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DESCRIPTION

[0001] The present invention relates to a power supply device supplying electrical power to an electric vehicle, particularly a railway vehicle.

5 [0002] The invention also relates to a power train for an electric vehicle, particularly a railway vehicle, comprising such a power supply device.

[0003] The invention also relates to an electric vehicle, particularly a railway vehicle, comprising such a power train.

[0004] The power supply device comprises an electrical energy converter. The electrical energy
10 converter includes at least two input terminals and two output terminals; for each input terminal, a switching arm comprising two switching halfarms is connected in series between the two output terminals and connected together at an intermediate point, the intermediate point being connected to said input terminal. Each switching halfarm includes at least one switch. The electrical energy converter includes a control module configured to control the switches. The
15 power supply device comprises at least two first connection terminals intended to be connected to a first alternating-current electrical power source, and a second and a third connection terminal intended to be connected to a second direct-current electrical power source.

[0005] The invention applies to the field of transportation, particularly the field of railway transportation. More specifically, the invention applies to the electrical power supply of electric
20 towing vehicles such as locomotives and motor coaches.

[0006] Electric railway vehicles are generally equipped with electric motors. The power supply to the electric motor of such a vehicle requires a direct current voltage with a defined amplitude. This direct-current voltage is generally fed to an inverter which directly delivers electrical power to the electric motor required for the operation thereof.

25 [0007] To power such a vehicle, using alternating current delivered from an overhead catenary via a pantograph is known. This alternating current is generally converted to direct-current power suitable for feeding the inverter by means of a transformer and an alternating current to direct current converter, referred to as an AC-DC converter.

[0008] Furthermore, when the vehicle is traveling on a track not equipped with an overhead
30 catenary, an electric battery (possibly in conjunction with a fuel cell) needs to be used to power the vehicle. Such an electric battery provides direct-current power. The voltage supplied by the electric battery may be lower than the voltage required to feed the inverter. A direct-current to direct-current converter, referred to as a DC-DC converter, is then used to amplify this direct-current voltage in order to obtain a direct-current voltage suitable for feeding the inverter.

[0009] However, such an electrical architecture is relatively bulky and costly.

[0010] Document US 2017/0086329 A1 discloses an electrical power supply device comprising a cooling unit of a conversion circuit and a cooling unit of an inverter.

[0011] Document US 2016/211749 A1 discloses an electrical power supply device comprising
5 a DC-DC converter.

[0012] Consequently, the purpose of the invention is to propose a power supply device that is less bulky and costly and more reliable.

[0013] To that end, the subject matter of the invention is a power supply device according to claim 1.

10 [0014] Such a power supply device avoids the use of two dedicated converters, one for converting the alternating-current coming from the first source of alternating-current electrical power and one for converting the direct-current voltage coming from the second source of direct-current power, by using a single converter comprising two conversion modes specific to the two respective types of conversion, and an associated switching module.

15 [0015] According to other advantageous aspects, the power supply device complies with any one of claims 2 to 8.

[0016] The subject matter of the invention is also a power train according to claim 9.

[0017] The subject matter of the invention is also an electric vehicle according to claim 10.

[0018] These features and advantages of the invention will become clear from a reading of the
20 following description, given solely as a non-limiting example in reference to the appended drawings, in which:

- figure 1 is a schematic diagram of an electric transportation vehicle, such as a railway vehicle, comprising a power train including a power supply device according to the invention
25 connected to a first electrical power source as well as a second electrical power source, and
- figure 2 is a schematic diagram of how various amperages evolve over time, specifically the amperage of a current flowing in the second electrical power source according to various operating situations.

30 [0019] Figure 1 shows an electric vehicle 6, in particular a railway vehicle, such as a train or a tramway, comprising a power train 8, power train 8 including a pantograph 14 capable of coming into contact with an overhead catenary 16, in order to electrically connect electric vehicle 6 to an electrical power supply grid.

[0020] Power train 8 comprises a circuit-breaker 18 connected to pantograph 14. Circuit-breaker 18 is known per se and is not described in greater detail.

[0021] Power train 8 further comprises an electric motor, not shown, and a power supply device 20 for supplying electrical power to the electric motor, power supply device 20 being intended to be connected to a first alternating-current electrical power supply device 22 for supplying an alternating current voltage, V_{AC} , to power supply device 20.

[0022] As an optional complement, power train 6 comprises an intermediate circuit, not shown, connected between power supply device 20 and the electric motor.

[0023] Power train 8 further comprises a second direct-current electrical power source 24 connected to power supply device 20 and capable of supplying a direct-current voltage, V_B .

[0024] The electric motor is known per se, and is used to rotate the wheels of electric vehicle 6 so as to propel said electric vehicle 6. The electric motor is, for example an alternating-current motor, with the intermediate circuit converting a direct-current voltage, V_{DC} , coming from power supply device 20 to an alternating-current voltage supplied to the input of the motor.

[0025] The intermediate circuit comprises, for example, a filter capacitor connected to the output of power supply device 20, and an inverter configured to convert the direct-current voltage, V_{DC} , coming from power supply device 20 to an alternating-current voltage delivered to the electric motor.

[0026] Power supply device 20 comprises an electrical power converter 26 for delivering the direct-current voltage, V_{DC} , to the output of power supply device 20, at least two first connection terminals 27 intended to be connected to first source 22, and a second connection terminal 28 and a third connection terminal 29 intended to be connected to second source 24. In the example of figure 1, power supply device 20 comprises exactly two first connection terminals 27.

[0027] Power supply device 20 further comprises a switching module 30 connected between first connection terminals 27, second connection terminal 28, and converter 26.

[0028] Converter 26 comprises at least two input terminals (31) and two output terminals (32).

[0029] Converter 26 is configured to convert a voltage received at input terminals 31 thereof to a direct-current voltage, V_{DC} , delivered across output terminals 32 thereof.

[0030] Converter 26 comprises a switching arm 35 for each input terminal 31. In the example of figure 1, converter 26 includes exactly two input terminals 31 and two switching arms 35.

[0031] Each switching arm 35 comprises two switching halfarms 36 connected in series between the two output terminals 32 and connected together at an intermediate point 37, intermediate point 37 being connected to a corresponding input terminal 31.

[0032] Each switching halfarm 36 includes one or more switches 38, switches 38 being connected in series if applicable. In the example of figure 1, each switching halfarm 36 comprises a single switch 38.

[0033] As a non-illustrated variant, each switching halfarm 36 includes N switching half-branches connected in parallel, N being a whole number equal to or greater than 2, each switching half-branch comprising at least one switch 38. Each switching halfarm 36 thus includes at least N switches 38.

[0034] Converter 26 further comprises a control module, not shown, configured to control switches 38.

[0035] Each switch 38 comprises, for example, a controllable semiconductor switching component 60 and a diode (62) which is connected in antiparallel with the controllable semiconductor switching component 60.

[0036] As is known per se, each controllable semiconductor switching component 60 includes two conduction electrodes and a control electrode, each controllable semiconductor switching component 60 being controllable, via the control electrode thereof, between a state from among a conduction state in which current flows between the conduction electrodes and a blocked state in which current does not flow between the conduction electrodes. Diode 62 is thus connected between the conduction electrodes.

[0037] The control module is configured to function according to a first conversion mode when switching module 30 is in a first configuration, and according to a second conversion mode when switching module 30 is in a second configuration.

[0038] When the control module is functioning in the first conversion mode, converter 26 is configured to convert the alternating-current voltage, V_{AC} , coming from first connection terminals 27 to the direct-current voltage, V_{DC} . Converter 26 then serves a function as a boost chopper and rectifier.

[0039] When the control module is functioning in the second conversion mode, converter 26 is configured to convert the direct-current voltage V_B coming from the second and third connection terminals 28, 29 to another direct-current voltage, V_{DC} , with the other direct-current voltage, V_{DC} , preferably having a value greater than the voltage between the second and third connection terminals 28, 29. Converter 26 then serves a function as a chopper, preferably a boost chopper.

[0040] The control module includes, for example, a programmable logic component, such as an FPGA (Field-Programmable Gate Array).

[0041] The control module is connected, for example, to the control electrode of each controllable semiconductor switching component 60 and is capable of delivering a

corresponding control signal. In particular, the control module is capable of delivering a control signal as a function of the operating mode in which it is operating, from among the first and second operating modes, in order to perform the corresponding energy conversion.

[0042] At least one controllable semiconductor switching component 60 is preferably a transistor, each controllable semiconductor switching component 60 preferably also being a transistor.

[0043] At least one controllable semiconductor switching component 60 is, for example, a field-effect transistor, also called an FET, preferably an insulated-gate field-effect transistor, more commonly called a MOSFET or Metal-Oxide-Semiconductor Field-Effect Transistor. Each controllable semiconductor switching component 60 is preferably a MOSFET. In this case the conduction electrodes are drain and source electrodes and the control electrode is a gate electrode.

[0044] For example, at least one controllable semiconductor switching component 60 is made of silicon carbide, also called SiC. Each controllable semiconductor switching component 60 is preferably made of silicon carbide.

[0045] As a variant, each controllable semiconductor switching component 60 is an insulated-gate bipolar transistor, also called an IGBT. In this case the conduction electrodes are collector and emitter electrodes and the control electrode is a gate electrode.

[0046] As yet another variant, each controllable semiconductor switching component 60 is a thyristor, for example a gate turn-off thyristor, also called a GTO thyristor.

[0047] Third connection terminal 29 is connected to one of output terminals 32.

[0048] Switching module 30 is capable of switching between the first configuration in which each first terminal 27 is connected to a corresponding input terminal 31 of converter 26, and the second configuration in which second connection terminal 28 is connected to at least two separate input terminals 31 of converter 26.

[0049] Advantageously, when switching module 30 is in the second configuration, second connection terminal 28 is connected to each of separate input terminals 31 of converter 26 via an electromagnetic coil 39.

[0050] In the example of figure 1, switching module 30 comprises a first contact switch (40) connected between one of first connection terminals 27 and one of input terminals 31 of converter 26. Switching module 30 comprises, for each input terminal 31 to which second connection terminal 28 is connected when the switching module is in the second configuration, a second contact switch 41 connected between second connection terminal 28 and said input

terminal 31, more specifically between one of electromagnetic coils 39 and said input terminal 31.

[0051] Switching module 30 further comprises a control unit, not shown, capable of controlling the first and second contact switches, 40 and 41, respectively, with the control unit being
5 configured to control first contact switch 40 to a closed state and second contact switches 41 to an open state when switching module 30 is in the first configuration, and capable of controlling first contact switch 40 to an open state and at least a second contact switch 41 to a closed state when switching module 30 is in the second configuration.

[0052] Advantageously, the control unit is configured to control each second contact switch 41
10 to a closed state when switching module 30 is in the second configuration.

[0053] As a complement, switching module 30 is configured to define the conversion mode of the control module of converter 26, the first conversion mode being defined when switching module 30 is in the first configuration, and the second conversion mode being defined when switching module 30 is in the second configuration.

[0054] As an optional complement, power supply device 20 further comprises a precharge
15 module 42 connected between first contact switch 40 and input terminal 31 to which first contact switch 40 is connected.

[0055] Precharge module 42 is configured to limit the current flowing through switches 38 when power train 8 is first powered up, in order to charge the filter capacitor.

[0056] Advantageously, precharge module 42 is in addition connected between one of second
20 contact switches 41 and input terminal 31 to which said second contact switch 41 is connected. More specifically, precharge module 42 is connected between a node 43 and one of input terminals 31, node 43 being connected to first contact switch 40 and to one of second contact switches 41.

[0057] Precharge module 42 comprises a precharge resistor 44 in series with a precharge switch
25 45 and a short circuit switch 46, short circuit switch 46 being connected in parallel with precharge resistor 44 and precharge switch 45.

[0058] Precharge switch 45 and short circuit switch 46 are configured to be switched between a
30 state from among a closed state in which current flows through precharge switch 45 or short circuit switch 46, and an open state in which current does not flow through precharge switch 45 or short circuit switch 46.

[0059] As an optional complement, power train 8 comprises a voltage transformer 47 including
a primary winding 48 which can be connected to pantograph 14 via circuit-breaker 18, a

secondary winding 52 which can be connected to first connection terminals 27, and a magnetic core 54 placed between primary winding 48 and secondary winding 52.

[0060] Transformer 47 is capable of decreasing the amplitude of an alternating-current voltage delivered by overhead catenary 16 via pantograph 14 and circuit-breaker 18, as a function of a transformation ratio, and delivering an alternating-current voltage, V_{AC} , to secondary winding 52 thereof.

[0061] In the example of figure 1, second source 24 comprises an electric battery 56 connected between second and third terminals 28, 29, capable of delivering the direct-current voltage V_B between second and third terminals 28, 29.

[0062] Alternatively, second source 24 comprises a fuel cell, or any type of energy storage system, connected between second and third terminals 28, 29, capable of delivering the direct-current voltage V_B between second and third terminals 28, 29.

[0063] Alternatively still, second source 24 comprises a fuel cell coupled to an electric battery or to any type of energy storage system.

[0064] The operation of power supply device 20 will now be described.

[0065] When electric vehicle 6 is electrically connected to a power supply grid via pantograph 14 and overhead catenary 16, first source 22 is used to power the electric motor, switching module 30 is in the first configuration, and the control module functions in the first conversion mode. Converter 26 is then used to convert the alternating-current voltage, V_{AC} , delivered by first source 22 to first terminals 27, to the direct-current voltage, V_{DC} , at output terminals 32.

[0066] When electric vehicle 6 is not electrically connected to a power supply grid and is therefore in a so-called autonomous mode, second source 24 is used to power the electric motor, switching module 30 is in the second configuration, and the control module functions in the second conversion mode. Converter 26 is then used to convert the direct-current voltage, V_B , delivered by second source 24 to second and third terminals 28, 29, to the direct-current voltage, V_{DC} , at output terminals 32.

[0067] Figure 2 shows a graph 100 of how an amperage I_B of a current flowing through second source 24 evolves over time in various cases when electric vehicle 6 in figure 1 is in the autonomous mode.

[0068] Graph 100 comprises a curve 102 showing the change over time of an amperage I_B of the current flowing through second source 24 when a single second contact switch 41 is in the closed state, with curves 104 and 106 showing the change over time of an amperage I_{B1} and an amperage I_{B2} , respectively, of the current flowing through corresponding second contact switch 41 when both second contact switches 41 are in the closed state, and curve 108 showing the amperage I_B

of the current flowing through second source 24 when both second contact switches 41 are in the closed state.

[0069] When both second contact switches 41 are in the closed state, the amperage I_B (curve 108) becomes the sum of amperages I_{B1} and I_{B2} (curves 104 and 106).

5 [0070] A person skilled in the art will note that the amplitude of amperage I_B is lower when both contact switches 41 are in the closed state. In addition, the period T of amperage I_B when both contact switches 41 are in the closed state is shorter than the period T' when a single contact switch 41 is in the closed state.

[0071] Using a plurality of switching arms 35 to convert voltage V_B thus makes it possible to
10 limit the current ripple from second source 24 and therefore to limit wear and tear on battery 56, or alternatively the fuel cell or any other type of energy storage system included in second source 24, the latter being sensitive to an excessively high current ripple and too low an oscillation frequency. This also makes it possible to increase the power converted by converter 26, with switches 38 having identical properties.

15 [0072] When the electric motor is started, when electric vehicle 6 is not in the autonomous mode, precharge module 42 is controlled to precharge the filter capacitor of the intermediate circuit, according to the following steps.

[0073] Initially, precharge switch 45 is in the closed state and short circuit switch 46 is in the open state. The first or the second source is connected to converter 26 via precharge resistor 44
20 and voltage V_{DC} progressively increases until a final value is reached.

[0074] When voltage V_{DC} reaches a value close to its final value, such as within 5%, short circuit switch 46 is switched to the closed state and short-circuits precharge resistor 44.

[0075] Lastly, precharge switch 45 is then switched to the open state.

[0076] Precharge resistor 44 then limits the current flowing through switches 38 of converter 26
25 and through the filter capacitor while the filter capacitor is being charged. This limits wear and tear on the transistors of switches 38 and the sizing of the filter capacitor.

[0077] When precharge module 42 is included between one of second contact switches 41 and input terminals 31, to which said second contact switch 41 is connected, the electric motor can be started, according to the same steps described earlier, when electric vehicle 6 is in the
30 autonomous mode.

[0078] It is thus understood that power supply device 20 is capable of powering the electric motor regardless of whether the electric vehicle is in the autonomous mode or not. Power supply device 20 obviates the need for an additional converter dedicated to converting the electrical

power coming from the second source of direct-current electrical power, by operating according to the above two conversion modes.

two contact switches 41 are in the closed state is shorter than the period T' when a single contact switch 41 is in the closed state.

5 [0079] Using a plurality of switching arms 35 to convert voltage V_B thus makes it possible to limit the current ripple from second source 24 and therefore to limit wear and tear on battery 56, or alternatively the fuel cell or any other type of energy storage system included in second source 24, the latter being sensitive to an excessively high current ripple and too low an oscillation frequency. This also makes it possible to increase the power converted by converter 26, with
10 switches 38 having identical properties.

[0080] When the electric motor is started, when electric vehicle 6 is not in the autonomous mode, precharge module 42 is controlled to precharge the filter capacitor of the intermediate circuit, according to the following steps.

[0081] Initially, precharge switch 45 is in the closed state and short circuit switch 46 is in the
15 open state. The first or the second source is connected to converter 26 via precharge resistor 44 and voltage V_{DC} progressively increases until a final value is reached.

[0082] When voltage V_{DC} reaches a value close to its final value, such as within 5%, short circuit switch 46 is switched to the closed state and short-circuits precharge resistor 44.

[0083] Lastly, precharge switch 45 is then switched to the open state.

20 [0084] Precharge resistor 44 then limits the current flowing through switches 38 of converter 26 and through the filter capacitor while the filter capacitor is being charged. This limits wear and tear on the transistors of switches 38 and the sizing of the filter capacitor.

[0085] When precharge module 42 is included between one of second contact switches 41 and input terminals 31, to which said second contact switch 41 is connected, the electric motor can
25 be started, according to the same steps described earlier, when electric vehicle 6 is in the autonomous mode.

[0086] It is thus understood that power supply device 20 is capable of powering the electric motor regardless of whether the electric vehicle is in the autonomous mode or not. Power supply device 20 obviates the need for an additional converter dedicated to converting the electrical
30 power coming from the second source of direct-current electrical power, by operating according to the above two conversion modes.

PATENTKRAV

1. Anordning (20) til tilførsel af elektrisk energi til et elektrisk køretøj (6), navnlig et skinnekøretøj, omfattende:

- 5 - en elektrisk energiomformer (26), der omfatter:
 + mindst to indgangsklemmer (31) og to udgangsklemmer (32),
 + for hver indgangsklemme (31), en omkoblingsarm (35), der omfatter to
 omkoblingshalvarme (36), der er serieforbundet mellem de to udgangsklemmer (32)
 og forbundet med hinanden i et mellempunkt (37), hvilket mellempunkt (37) er
10 forbundet med indgangsklemmen (31), hvor hver omkoblingshalvarme (36) omfatter
 mindst én afbryder (38), og
 + et styremodul, der er konfigureret til at styre afbryderne (38),
 - mindst to første forbindelsesklemmer (27), der er beregnet til at blive forbundet med
 en første kilde (22) til elektrisk vekselstrømsenergi, og
15 - en anden og en tredje forbindelsesklemme (28, 29), der er beregnet til at blive
 forbundet med en anden kilde (24) til elektrisk jævnstrømsenergi,
- kendetegnet ved, at** den endvidere omfatter et omkoblingsmodul (30), der er forbundet
mellem de omformerens (26) første forbindelsesklemmer (27), anden forbindelsesklemme
(28) og indgangsklemmer (31), hvilket omkoblingsmodul (30) kan omkoble mellem en første
20 konfiguration, hvori hver af de første forbindelsesklemmer (27) er forbundet med en
 tilsvarende af omformerens (26) indgangsklemmer (31), og en anden konfiguration, hvori den
 anden forbindelsesklemme (28) er forbundet med mindst to af omformerens (26) separate
 indgangsklemmer (31),
 og **ved, at** styremodulet er konfigureret til at fungere ifølge en første omformningsmodus, når
25 omkoblingsmodulet (30) er i den første konfiguration, og ifølge en anden
 omformningsmodus, når omkoblingsmodulet (30) er i den anden konfiguration.

- 2.** Tilførselsanordning (20) ifølge krav 1, hvori, når styremodulet er ifølge den første
omformningsmodus, omformeren (26) er konfigureret til at omforme en vekselspænding
30 (V_{AC}), der udgår fra de første forbindelsesklemmer (27), til en jævnspænding (V_{DC}), og
 når styremodulet er ifølge den anden omformningsmodus, omformeren er konfigureret til at
 omforme en jævnspænding (V_B), der udgår fra anden og tredje forbindelsesklemmer (28, 29),
 til en anden jævnspænding (V_{DC}).

3. Tilførselsanordning (20) ifølge krav 2, hvori, når styremodulet er ifølge den anden omformningsmodus, den anden jævnspænding (V_{DC}) har en værdi, der er højere end jævnspændingen (V_B) mellem anden og tredje forbindelsesklemmer (28, 29).

5 **4.** Tilførselsanordning (20) ifølge et hvilket som helst af de foregående krav, hvori omkoblingsmodulet (30) omfatter:

- en første kontakt (40), der er forbundet mellem én af omformerens (26) første forbindelsesklemmer (27) og én af dens indgangsklemmer (31),
- for hver indgangsklemme (31), hvortil den anden forbindelsesklemme (28) er
- 10 forbundet, når omkoblingsmodulet (30) er i den anden konfiguration, en første kontakt (41), der er forbundet mellem den anden forbindelsesklemme (28) og indgangsklemmen (31), og
- en styreenhed, der kan styre første (40) og anden (41) kontakter.

15 **5.** Tilførselsanordning (20) ifølge krav 4, hvori styreenheden kan styre den første kontakt (40) i en lukket tilstand og anden kontakter (41) i en åben tilstand, når omkoblingsmodulet (30) er i den første konfiguration, og kan styre den første kontakt (40) i en åben tilstand og mindst én anden kontakt (41), fortrinsvis enhver anden kontakt (41), i en lukket tilstand, når omkoblingsmodulet (30) er i den anden konfiguration.

20

6. Tilførselsanordning (20) ifølge et hvilket som helst af de foregående krav, hvori omkoblingsmodulet (30) er konfigureret til at forbinde den anden forbindelsesklemme (28) med hver af omformerens (26) indgangsklemmer (31) via en elektromagnetisk spole (39) når omkoblingsmodulet (30) er i den anden konfiguration.

25

7. Tilførselsanordning (20) ifølge et hvilket som helst af de foregående krav, hvori tilførselsanordningen (20) endvidere omfatter, mellem omkoblingsmodulet (30) og én af indgangsklemmerne (31), et forladningsmodul (42), der omfatter en forlademodstand (44), der er serieforbundet med en forladningskontakt (45), og en kortslutningskontakt (46),

30 hvilken kortslutningskontakt (46) er parallelforbundet med forladningsmodstanden (44) og forladningskontakten (45).

8. Tilførselsanordning (20) ifølge et hvilket som helst af de foregående krav, hvori hver afbryder (38) omfatter en styrbar omkoblingshalvlederkomponent (60) og en diode (62), der

er antiparallelt forbundet med den styrbare omkoblingshalvlederkomponent (60).

9. Trækkæde (8) til et elektrisk køretøj (6), navnlig et skinnekøretøj, der omfatter en elektrisk motor og en anordning (20) til at tilføre den elektriske motor elektrisk energi, **kendetegnet**

5 **ved, at** tilførselsanordningen (20) er ifølge et hvilket som helst af de foregående krav.

10. Elektrisk køretøj (6), navnlig et skinnekøretøj, der omfatter en trækkæde (8), **kendetegnet ved, at** trækkæden (8) er ifølge det foregående krav.

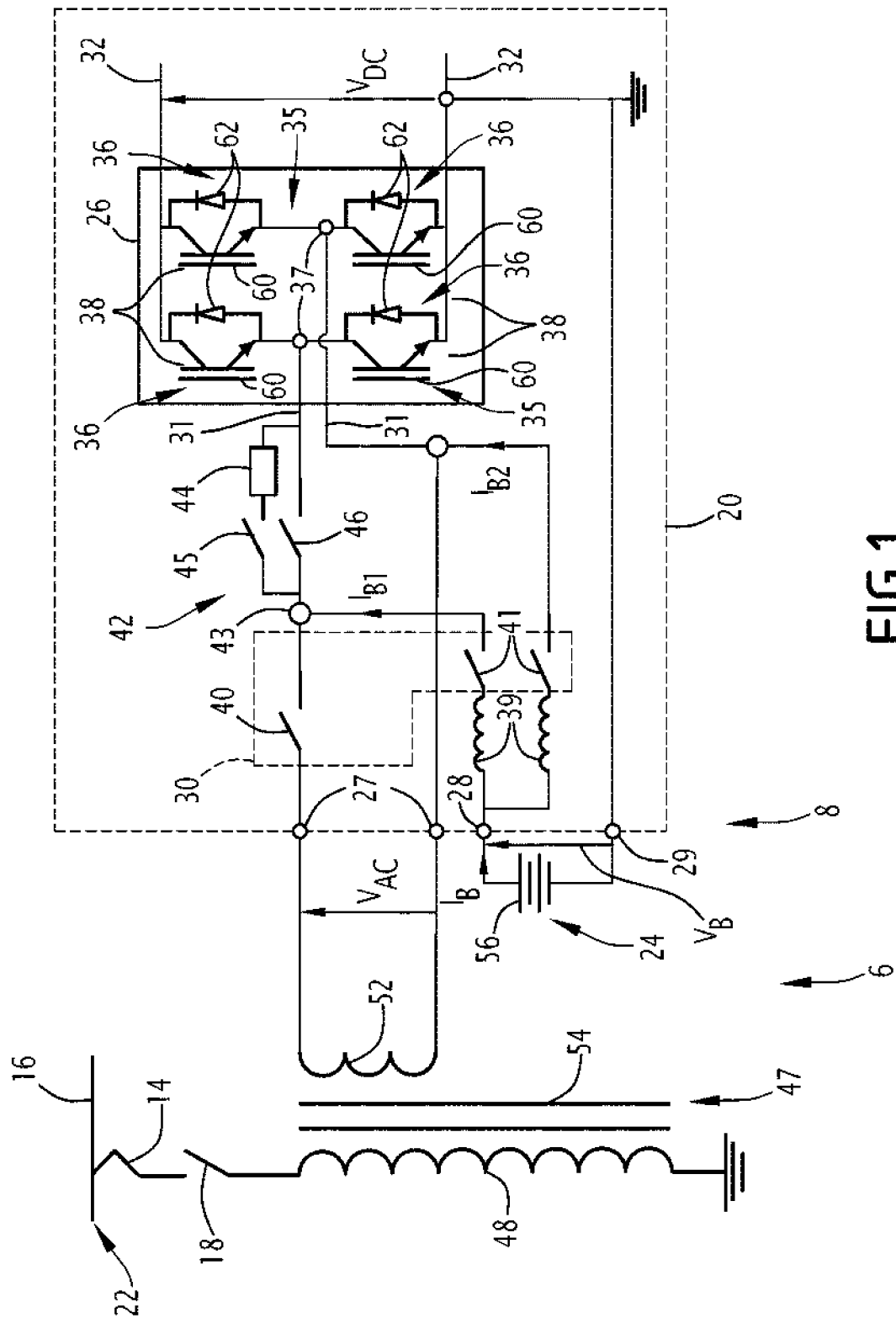
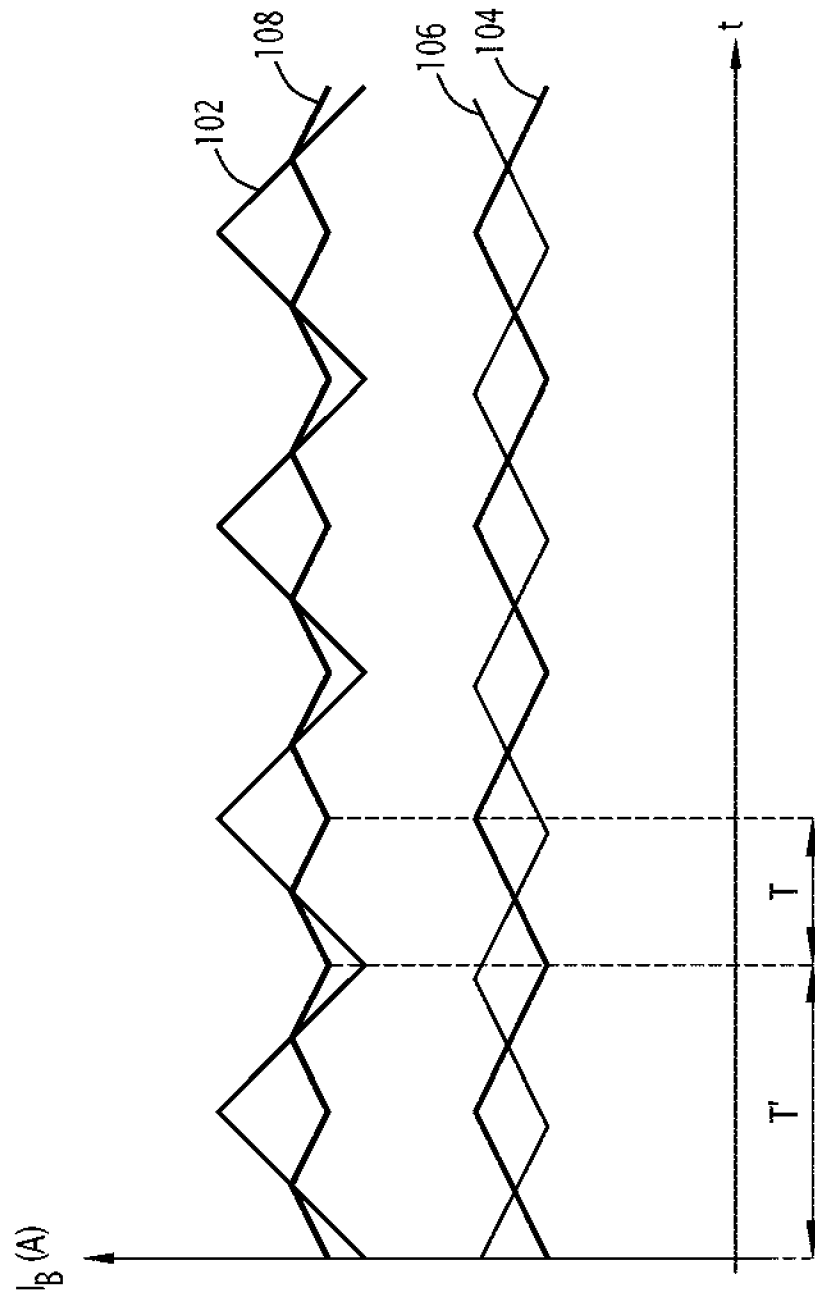


FIG. 1

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FIG.2