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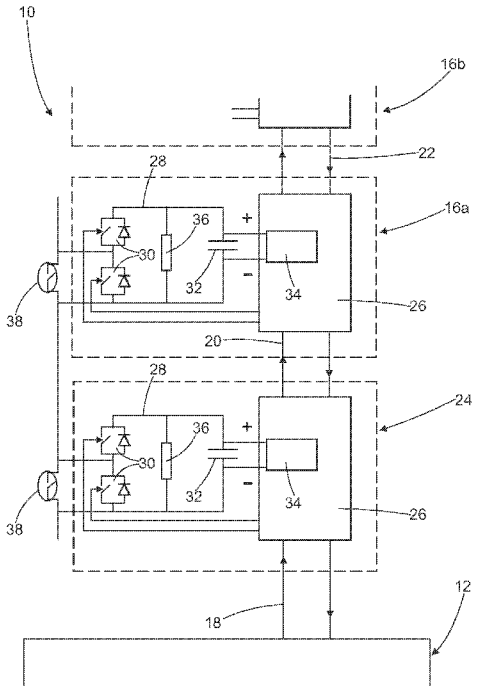


Fig. 6

(57) Abstract: A voltage source converter (10) for high voltage DC power transmission and reactive power compensation comprises a global control unit (12), at least one control hub (14) and at least one slave converter cell associated (16a, 16b) with the or each control hub (14), the or each control hub (14) being configured to receive data from and transmit data to the global control unit (12) and to receive data from and transmit data to the or each of its associated slave converter cells, and the or each slave converter cell being configured to receive data from and transmit data to the global control unit (12) via at least its associated control hub (14), wherein the or each of the slave converter cells is controllable to modify its voltage contribution to the voltage source converter (10) in response to control signals received from the global control unit (14).

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CONVERTER

The invention relates to a voltage source converter for high voltage direct current (HVDC) power transmission and reactive power compensation.

In power transmission networks alternating current (AC) power is typically converted to direct current (DC) power for transmission via overhead lines and/or undersea cables. This conversion removes the need to compensate for the AC capacitive load effects imposed by the transmission line or cable, and thereby reduces the cost per kilometer of the lines and/or cables. Conversion from AC to DC thus becomes cost-effective when power needs to be transmitted over a long distance.

The conversion of AC to DC power is also utilized in power transmission networks where it is necessary to interconnect the AC networks operating at different frequencies.

In any such power transmission network, converters are required at each interface between AC and DC power to effect the required conversion, and one such form of converter is a voltage source converter (VSC).

In a conventional line commutated converter (LCC), large thyristor devices are employed to effect the required AC to DC conversion. A ground level control is used to control the switching of the thyristor devices, the control providing instructions to each thyristor device using optical communication and data-back lines to bridge the high voltage boundary

between each thyristor and the ground level control system. The optical communication and data-back lines are provided in the form of two fibre optic cables and digitized light pulses are employed to pass data across the high voltage boundary.

A multilevel voltage source converter may also be used to effect the AC to DC conversion, the converter utilizing individual cells including, for example, a half-bridge or full-bridge element. Each of the half-bridge or full-bridge elements includes switches connected in parallel with a charged capacitor, the switches being controllable to insert the capacitor into the voltage source converter in order to contribute a voltage step to the output waveform. Each cell may be switched at a different time in order to produce a converter AC side waveform with the maximum number of voltage steps to provide a near-perfect approximation of a sinusoid. The operation of each cell relies on the use of semiconductor switches with turn-off capability such as insulated gate bipolar transistors (IGBT), field-effect transistors (FET) and gate turn-off thyristors (GTO).

According to an aspect of the invention there is provided a voltage source converter for high voltage DC power transmission and reactive power compensation comprising a global control unit, at least one control hub and at least one slave converter cell associated with the or each control hub, the or each control hub being configured to receive data from and transmit data to the global control unit and to the or each of its associated slave converter cells, and the

or each slave converter cell being configured to receive data from and transmit data to the global control unit via at least its associated control hub, wherein the or each of the slave converter cells is controllable to modify its voltage contribution to the voltage source converter in response to control signals received from the global control unit.

The provision of one or more control hubs leads to a reduction in the number of data transmission links between the global control unit and the slave converter cells than would otherwise be required in the absence of the or each control hub in order to allow a ground level control system to control each of the individual cells of the voltage source converter. The provision of one or more control hubs means that it is not necessary to link the global control unit directly to each of the slave converter cells. The global control unit is instead linked directly to the or each control hub, the or each control hub being in turn configured to communicate with the slave converter cells such that local data transmission links are only required between the or each control hub and the associated slave converter cells.

The distance between individual converter cells is less than the distance between each of the converter cells and the global control unit. Consequently the ability to utilize local data transmission links to establish a communication link between the global control unit and the slave converter cells, via the or each control hub, reduces the amount of fibre optic cables that would otherwise be required

and thereby allows the overall size, weight and cost of the voltage source converter to be reduced when compared with a voltage source converter in which each of the individual cells is connected directly to the global control unit.

This is particularly advantageous in a multilevel voltage source converter employing half-bridge elements or full-bridge elements. This is because the voltage ratings of the semiconductor switches are lower than that of conventional thyristors, which limits the voltage range of half-bridge and full-bridge elements. This means that a greater number of cells, and therefore a greater number of semiconductor switches, are required in a multilevel voltage source converter in order to achieve the same megavolt-ampere (MVA) rating as a thyristor-based converter.

Preferably the or each control hub is provided in the form of a master converter cell and the or each master converter cell is controllable to modify its voltage contribution to the voltage source converter in response to control signals received from the global control unit.

Preferably each converter cell is configured to receive data from and transmit data to at least one other converter cell.

Configuring the converter cells to permit bidirectional data transmission allows the or each control hub to receive data from and transmit data to a slave converter cell and therefore helps to further

simplify the communication infrastructure of the voltage source converter.

Preferably the or each control hub is configured to transmit data-back signals to the global control unit and each slave converter cell is configured to transmit data-back signals to the global control unit via at least its associated control hub.

The use of data-back signals allow the global control unit to determine the status of the or each control hub and each of the converter cells via information provided in the data-back signals. It therefore allows the global control unit to monitor, as well as controlling, the or each control hub and each of the converter cells.

Preferably each converter cell includes a local control unit to transmit and receive data.

The provision of a local control unit in each converter cell allows the converter cell to receive control signals containing instructions to modify its voltage contribution to the voltage source converter, and to transmit data-back signals based on the status of the converter cell in a format that is understood by the global control unit.

In embodiments of the invention each converter cell may include a chain-link module including at least one pair of semiconductor switches connected in parallel with an energy storage device, the chain-link module being operably associated with the local control unit so as to control the switching of the semiconductor switches to provide a voltage step in response to the received control signals.

In order to provide a unidirectional chain-link module, a pair of semiconductor switches may be connected in parallel with the energy storage device in a half-bridge assembly to define a 2-quadrant unipolar module which can provide zero or positive voltage and can conduct current in both directions.

In order to provide a bidirectional chain-link module, two pairs of semiconductor switches may be connected in parallel with the energy storage device in a full-bridge assembly to define a 4-quadrant bipolar module which can provide positive, zero or negative voltage and can conduct current in both directions.

In such embodiments, the chain-link modules may be connected in series to define a chain-link converter, the semiconductor switches the chain-link modules being operable to provide a continuously variable voltage source.

The use of a chain-link converter allows a combined voltage to be constructed, the combined voltage being higher than the voltage provided by each of the individual chain-link modules via the insertion of multiple modules into the chain-link converter. By continuously varying the value of the combined voltage, the chain-link converter may be operated to generate complex voltage waveforms.

The semiconductor switches used in the chain-link modules may be provided in the form of insulated-gate bipolar transistors, field-effect transistors and/or gate turn-off thyristors.

The use of semiconductor devices is advantageous because such devices are small in size and

weight, and have relatively low power dissipation, which minimizes the need for cooling equipment. It therefore leads to significant reductions in power converter cost, size and weight.

The energy storage devices used in the chain-link modules may be provided in the form of any device that is capable of storing and releasing its electrical energy to provide a voltage. The energy storage devices may therefore be provided in the form of a charged capacitor, battery, fuel cell or receives power from a dedicated generator with local rectification.

Such flexibility is useful when designing converter stations that are intended for construction in different locations where the availability of equipment may vary due to locality or transport difficulties.

In other embodiments of the invention each converter cell may include a multilevel converter, the multilevel converter being operably associated with the local control unit of the converter cell to modify the voltage contribution of the converter cell to the voltage source converter in response to received control signals.

In such embodiments, the multilevel converter of each converter cell may be a flying capacitor converter or a neutral point diode-clamped converter.

The use of multilevel converters allows the generation of high precision waveforms.

Various structural configurations of the converter cells are envisaged.

In one embodiment, the or each control hub may be linked in series with at least one slave converter cell so as to define a serial assembly in which the control hub is located at a first end of the serial assembly, a slave converter cell is located at the opposite end of the serial assembly and each converter cell in the serial assembly received data from and transmits data to the or each neighboring converter cell.

The serial assembly including a control hub and one of more slave converter cells provides a simple way to link the components of the voltage source converter without resorting to a complex data transmission link layout to interconnect the or each control hub and the or each associated slave converter cell.

The voltage source converter may include a plurality of serial assemblies arranged adjacent to one another wherein the slave converter cell located at the opposite end of each of the serial assemblies is configured to receive data from and transmit data to the slave converter cell located at the opposite end of the or each neighboring serial assembly.

Configuring the slave converter cell located at the opposite end of each serial assembly in this manner improves the reliability of the voltage source converter in that it provides a back-up communication route between the global control unit and the converter cells in the event of a breakdown in the

flow of communication between the converter cells of a serial assembly or a breakdown in the flow of communication between the control hub of a serial assembly and the global control unit. For example, in the event of a communication failure between the global control unit and the control hub of a first serial assembly, the global control unit may communicate with the or each slave converter cell of the first serial assembly via a second, adjacent, serial assembly.

In another embodiment, the voltage source converter may include a data bus and the or each control hub may be configured to receive data from and transmit data to the or each of its associated slave converter cells via the data bus and the or each slave converter cell may be configured to receive data from and transmit data to its associated control hub via the data bus.

The inclusion of a data bus provides a common communication link between each of the slave converter cells and their respective control hub(s).

Preferably the voltage source converter includes a plurality of slave converter cells associated with the or each control hub and each slave converter cell is configured to receive data from and transmit data to at least one other slave converter cell via the data bus.

The inclusion of the data bus is advantageous in such embodiments in that it renders it unnecessary to install additional data transmission links between the converter cells to permit communication between the converter cells.

Preferably, so as to provide a back-up communication route, the global control unit is configured to port directly into the data bus. Such an arrangement allows the global control unit to communicate with the slave converter cells in the event the data transmission links between the global control unit and the or each control hub fail.

The data bus may be a fibre optic data bus or a free-space optical data bus. In other embodiments, the data bus may be an inductive, magnetic, radio-frequency, microwave or ultra-wideband radio data bus.

In embodiments in which the or each control hub is provided in the form of a master converter cell, the or each slave converter cell may be configured to define a block switching assembly with its associated master converter cell so that operations of the master converter cell and the slave converter cell are coordinated.

The provision of a block switching assembly permits the global control unit to provide instructions in a single set of control signals to a block switching assembly including multiple converter cells instead of providing separate control signals directly to each converter cell. This simplifies the design of the global control unit since less channels are required to communicate with block switching technologies than to communicate directly with each converter cell.

Preferably the voltage source converter includes at least two control hubs and a plurality of slave converter cells, each of the slave converter cells being associated with at least two control hubs

and being configured to receive data from and transmit data to the global control unit via at least its associated control hubs.

Each additional control hub provides a backup communication route between the global control unit and the voltage source converter in the event of a communication failure between one control hub and the global control unit.

The global and local data transmission links between the global control unit, the or each control hub and the of each converter cell may include any device that is capable of transmitting data. Data may for example therefore by transmitted using fibre optical lines, electronic level shifting circuits, magnetic isolation and/or electromagnetic waves.

Preferred embodiments of the invention will now be described, by way of non-limiting examples, with reference to the accompanying drawings in which:

Figure 1 shows a voltage source converter according to a first embodiment of the invention;

Figure 2 shows a voltage source converter according to a second embodiment of the invention;

Figure 3 shows a voltage source converter according to a third embodiment of the invention;

Figure 4 shows a voltage source converter according to a fourth embodiment of the invention;

Figure 5 shows a voltage source converter according to a fifth embodiment of the invention;

Figure 6 shows a detailed view of the converter cells of the voltage source converter shown in Figure 2; and

Figure 7 shows a voltage source converter according to a sixth embodiment of the invention.

A voltage source converter 10 according to an embodiment of the invention is shown in Figure 1 and includes a global control unit 12, a control hub 14 and first and second slave converter cells 16a,16b associated with the control hub 14.

The control hub 14 is provided in the form of a master converter cell 24, and each of the master converter cell 24 and the first and second slave converter cells 16a,16b is operable to contribute a voltage to a combined voltage output of the voltage source converter 10.

The master converter cell 24 is configured to receive data from and transmit data to the global control unit 12 via global data transmission links 18, and to receive data from and transmit data to the first and second slave converter cells 16a,16b via local transmission links 20,22. Each of the first and second slave converter cells 16a,16b is configured to receive data from and transmit data to the master converter cell 24 via the local transmission links 20,22.

The voltage output available from the voltage source converter 10 shown in Figure 1 may be increased by increasing the number of slave converter cells associated with and interconnected with the control hub 14 via local transmission links.

In another embodiment, shown in Figure 2, the control hub 14 in the form of a master converter cell 24 is linked in series with first and second slave converter cells 16a,16b so as to define a serial

assembly 21. In this embodiment the master converter cell 24 is located at a first end of the serial assembly 21, the second slave converter cell 16b is located at the opposite end of the serial assembly 21 and the first slave converter cell 16a is connected between the master converter cell 24 and the second slave converter cell 16b.

In this embodiment, the master converter cell 24 in the serial assembly 21 is configured to receive data from and transmit data to the global control unit 12 via global data transmission links 18, and to receive data from and transmit data to the first slave converter cell 16a via local data transmission links 20. The first slave converter cell 16a is configured to receive data from and transmit data to the second slave converter cell 16b via local data transmission links 22.

The voltage output available from the voltage source converter 10 shown in Figure 2 may be increased by connecting additional slave converter cells in series with the second slave converter cell 16b at the other end of the serial assembly 21 using local data transmission links. Each additional slave converter cell communicates with the master converter cell 24 via each of the slave converter cells interconnected between it and the master converter cell 24.

The serial assembly 21 of the master converter cell 24 and the associated slave converter cells 16a,16b shown in Figure 2 provides a simple way to link the components of the voltage source converter

10 without resorting to a complex data transmission link layout to interconnect the master converter cell 24 and the associated slave converter cells 16a,16b.

A voltage source converter 10 according to a further embodiment is shown in Figure 3 and includes a pair of serial assemblies 21 arranged adjacent to one another. Each of the serial assemblies 21 is constructed in the same manner as the serial assembly 21 shown in Figure 2 and the second slave converter cells 16b located at the ends of the serial assemblies 21 are linked via local data transmission links 23 to form a ring. The local data transmission links 23 allow the second slave converter cells of each of the serial assemblies 21 to receive data from and transmit data to each other.

Interconnecting the second converter cells 16b of the serial assemblies 21 in this manner provides a back-up communication route in the event of a communication failure between the global control unit 12 and the master converter cell 24 of one of the serial assemblies 21. For example, in the event of physical damage to the global data transmission link 18 between the global control unit 12 and the master converter cell 24 of one of the serial assemblies 21, the global control unit 12 remains able to communicate with all of the converter cells 16a,16b,24 of the apparently cut-off serial assembly 21 via the other of the serial assemblies 21.

It is envisaged that in other embodiments of the invention the voltage source converter may include any number of serial assemblies, each of which

is arranged to be adjacent to at least one other serial assembly wherein the slave converter cell located at the opposite end of each of the serial assemblies is configured to receive data from and transmit data to the slave converter cell located at the opposite end of the or each neighboring serial assembly to form one of more communication rings.

A voltage source converter 10 according to a yet further embodiment is shown in Figure 4 and includes a global control unit 12, two control hubs 14 in the form of master converter cells 24 and a plurality of slave converter cells 16a-16e. Each of the slave converter cells 16a-16e is associated with the two master converter cells 24 and configured to receive data from and transmit data to the global control unit 12 via the master converter cells 24.

Each of the master converter cells 24 is configured to receive data from and transmit data to the global control unit 12 via global transmission links 18.

The master converter cells 24 together with the slave converter cells 16a-16e are also arranged to form a closed string of converter cells in which each of the converter cells 16a-16e,24 is configured to receive data from and transmit data to two other converter cells via local data transmission links 20,22. Each converter cell 16a-16e,24 is therefore configured to receive control signals from and transmit data-back signals to first and second neighboring converter cells.

Such a configuration permits bidirectional transmission of data around the closed string of converter cells 16a-16e,24. Consequently, in the event of a communication failure between a converter cell and one of its neighboring cells, neither of the cells becomes isolated by virtue of the communication between each of the cells and their other neighboring cells. The string of converter cells 16a-16e,24 therefore remains in communication with the global control unit 12 and none of the converter cells 16a-16e,24 is isolated by virtue of the communication failure between two of the converter cells 16a-16e,24.

A voltage source converter 10 according to another embodiment is shown in Figure 5 and includes two control hubs in the form of master converter cells 24 connected to a global control unit 12 via global transmission links 18 and to a data bus 40 via local data transmission links 20.

The voltage source converter 10 shown in Figure 5 also includes first, second and third slave converter cells 16a-16c connected to the data bus 40 via local data transmission links 22.

The use of a common data bus 40 allows each of the converter cells 16a-16c,24 to receive data from and transmit data to the other converter cells 16a-16c,24 via the data bus. This results in size, weight and cost savings in terms of the number of data transmission links that are required because it is not necessary to physically connect each converter cell 16a-16c,24 to the other converter cells 16a-16c,24.

It is envisaged that in such embodiments, the global control unit 12 may be configured to port directly into the common data bus 40 to avoid the risk of converter failure in the event of a communication failure between both of the master converter cells 24 and the global control unit 12.

The common data bus 40 may be provided in the form of a fibre optic data bus or a free-space optical data bus. In other embodiments the common data bus 40 my be provided in the form of an inductive, magnetic, radio-frequency, microwave or ultra-wideband radio data bus.

In each of the embodiments shown in Figures 3, 4 and 5, the voltage source converter 10 includes two control hubs 14 in the form of master converter cells 24 that are linked to a global control unit 12 via global transmission links 18. Such arrangements provide advantages in terms of increased reliability in that, in the event of a communicate failure between the global control unit 12 and one of the master converter cells 24, the global control unit 12 remains able to communicate with the converter cells 16,24 via the other of the master converter cells 24.

In the embodiments shown in Figures 1 to 5, each of the converter cells 16,24 is controllable to modify its voltage contribution to the respective voltage source converter 10 in response to signals received from the respective global control unit 12.

The transmission links 18,20,22,23 included in the voltage source converters 10 shown Figures 1 to 5, which may be provided in the form of fibre optic

lines, electronic level shifting circuits, magnetic isolation and/or electromagnetic waves, allow the global control unit 12 in each case to communicate directly with the or each master converter cell 24 and to communicate with slave converter cells 16 via the or each master converter cell 24. Transmission links are not therefore required directly between the global control unit 12 and each of the converter cells 16.

In each of the voltage source converters 10 shown in Figures 1 to 5, the distance between adjacent converter cells is typically less than the distance between each of the converter cells 16,24 and the global control unit 12. Consequently the provision of the local data transmission links 20,22 provides savings in terms of size and cost over arrangements in which the global control unit 12 is linked directly to each of the converter cells 16, 24.

The converter cells 16,24 in each of the voltage source converters 10 shown in Figures 1 to 5 are preferably configured to transmit data-back signals via the transmission links 18,20,22,23 thereby rendering it possible for the global control unit 12 to monitor the status of each of the converter cells 16,24 via information provided in the data-back signals.

Each of the converter cells 16,24 includes a local control unit to receive data from and transmit data to the local control unit of the or each neighboring converter cell via the local data transmission links 20,22.

Referring to Figure 6, showing the converter cells 16a,16b,24 of the voltage source

converter 10 shown in Figure 2, the first slave converter cell 16a includes a local control unit 26 to receive data from and transmit data to local control units 26 of the master converter cell 24 and the second slave converter cell 16b via the local transmission links 20,22.

The local control unit 26 of the master converter cell 24 is connected to the global control unit 12 via global data transmission links 18 to enable transmission of data between the master converter cell 24 and the global control unit 12.

The provision of a local control unit 26 in each converter cell 16a,16b,24 allows the converter cell to receive control signals containing instructions to modify its voltage contribution to the voltage source converter 10, and to transmit data-back signals based on the status of the converter cell in a formal that will be understood by the global control unit 12.

Referring again to Figure 6, each of the converter cells 16a,16b,24 includes a half-bridge module 28 for the purposes of contributing a voltage to the voltage source converter 10.

The half-bridge module 28 of each of the converter cells 16a,16b,24 includes a pair of insulated gate bipolar transistors 30 connected in parallel with a capacitor 32 in a half-bridge arrangement to define a 2-quadrant unipolar module that can provide zero or positive voltage and can conduct current in both directions.

The insulated gate bipolar transistors 30 of each half-bridge module 28 are operable to either

bypass the capacitor 32 or to insert the capacitor 32 into the voltage source converter 10 so that the capacitor 32 contributes a voltage step to the output waveform.

The local control unit 26 of each converter cell 16a,16b,24 includes a power supply unit 34 connected in parallel with the capacitor 32 of the respective half-bridge module 28 to enable electrical energy to be exchanged between the capacitor 32 and the power supply unit 34.

Grading resistors 36 are connected in parallel with the capacitors 32 of the half-bridge modules 28 of the converter cells 16a,16b,24 and mechanical bypass switches 38 are also connected to the half-bridge modules 28 so that the half-bridge modules 28 may be bypassed in the event of converter failure.

The half-bridge modules 28 of the converter cells 16,24 of each of the voltage source converters 10 shown in Figures 1 to 5 are connected in series to define a chain-link converter, the insulated gate bipolar transistors 30 in each of the half-bridge modules 28 being controllable so as to facilitate the creation of a continuously variable voltage source.

As outlined above, each of the half-bridge modules may be bypassed or inserted into the chain-link converter by changing the states of the insulated gate bipolar transistors 30. A module 28 is bypassed when the insulated gate bipolar transistors 30 are configured to form a short circuit in the module 28, causing the current in the voltage source converter 10 to pass through the short circuit and bypass the

respective capacitor 32. A module 28 is inserted into the chain-link converter when the insulated gate bipolar transistors 30 of the module are configured to allow the converter current to flow into and out of the respective capacitor 32, which is then able to discharge its stored energy and thereby provide a voltage. It is therefore possible to build up a combined voltage across the chain-link converter which is higher than the individual module voltage via the insertion of multiple modules, each providing its own voltage, into the chain-link converter.

The insulated gate bipolar transistors 30 in each module 28 may be controlled to configure the timing of the insertion and/or bypass of individual modules in the chain-link converter so as to facilitate the construction of complex waveforms. For example, the modules 28 may be switched at different times to produce a near-perfect approximation of a sinusoid voltage waveform.

It is envisaged that in other embodiments other semiconductor switches may be used instead of insulated gate-bipolar transistors. For example, field effect transistors and/or gate turn-off thyristors may be used. It is also envisaged that in other embodiments a battery or fuel cell may be used in each module 28 in place of a capacitor 32 or each module 28 may receive power from a dedicated generator with local rectification.

In yet further embodiments of the invention it is envisaged that each converter cell 16,24 may include a multilevel converter such as a flying

capacitor converter or a neutral point diode clamped converter. In such embodiments, the local control unit 26 of each converter cell 16,24 may be operably associated with the respective multilevel converter to modify the voltage contribution of the converter cell to the voltage source converter in respect of received control signals. The inclusion of multilevel converters permits the generation of high precision waveforms in the voltage source converter.

Whilst the structure and operation of each of the converter cells 16a,16b,24 outlined above is described with reference to the voltage source converter 10 shown in Figure 2, it is envisaged that the converter cells 16,24 of the voltage source converters 10 shown in Figure 1 and Figures 3 to 5 are constructed in the same manner.

In use, the local control unit 26 of the or each control hub 14 of each of the voltage source converters 10 shown in Figures 1 to 5 receives control signals from the respective global control unit 12 via global data transmission links 18. These control signals are transmitted via local data transmission links 20,22,23 from the master converter cell 24 to each of the associated slave converter cells either directly or via an intermediate slave converter cell.

The control signals include instructions to operate the half-bridge module 28 of the converter cells 16,24. Based on these instructions the local control unit 26 of each converter cell 16,24 controls the switching of the respective insulated gate bipolar transistors 30 to either bypass the respective

capacitor 32 or to insert the respective capacitor 32 to provide a voltage step.

The switching demand of each converter cell 16,24 may be sent as separate instructions in a single set of control signals using the same data transmission links 18,20,22,23. Alternatively at least one slave converter cell may be operably associated with the or each master converter cell 24 to define a block switching assembly in which the operations of the master converter cell 24 and each of its associated slave converter cells 16 are coordinated. For example, the half-bridge modules 28 of the converter cells 16,24 may be controlled to switch at the same time or the half-bridge modules 28 of the slave converter cells 16 may be controlled to switch after the half-bridge module 28 of the or each master converter cell 24 using a pre-set time delay.

This allows the global control unit 12 to provide instructions for the block switching assembly in the same set of control signals, which is transmitted to the or each master converter cell 24 of the voltage source converter 10. This allows the number of channels in the global control unit 12 to be reduced since less channels are required to communicate with block switching assemblies including multiple converter cells than are required when communicating individually with each converter cell.

Data-back signals are generated by the local control unit 26 of each converter cell 16,24 based on the status of the respective half-bridge module 28. The data-back signals are transmitted via

the local data transmission links 20,22,23 from each slave converter cell 16 to the or each master converter cell 24 either directly or via any intermediate slave converter cell or common data bus 40. In whichever case, the local control unit 26 of the master converter cell 24 transmits the data-back signals to the global control unit 12 via the global data transmission links 18.

While operation of the voltage source converter 10 shown in each of Figures 1 to 5 has been described with reference to the inclusion of half-bridge modules 28 in each of the converter cells 16,24, it is envisaged that in other embodiments each of the converter cells 16,24 may include a full-bridge module. In a full-bridge module, two pairs of insulated gate bipolar transistors are connected in parallel with a capacitor in a full-bridge assembly to define a 4-quadrant bipolar module which can provide positive, zero or negative voltage and can conduct current in both directions.

Whilst each of the embodiments shown in Figures 1 to 5 has been described with reference to the use of one or more control hubs 14 provided in the form of master converter cells 24, it is envisaged that in other embodiments, the or each control hub 14 may be provided in the form of a cell block control communication decoder 42, such as that as shown in Figure 7.

The use of a control hub 14 in the form of a cell block control communication decoder 42 allows the number of global data transmission links 18 between

the control hub 14 and the global control unit 12 to be minimized to a pair of global data transmission links 18. This is particularly advantageous when there is a considerable distance between the global control unit 12 and the converter cells 16a-16d.

The cell block communication decoder 42 acts as an intermediate electronics processing stage between the global control unit 12 and the slave converter cells 16a-16d. The cell black communication decoder 42 receives control signals from the global control unit 12 via a global data transmission link 18. The control signals are then transmitted to each of the slave converter cells 16a-16d via local data transmission links 20 and, optionally between neighboring slave converter cells 16a-16d via local data transmission links 22. Similarly each of the slave converter cells 16a-16d transmits data-back signals to the decoder which in turn transmits the information to the global control unit 12 via a single global data transmission link 18.

CLAIMS

1. A voltage source converter (10) for high voltage DC power transmission and reactive power compensation comprising a global control unit (12), at least one control hub (14) and at least one slave converter cell (16a, 16b) associated with the or each control hub, the or each control hub being configured to receive data from and transmit data to the global control unit and to receive data from and transmit data to the or each of its associated slave converter cells, and the or each slave converter cell being configured to receive data from and transmit data to the global control unit via at least its associated control hub, wherein the or each of the slave converter cells is controllable to modify its voltage contribution to the voltage source converter in response to control signals received from the global control unit.

2. A voltage source converter according to Claim 1 wherein the or each control hub (14) is provided in the form of a master converter cell (24), the or each master converter cell being controllable to modify its voltage contribution to the voltage source converter in response to control signals received from the global control unit.

3. A voltage source converter according to Claim 1 or Claim 2 wherein the or each control hub (14) is configured to transmit data-back signals to the global control unit and each slave converter cell (16a,

16b) is configured to transmit data-back signals to the global control unit via at least its associated control hub.

4. A voltage source converter according to any preceding claim wherein each converter cell (16a, 16b) is configured to receive data from and transmit data to at least two other converter cells.

5. A voltage source converter according to any preceding claim wherein each converter cell (16a, 16b) includes a local control unit (26) to transmit and receive data.

6. A voltage source converter according to Claim 5 wherein each converter cell (16a, 16b) further includes a chain-link module (28) including at least one pair of semiconductor switches (30) connected in parallel with an energy storage device (32), the chain-link module being operably associated with the local control unit so as to control the switching of the semiconductor switches to provide a voltage step in response to the received control signals.

7. A voltage source converter according to Claim 6 wherein the chain-link module (28) of each converter cell includes a pair of semiconductor switches (30) connected in parallel with an energy storage device (32) in a half-bridge arrangement to define a 2-quadrant unipolar module.

8. A voltage source converter according to Claim 6 wherein the chain-link module (28) of each converter cell includes two pairs of semiconductor switches (30) connected in parallel with the energy storage device (32) in a full-bridge arrangement to define a 4-quadrant bipolar module.

9. A voltage source converter according to any of Claims 6 to 8 wherein the chain-link modules (28) of the converter cells are connected in series to define a chain-link converter, the semiconductor switches in the chain-link modules being operable to provide a continuously variable voltage source.

10. A voltage source converter according to any of Claims 6 to 9 wherein the semiconductor switches (30) of each chain-link module are provided in the form of insulated gate bipolar transistors, field effect transistors and/or gate turn-off thyristors.

11. A voltage source converter according to any of Claims 6 to 10 wherein the energy storage device (32) of each chain-link module is provided in the form of a charged capacitor, battery, fuel cell or receives power from a dedicated generator with local rectification.

12. A voltage source converter according to Claim 5 wherein each converter cell further includes a multilevel converter, the multilevel converter being operably associated with the local control unit (26) to

modify the voltage contribution of the converter cell to the voltage source converter in response to received control signals.

13. A voltage source converter according to Claim 12 wherein the multilevel converter of each converter cell is a flying capacitor converter or a neutral point diode clamped converter.

14. A voltage source converter according to any preceding claim wherein the or each control hub (14) is linked in series with at least one slave converter cell (16a, 16b) so as to define a serial assembly in which the control hub cell (14) is located at a first end of the serial assembly, a slave converter cell is located at the opposite end of the serial assembly and each converter cell in the serial assembly receives data from and transmits data to the or each neighboring converter cell.

15. A voltage source converter according to Claim 14 including a plurality of serial assemblies arranged adjacent to one another wherein the slave converter cell (16a, 16b) located at the opposite end of each of the serial assemblies is configured to receive data from and transmit data to the slave converter cell located at the opposite end of the or each neighboring serial assembly.

16. A voltage source converter according to any preceding claim further including a data bus (40)

and wherein the or each control hub (14) is configured to receive data from and transmit data to the or each of its associated slave converter cells via the data bus (40) and the or each slave converter cell is configured to receive data from and transmit data to its associated control hub via the data bus.

17. A voltage source converter according to Claim 16 further including a plurality of slave converter cells (16a) associated with the or each control hub (14) wherein each slave converter cell is configured to receive data from and transmit data to at least one other slave converter cell via the data bus (40).

18. A voltage source converter according to Claim 16 or Claim 17 wherein the global control unit (12) is configured to port directly into the data bus.

19. A voltage source converter according to any of Claims 16 to 18 wherein the data bus (40) is a fibre optic data bus or a free-space optical data bus.

20. A voltage source converter according to any of Claims 16 to 18 wherein the data bus (40) is an inductive, magnetic, radio-frequency, microwave or ultra-wideband radio data bus.

21. A voltage source converter according to Claim 2 and any claim dependent therefrom wherein the or each slave converter cell (16) is configured to

define a block switching assembly with its associated master converter cell (24) so that operations of the master converter cell and the slave converter cell are coordinated.

22. A voltage source converter according to any preceding claim wherein the voltage source converter (10) includes at least two control hubs (14) and a plurality of slave converter cells (16a, 16b, 16c, 16d, 16e), each of the slave converter cells being associated with at least two control hubs and being configured to receive data from and transmit data to the global control unit (14) via at least its associated control hubs.

23. A voltage source converter according to any preceding claim wherein data is transmitted between the global control unit (12), the or each control hub (14) and the converter cells (16) using fibre optic lines, electronic level shifting circuits, magnetic isolation and/or electromagnetic waves.

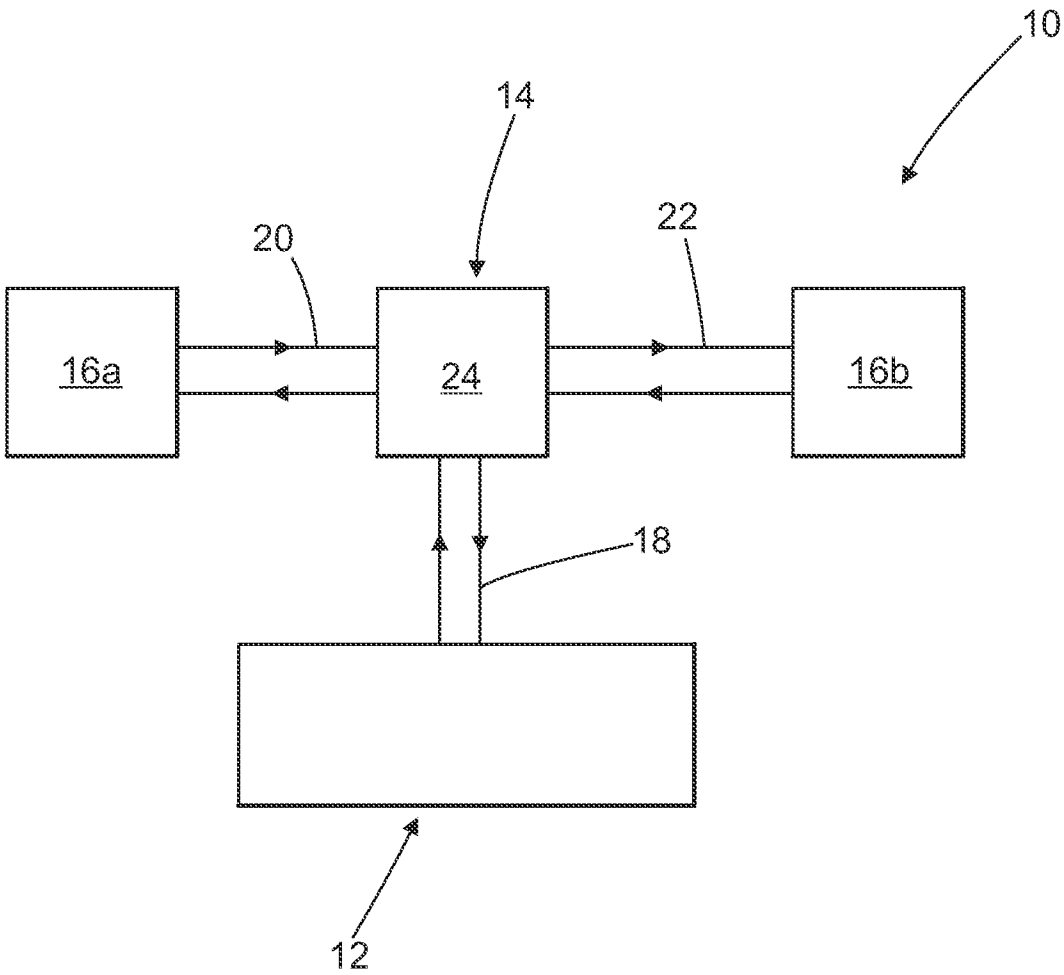


Fig. 1

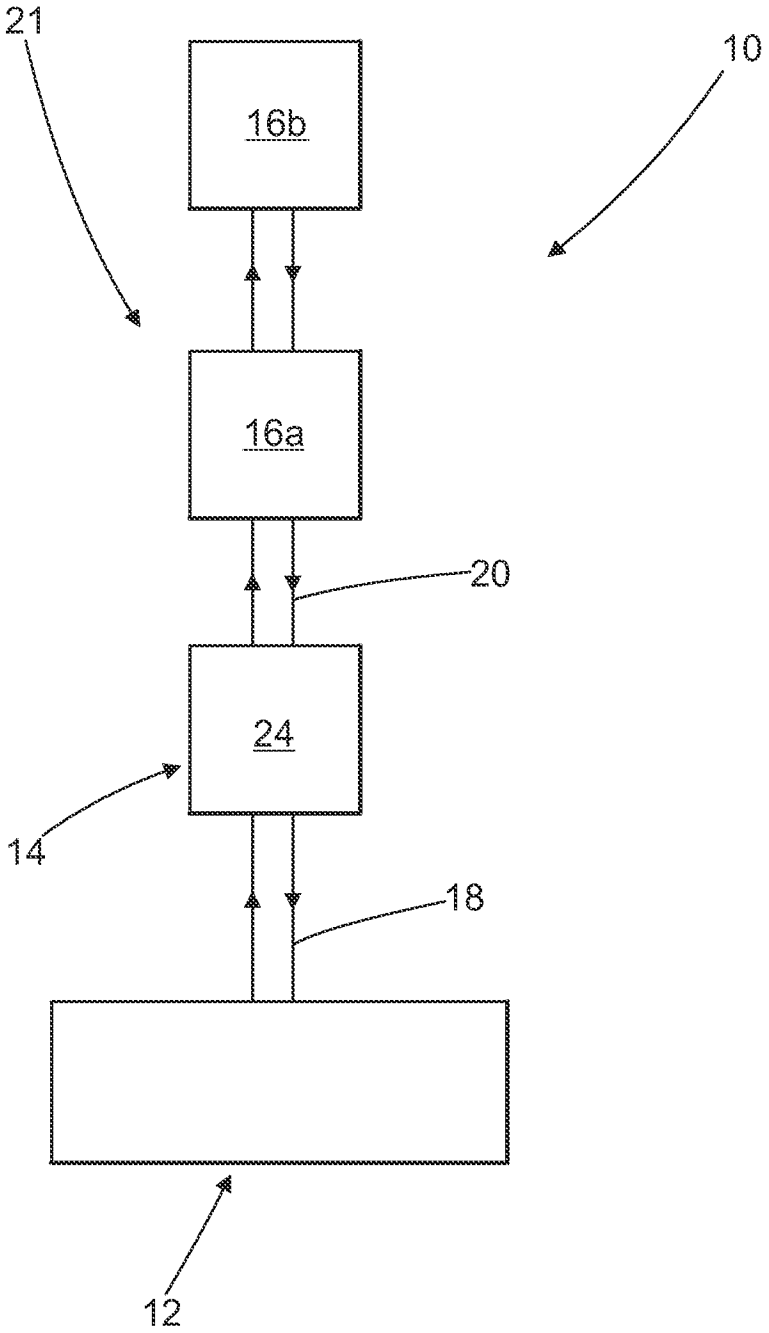


Fig. 2

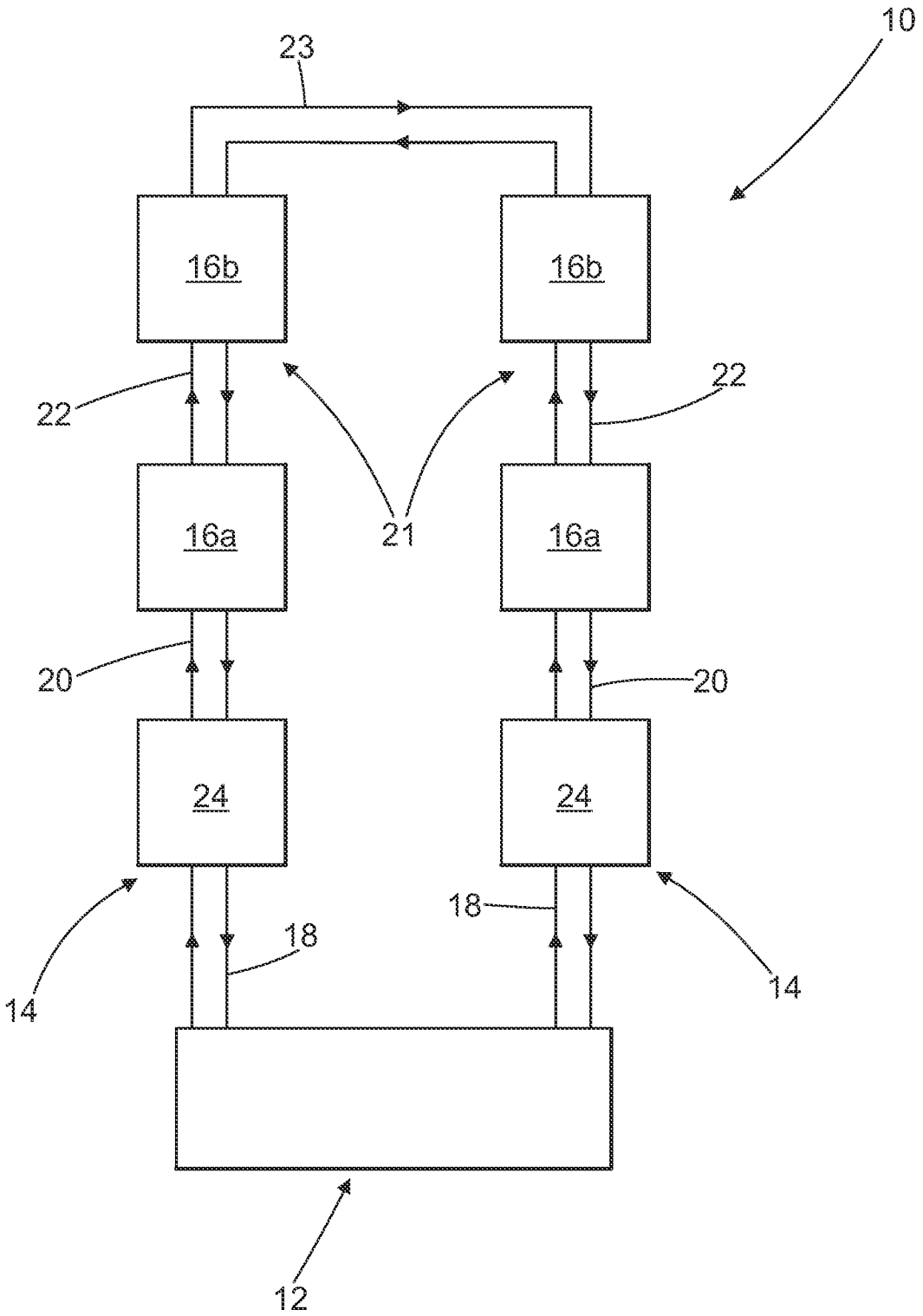


Fig. 3

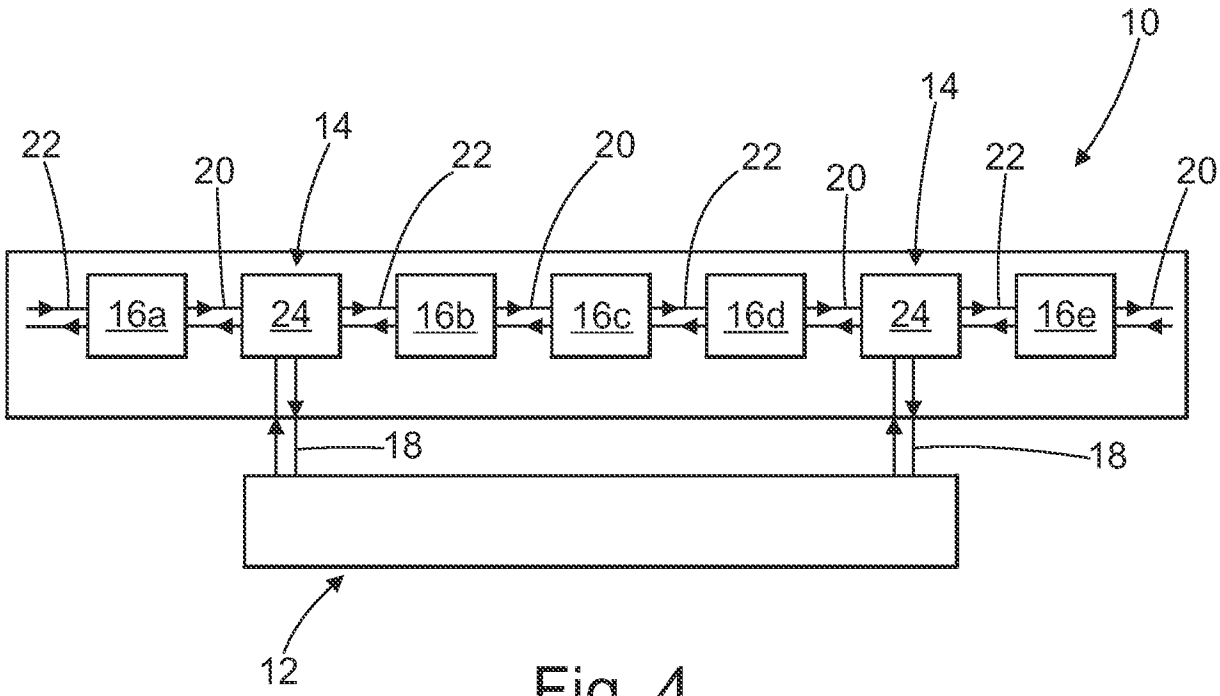

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Fig. 4

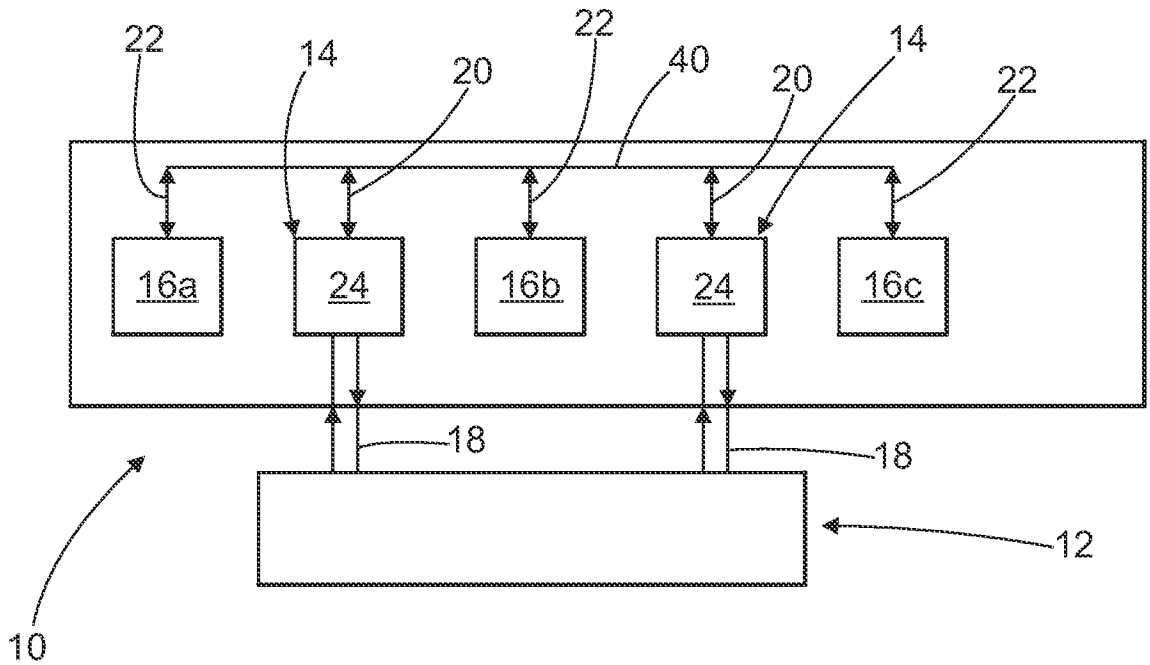

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16b
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16c
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Fig. 5

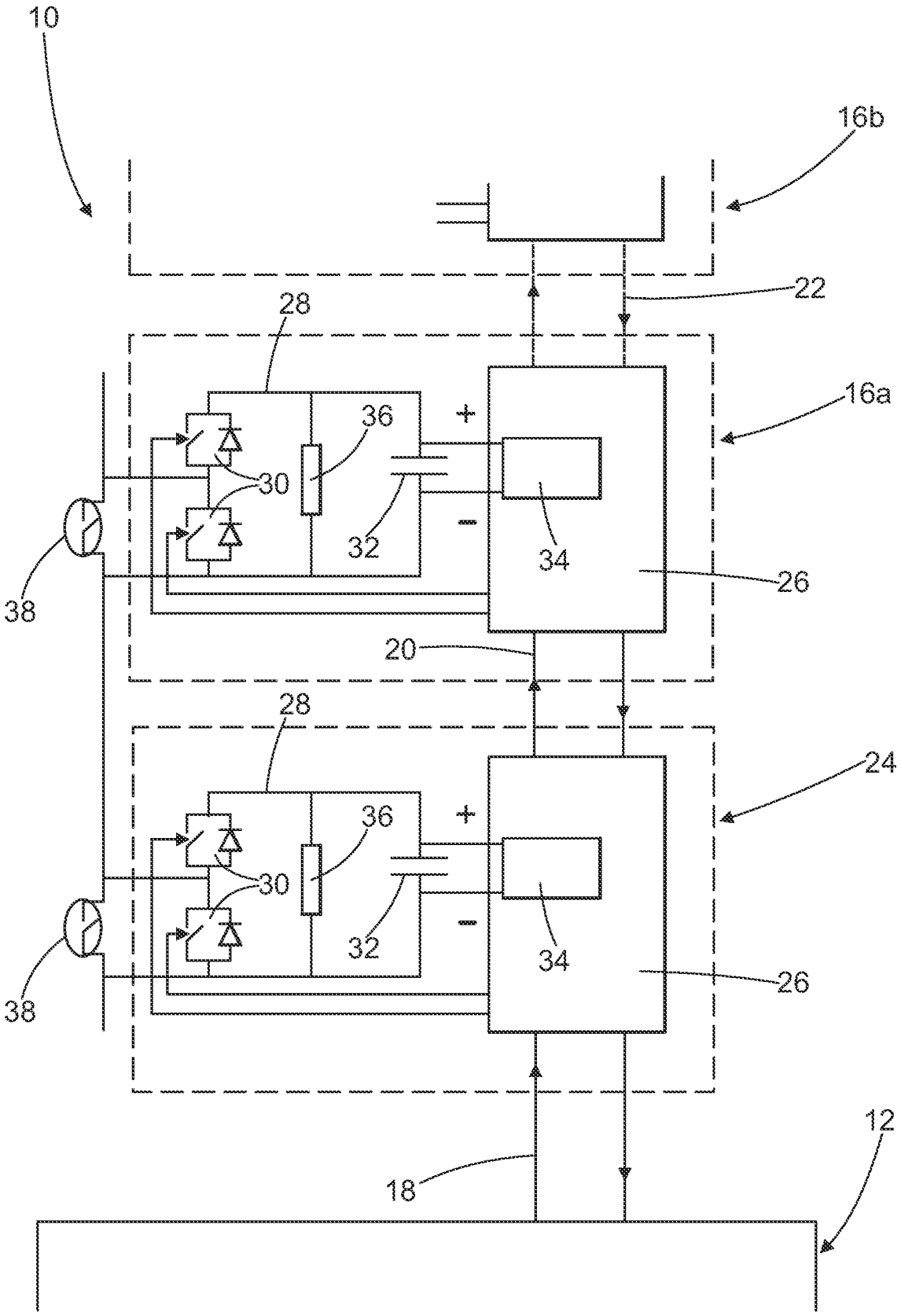


Fig. 6

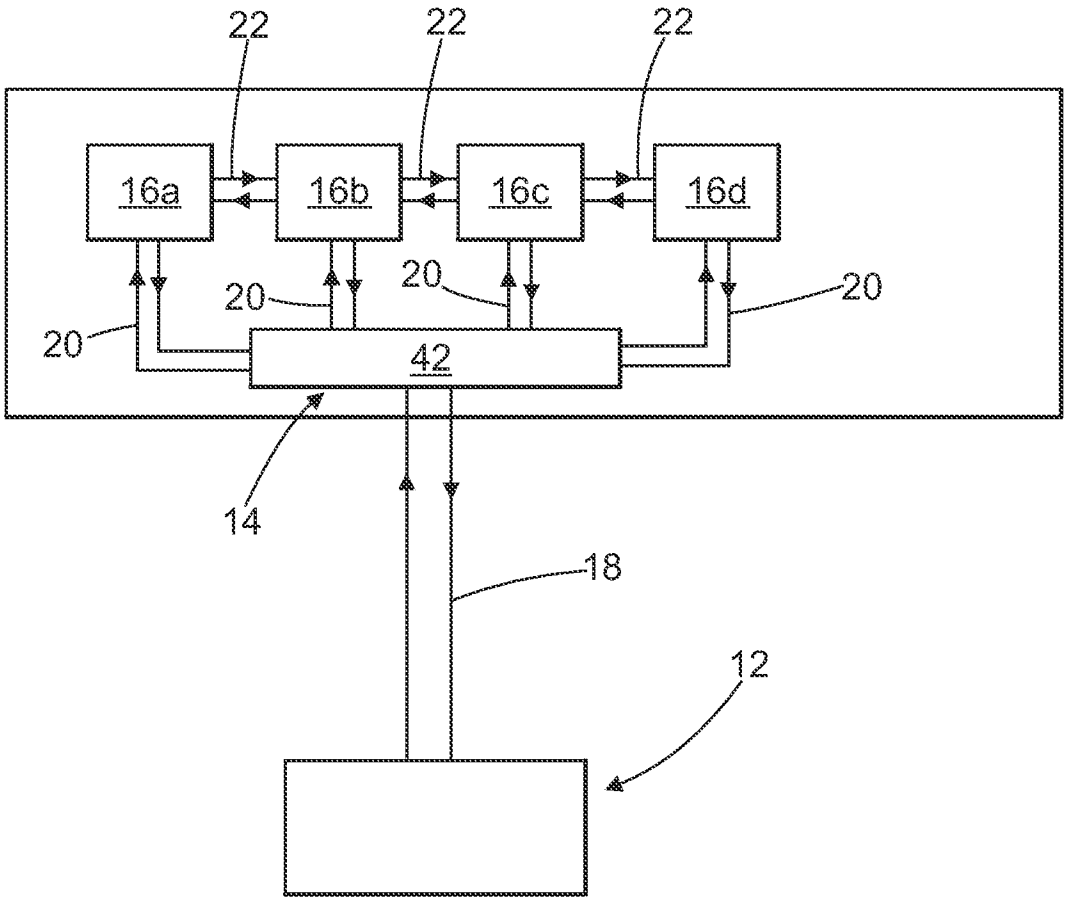


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/054304

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02M7/49 H02M1/084
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H02M H02J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	DE 10 2005 045957 A1 (SIEMENS AG [DE]) 16 November 2006 (2006-11-16) figure 2 paragraphs [0004], [0005], [0007] - [0009], [0011], [0022] - [0024]	1-23
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 February 2011	24/02/2011

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kail, Maximilian

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/054304

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

International application No
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