Abstract: It is presented a power converter assembly arranged to convert power between AC on a main AC connection and DC on a DC connection. The power converter assembly comprises: a plurality of converter devices; at least one converter transformer connected between one of the converter devices and an intermediate AC bus, respectively; at least one voltage transformers connected on one side to the intermediate bus and arranged to be connected on the other side to a main AC connection.
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POWER CONVERTER ASSEMBLY

TECHNICAL FIELD

The invention relates to a power converter assembly for converting power between alternating current, AC, and direct current, DC.

BACKGROUND

High voltage DC (HVDC) is increasing in usage due to a number of benefits compared to AC for power transmission. In order to connect a HVDC link or an HVDC grid to an AC grid, conversion needs to occur from DC to AC or AC to DC. This conversion is performed in converter stations.

However, these converter stations are large and heavy, which not only creates demands during installation, but also when transporting the converter stations from a factory where the converter station is assembled to an installation site.

SUMMARY

It is an object to provide a power converter assembly which is easier to transport than the power converter assemblies in the prior art.

According to a first aspect, it is provided a power converter assembly arranged to convert power between AC on a main AC connection and DC on a DC connection. The power converter assembly comprises: a plurality of converter devices; at least one converter transformer connected between one of the converter devices and an intermediate AC bus, respectively; at least one voltage transformers connected on one side to the intermediate bus and arranged to be connected on the other side to a main AC connection. The converter transformers for transforming to the intermediate bus can be made smaller compared to if the converter transformers would need to be connected to the main AC connection. In this way, the converter devices can be provided with the converter transformers with reduced size and weight.

All power between the main AC connection and the DC connection may pass the intermediate AC bus. In this way, the power conversion of the power
converter assembly can be controlled by controlling the voltage of the intermediate AC bus. For example, when in use, the voltage of the intermediate AC bus may be used to control the voltage on the DC connection.

In one embodiment, the voltage of the intermediate AC bus can be controlled to control the voltage on the DC connection. For example, this can be achieved by controlling the at least one voltage transformers. Each one of the at least one converter transformer may be a fixed voltage transformer. In this context a fixed voltage transformer is to be interpreted as a transformer with a fixed turns ratio between the primary and secondary side. A fixed voltage transformer is smaller and easier to transport, compared to a variable voltage transformer.

The power converter assembly according to claim 1, further comprising at least one combined transformer connected one side to one of the converter devices and arranged to be connected on the other side to a main AC connection.

The magnitude of the DC offset of any converter devices connected to the at least one combined transformer is lower than of any converter devices connected to the at least one transformer. In this way, for low DC offsets where voltage conversion requirements are lower, a combined transformer can be provided. Since the voltage conversion requirements are lower, a relatively small combined transformer can still be provided.

The number of converter transformers may be equal to the number of converter devices. This provides for a consistent topology which can be easier to maintain and repair.

The number of voltage transformers may differ from the number of converter transformers.
Each one of the converter devices may be a power converter for converting in at least either direction between alternating current, AC, and direct current, DC.

The number of voltage transformers may be equal to the number of converter transformers. This allows for fault isolation, where e.g. a failed converter transformer can be isolated from other converter transformers, where the other converter transformers can then continue to operate with their respective corresponding voltage transformer.

The number of voltage transformers may be lower than the number of converter transformers. This can be a more cost effective alternative. For example, there can be only one voltage transformer between the intermediate AC bus and the main AC bus.

The converter devices may be connected in series between a positive terminal of the DC connection and a negative terminal of the DC connection.

Each converter device may be connected to the intermediate AC bus via a respective converter transformer.

The voltage transformation of each one of the voltage transformers is greater than the voltage transformation of each one of the converter transformers. This reduces the size of the converter transformers, which can then be provided and transported assembled to the converter devices.

The converter devices and the at least one converter transformer may be contained in a single housing.

According to a second aspect, it is provided a power converter comprising a plurality of power converter assemblies according to any one of the preceding claims, wherein the power converter assemblies are connected to the same DC connection but different respective main AC connections, wherein the different respective main AC connections are different phases.
Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The invention is now described, by way of example, with reference to the accompanying drawings, in which:

Fig 1 is a schematic diagram showing a power converter assembly according to one embodiment;

Fig 2 is a schematic diagram showing a power converter assembly according to another embodiment;

Fig 3 is a schematic diagram showing a power converter assembly according to another embodiment; and

Fig 4 is a schematic diagram of a multi phase power converter for converting between DC and AC.

**DETAILED DESCRIPTION**

The invention will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout the description.
Fig 1 is a schematic diagram showing a power converter assembly 1 according to one embodiment. The power converter assembly 1, or at least part of it, is also known as a converter station. The purpose of the power converter assembly 1 is to convert power between a high voltage main AC connection AC, and a high voltage DC (HVDC) connection DC. The power converter assembly 1 could be capable of only unidirectional power conversion in either direction or optionally bidirectional power conversion.

There are one or more filters 8a-b connected to the main AC bus AC, to reduce harmonics and/or reduce inductive effects of the power converter assembly 1. There is further an intermediate AC bus AC2. There are one or more filters 9a-b also connected to the intermediate AC bus AC2. The voltage on the main AC bus AC, is higher than the voltage on the intermediate AC bus AC2. For example, the voltage on the intermediate bus AC2 in one example is between 50 and 300 kV and the voltage on the main AC bus AC, is 500 to 1500 kV. In one more specific, non-limiting example, the voltage on the intermediate bus is 245 kV and the voltage on the main AC bus is 1000 kV.

On the DC side, there are a first converter device 2a, a second converter device 2b, a third converter device 2c, and a fourth converter device 2d, connected in series between a positive terminal (DC+) of the DC connection and a negative terminal (DC-) of the DC connection. Each power converter device 2a-d can be a voltage source converter or a current source converter, which are both known in the art per se. Being serially connected between the terminals of the DC connection, each converter device 2a-d has a different DC offset. The middle point of the string of converter devices, in this example the point between the second and third converter devices 2b-c, can be grounded in the case of a symmetrical DC connection. While the power converter assembly 1 is here shown with four converter devices, the power converter assembly can be provided with any suitable number of converter devices.

A converter transformer 5a is provided between an AC side of the first converter device 2a and the intermediate AC bus AC2. Analogously, another converter transformer 5b is provided between the fourth converter device 2d...
and the intermediate AC bus AC\textsubscript{2}. The converter transformers 5a-b are fixed voltage transformers to keep any size and weight requirements for these low.

The intermediate bus AC\textsubscript{2} is connected to the main AC bus AC\textsubscript{1} via two voltage transformers 6a-b. While this embodiment is shown with two voltage transformers 6a-b, any number of voltage transformers can be provided, including one, three, four, etc. The voltage transformers 6a-b are here shown as variable voltage transformers but they could optionally be fixed voltage transformers.

The second converter device 2b is connected via a combined transformer 7a to the main AC bus AC\textsubscript{1}, without passing via the intermediate AC bus AC\textsubscript{2}. Analogously, the third converter device 2c is connected via a combined transformer 7b to the main AC bus AC\textsubscript{1}, without passing via the intermediate AC bus AC\textsubscript{2}. The combined transformers 7a-b are here shown as variable voltage transformers but they could optionally be fixed voltage transformers.

With the provided structure, the outer converter devices, i.e. the first and the fourth converter devices, 2a, d are connected via two transformers each to the main AC bus AC\textsubscript{1}. In this way, the converter transformers 5a-b are only responsible for DC isolation, which prevents conflicts between the first and fourth converter devices 2a, d being on different DC offsets. The two voltage transformers 6a, b are then responsible for voltage conversion between the intermediate AC bus AC\textsubscript{2} and the main AC bus AC\textsubscript{1}, relieving this task from the converter transformers.

The two inner converter devices, i.e. the second and third converter devices, 2b-c do not need the same extent of voltage conversion as the outer converter devices since the magnitude of the DC offset for these two converter devices 2b-c is lower. Hence, the voltage conversion from the inner converter devices 2b-c to the main AC bus can be achieved with combined transformers 7a-b with lower requirements on voltage conversion than is the case for the outer converter devices.
By dividing the transformers for the outer converter devices in two and only requiring DC isolation from the converter transforms 5a-b, the converter transformers 5a-b can be made much smaller. The voltage transformers 6a-b, which can be provided externally to the rest of the converter station, on the other hand, can be larger without affecting the transport of the rest of the converter station. In this way, the ability to transport of the converter station from factory to installation site is significantly improved.

In one example, the converter station comprises the converter devices 2a-d, the converter transformers and the intermediate AC bus AC₂. Optionally, the combined transformers and/or intermediate bus filters 9a-b are included in the converter station.

Also, by providing filters 9a-b connected to the intermediate AC bus AC₂, less filtering is required by the filters 8a-b on the main AC bus AC₁. This reduces complexity and cost, since filtering at the significantly higher voltage of the main AC bus AC₁ is more expensive and more complicated.

Also, using the intermediate AC bus AC₂, the design of the converter transformers 5a-b can be standardised, since only the voltage transformers need to be customised for voltage transformation to an appropriate voltage on the main AC bus AC₁.

Fig 2 is a schematic diagram showing a power converter assembly 1 according to another embodiment. This embodiment is similar to the embodiment of Fig 1. Here, however, all converter devices 2a-d are connected to the intermediate AC bus AC₂ via respective converter transformers 5a-d.

Furthermore, in this embodiment, the number of voltage transformers 6a-d is equal to the number of converter transformers 5a-d. In this way, there is no need for any combined transformers, as shown in Fig 1. Moreover, the voltage transformation of the power converter assembly 1 can be controlled by controlling the voltage transformers 6a-d and thus the voltage on the intermediate AC bus AC₂.
Fig 3 is a schematic diagram showing a power converter assembly according to another embodiment. This embodiment is similar to the embodiment of Fig 2. Here, however, only one voltage transformer 6a is provided for voltage transformation between the intermediate AC bus \( AC_2 \) and the main AC bus \( AC_1 \).

Fig 4 is a schematic diagram of a multi phase power converter 10 for converting between DC and AC. In this example, the multi phase power converter 10 is a three phase power converter and thus comprises three power converter assemblies la-c, as described above. In this way, the AC connection here comprises three phase terminals ACLA, ACIB, ACIC to be able to provide a three phase connection, e.g. to an AC grid, an AC power source or an AC power load. Optionally, an AC ground terminal AC0 is also provided (not shown). The multi phase power converter 10 can be configured for any number of suitable phases by providing the same number of power converter assemblies as the number of phases which are desired to support.

The invention has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the invention, as defined by the appended patent claims.
CLAIMS

1. A power converter assembly (l) arranged to convert power between alternating current, AC, on a main AC connection (AC₁) and direct current, DC, on a DC connection (DC), the power converter assembly (l) comprising:
   a plurality of converter devices (2a-d);
   at least one converter transformer (sa-d) connected between one of the converter devices (2a, 2d) and an intermediate AC bus (AC₂), respectively;
   at least one voltage transformers (6a-b) connected on one side to the intermediate bus (AC₂) and arranged to be connected on the other side to a main AC connection (AC₁).

2. The power converter assembly (l) according to claim 1, wherein all power between the main AC connection (AC₁) and the DC connection (DC) passes the intermediate AC bus (AC₂).

3. The power assembly (l) according to claim 2, wherein, in use, the voltage of the intermediate AC bus (AC₂) is used to control the voltage on the DC connection.

4. The power converter assembly (l) according to any one of the preceding claims, wherein each one of the at least one converter transformer (sa-d) is a fixed voltage transformer.

5. The power converter assembly (l) according to claim 1 or 4, further comprising at least one combined transformer (7a-b) connected one side to one of the converter devices, respectively, and arranged to be connected on the other side to a main AC connection (AC₁).

6. The power converter assembly (l) according to claim 5, wherein the magnitude of the DC offset of any converter devices connected to the at least one combined transformer (7a-b) is lower than of any converter devices connected to the at least one converter transformer (sa-b).
7. The power converter assembly (1) according to any one of claims 1 to 4, wherein the number of converter transformers (sa-d) is equal to the number of converter devices (2a-d).

8. The power converter assembly (1) according to any one of the preceding claims, wherein the number of voltage transformers (6a-b) differs from the number of converter transformers (sa-d).

9. The power converter assembly (1) according to any one of the preceding claims, wherein each one of the converter devices (2a-d) is a power converter for converting in at least either direction between alternating current, AC, and direct current, DC.

10. The power converter assembly (1) according to any one of the preceding claims, wherein the number of voltage transformers (6a-d) is equal to the number of converter transformers (sa-d).

11. The power converter assembly (1) according to any one of the preceding claims, wherein the number of voltage transformers (6a-b) is lower than the number of converter transformers (sa-d).

12. The power converter assembly (1) according to any one of the preceding claims, wherein the converter devices (2a-d) are connected in series between a positive terminal (DC+) of the DC connection and a negative terminal (DC-) of the DC connection.

13. The power converter assembly (1) according to any one of the preceding claims, wherein each converter device (2a-d) is connected to the intermediate AC bus (AC₂) via a respective converter transformer (sa-d).

14. The power converter assembly (1) according to any one of the preceding claims, wherein the voltage transformation of each one of the voltage transformers (6a-d) is greater than the voltage transformation of each one of the converter transformers (sa-d).
15. The power converter assembly (1) according to any one of the preceding claims, wherein the converter devices (2a-d) and the at least one converter transformer (sa-d) are contained in a single housing.

16. A multi phase power converter (10) comprising a plurality of power converter assemblies (1) according to any one of the preceding claims, wherein the power converter assemblies are connected to the same DC connection but different respective main AC connections, wherein the different respective main AC connections are different phases.
Fig. 2
## A. Classification of Subject Matter

**INV. H02M7/10**

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

**ADD.**

### B. Fields Searched

Minimum documentation searched (classification system followed by classification symbols)

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**EPO-Internal, WPI Data**

### C. Documents Considered to Be Relevant

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**X** Further documents are listed in the continuation of Box C.  

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