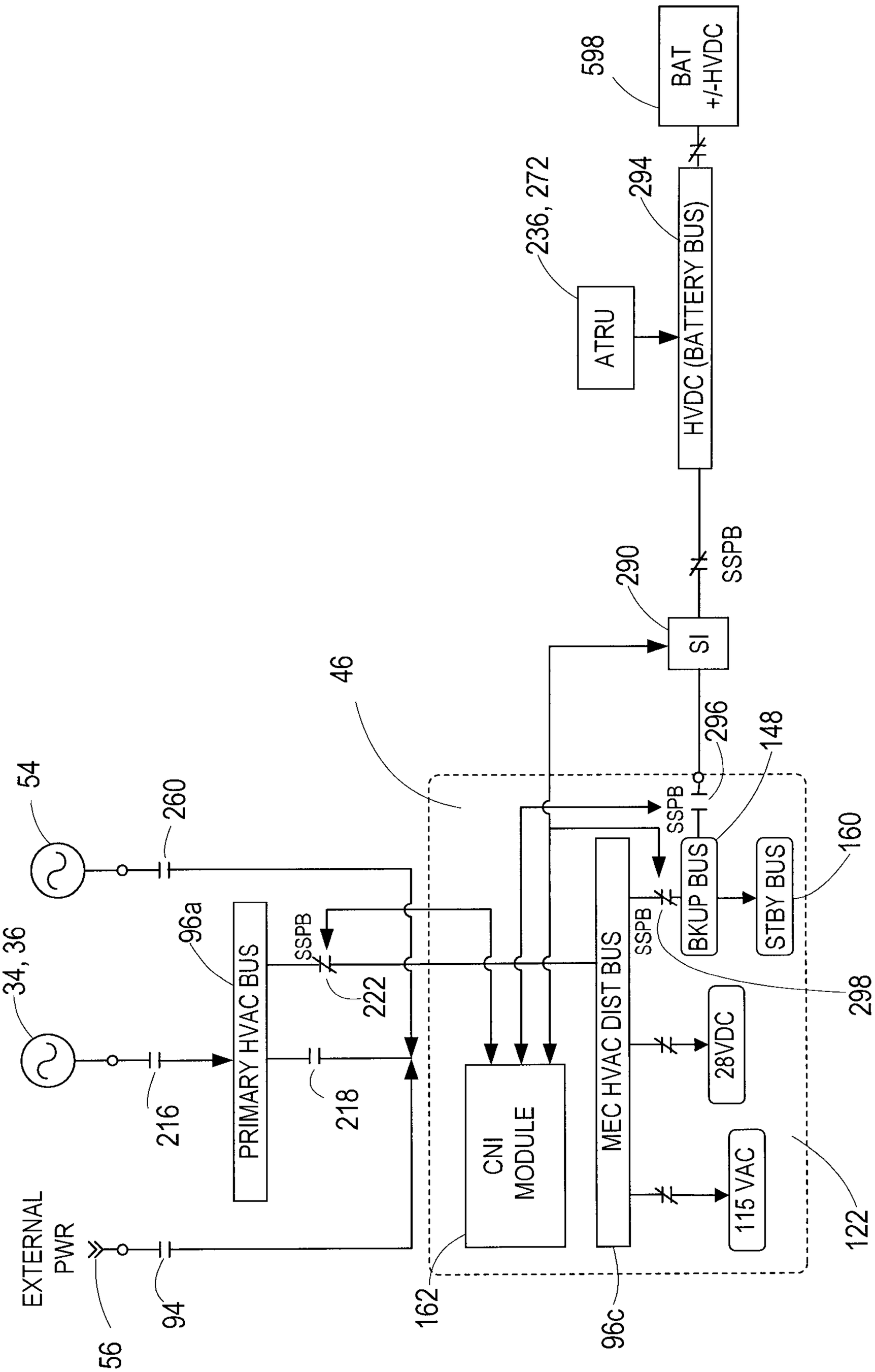

598
BAT
+/-HVDC
236, 272
ATRU
294
HVDC (BATTERY BUS)
290
SSPB
SI
46
54
260
34, 36
96a
SSPB
222
PRIMARY HVAC BUS
216
218
296
148
SSPB
BKUP BUS
STBY BUS
160
SSPB
298
MEC HVAC DIST BUS
28VDC
CNI
MODULE
115 VAC
122
EXTERNAL
PWR
56
94
162
96c

FIG. 18

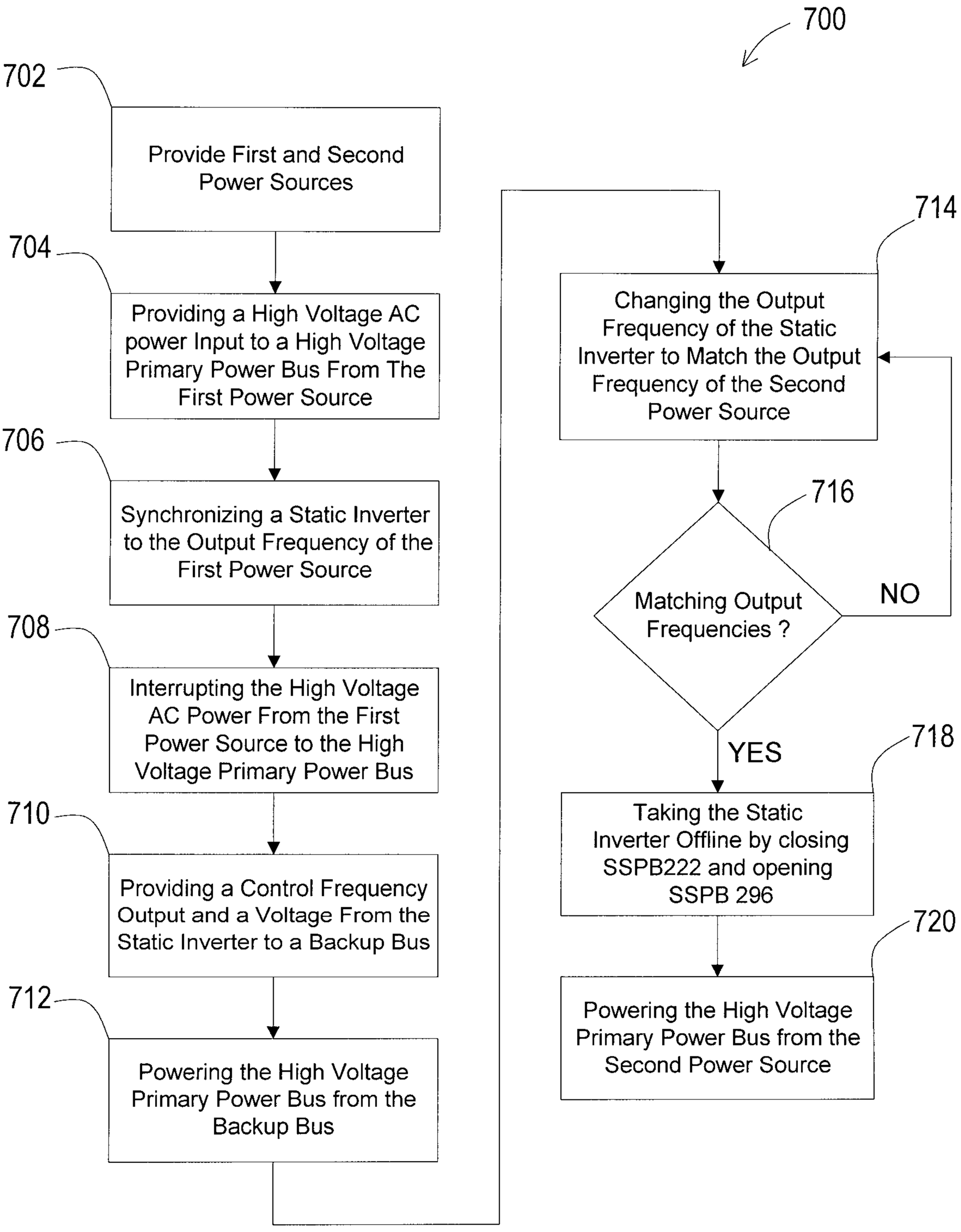
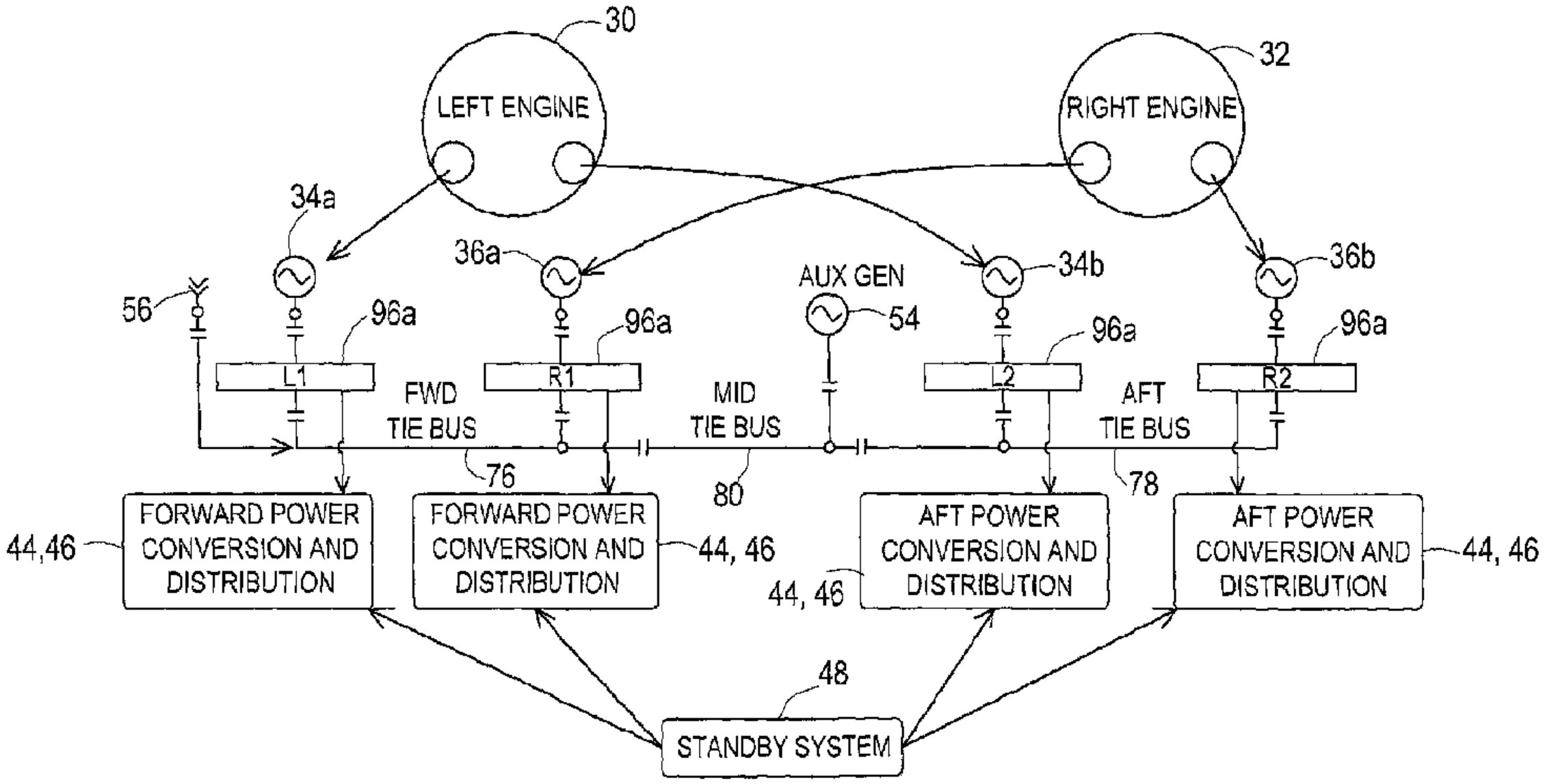

700
702
Provide First and Second Power Sources
704
Providing a High Voltage AC power Input to a High Voltage Primary Power Bus From The First Power Source
706
Synchronizing a Static Inverter to the Output Frequency of the First Power Source
708
Interrupting the High Voltage AC Power From the First Power Source to the High Voltage Primary Power Bus
710
Providing a Control Frequency Output and a Voltage From the Static Inverter to a Backup Bus
712
Powering the High Voltage Primary Power Bus from the Backup Bus
714
Changing the Output Frequency of the Static Inverter to Match the Output Frequency of the Second Power Source
716
Matching Output Frequencies ?
NO
YES
718
Taking the Static Inverter Offline by closing SSPB222 and opening SSPB 296
720
Powering the High Voltage Primary Power Bus from the Second Power Source

FIG. 19


30
LEFT ENGINE
32
RIGHT ENGINE
34a
36a
AUX GEN
54
34b
36b
56
96a
96a
96a
96a
L1
R1
L2
R2
FWD
TIE BUS
MID
TIE BUS
AFT
TIE BUS
76
80
78
44,46
FORWARD POWER
CONVERSION AND
DISTRIBUTION
FORWARD POWER
CONVERSION AND
DISTRIBUTION
44, 46
44, 46
AFT POWER
CONVERSION AND
DISTRIBUTION
AFT POWER
CONVERSION AND
DISTRIBUTION
44, 46
48
STANDBY SYSTEM