

(43) International Publication Date
2 October 2014 (02.10.2014)

- (51) **International Patent Classification:**
H02M 7/487 (2007.01) *H02M 7/49* (2007.01)
- (21) **International Application Number:**
PCT/EP2013/056556
- (22) **International Filing Date:**
27 March 2013 (27.03.2013)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
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- (81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,

DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— of inventorship (Rule 4.17(iv))

Published:

— with international search report (Art. 21(3))

(54) **Title:** HYBRID POWER CONVERTER WITH MODULAR MULTILEVEL STRINGS (M2LC) IN NEUTRAL POINT CLAMPING TOPOLOGY

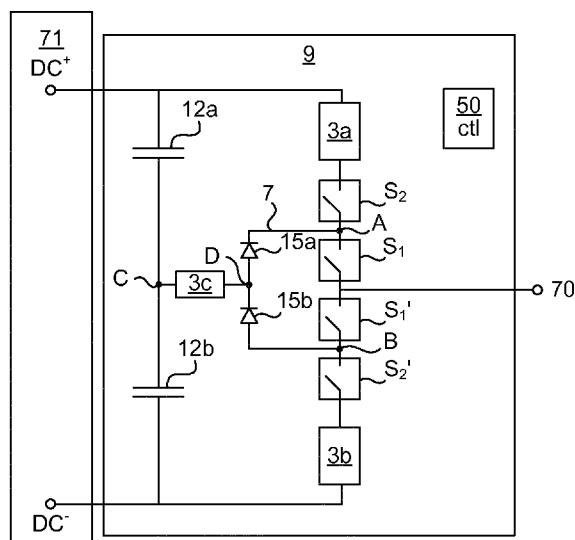


Fig. 3

(57) **Abstract:** It is presented power converter (1) for transferring power between a high voltage DC connection (71) and a high voltage AC connection (70, 70a-c). The power converter (1) comprises a power converter assembly (9) comprising: an upper converter arm (3a), an outer upper director switch (S2), an inner upper director switch (S1), an inner lower director switch (S1'), an outer lower director switch (S2'), and a lower converter arm (3b), connected serially in the mentioned order between the positive and negative terminals of the DC connection (71); and a clamping link (7) comprising at least one centre converter arm (3c, 3d, 3e). A midpoint (D) of the clamping link (7) is connected to a neutral point (C).

HYBRID POWER CONVERTER WITH MODULAR MULTILEVEL STRINGS (M2LC) IN NEUTRAL POINT CLAMPING TOPOLOGY

TECHNICAL FIELD

The invention relates to a power converter for converting power between a high voltage DC (Direct Current) connection and a high voltage AC
5 (Alternating Current) connection.

BACKGROUND

High voltage power conversion between DC and AC are known in the art for a variety of different applications. One such application is for links related to HVDC (high voltage DC).

10 WO 2010149200 presents a voltage source converter for use in high voltage DC power transmission and reactive power compensation. The voltage source converter comprises at least one converter limb including first and second DC terminals for connection in use to a DC network and an AC terminal for connection in use to an AC network. The or each converter limb defines first
15 and second limb portions, each limb portion including at least one switching element connected in series with a chain-link converter between a respective one of the first and second DC terminals and the AC terminal. The switching elements of the first and second limb portions is operable to switch the respective chain-link converters in and out of circuit between the respective
20 DC terminal and the AC terminal. The chain-link converters are operable to generate a voltage waveform at the AC terminal.

However, it would be advantageous to achieve an AC/DC converter for high voltage use which provides more efficient switching.

SUMMARY

25 An object of embodiments herein is to achieve more flexible switching.

According to a first aspect, it is presented a power converter for transferring power between a high voltage DC connection and a high voltage AC connection. The power converter comprises a power converter assembly comprising: an upper converter arm, an outer upper director switch, an inner

upper director switch, an inner lower director switch, an outer lower director switch, and a lower converter arm, connected serially in the mentioned order between the positive and negative terminals of the DC connection; and a clamping link comprising at least one centre converter arm, the clamping link
5 being arranged between an upper point and a lower point, the upper point being provided between the outer upper director switch and the inner upper director switch, and the lower point being provided between the inner lower and the outer lower director switch, wherein a mid point of the clamping link is connected to a neutral point. The high voltage AC connection is provided
10 between the inner upper director switch and the inner lower director switch. Each one of the converter arms comprises a plurality of converter cells and each one of the converter cells comprises a switching element and an energy storage element. With this arrangement, the clamping link can generate a voltage corresponding to the voltage of the upper and lower converter arms,
15 when switching to the upper and lower converter arms, respectively. In this way, the voltage across director switches during switching is zero, whereby switching losses are greatly reduced or even negligible. Through this zero voltage switching, great flexibility of when to switch is achieved, allowing better control of AC side voltage amplitude. Moreover, this flexibility can also
20 be used to control the timing difference between voltage and current to thereby control reactive power flow to and from the high voltage AC connection.

The at least one centre converter arms may be of a type which is capable of both positive and negative voltage output.

25 The power converter may further comprise a controller configured to, prior to switching any one of the director switches, control converter arms on either side of the director switch to be switched such that the voltage across the director switch to be switched is negligible. Negligible is here to be construed as a voltage which is very small in magnitude compared to the voltages of the
30 DC and/or AC connections. For example, the negligible voltage can be in the order of less than one hundredth or even less than one thousandth of the voltage across the DC connection. In any situation, the negligible voltage

allows the switching of the director switch to be switched to occur with low switching losses.

The converter arms on either side of the director switch to be switched may comprise one of the at least one centre converter arm. In other words, the
5 converter arms on either side of the director switch to be switched may comprise a centre converter arm and the upper converter arm, a centre converter arm and the lower converter arm or two centre converter arms.

Each one of the director switches may comprise a switching element and a diode. This is a relatively simple and sufficient structure for the director
10 switches.

The switching element of each one of the director switches may be a thyristor. Alternatively, the switching element of each one of the director switches may be a transistor.

Each one of the director switches may omit any energy storage element. In
15 other words, it is not necessary to include any energy storage elements (such as capacitors) in the director switches.

The power converter may further comprise two DC side capacitors serially arranged between the positive and negative terminals of the DC connection. In such a case, the neutral point is provided between the two DC side
20 capacitors.

The clamping link may comprise two serially connected clamping diodes and the power converter assembly may comprise a centre converter arm connected between the mid point of the clamping link between the two serially connected clamping diodes and the neutral point.

25 The clamping link may comprise an upper centre converter arm serially connected to a lower centre converter arm. In such a case, the mid point is provided at a point between the upper centre converter arm and a lower centre converter arm.

Each one of the converter arms may comprise at least one full bridge converter cell. This is one way to achieve four quadrant conversion.

Each one of the converter arms may comprise at least one half bridge converter cell.

- 5 All converter cells may be full bridge converter cells.

All converter cells may be half bridge converter cells.

The power converter may comprise three of the power converter assemblies for connection between a common high voltage DC connection and a three phase high voltage AC connection.

- 10 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
15 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:

- 20 Fig 1 is a schematic diagram of a power converter for converting between DC and AC;

Fig 2 is a schematic diagram of a three phase power converter for converting between DC and AC;

- 25 Fig 3 is a schematic diagram of a first embodiment of a power converter assembly of Figs 1-2;

Fig 4 is a schematic diagram of a second embodiment of the power converter assembly of Figs 1-2;

Figs 5A-B are schematic diagrams illustrating embodiments of the director switches of Figs 3-4;

Fig 6 is a schematic diagram illustrating possible converter cell arrangements of converter arms of Figs 3-4;

- 5 Figs 7A-C are schematic diagrams illustrating embodiments of converter cells of the converter arm of Fig 6; and

Fig 8 is a schematic graph illustrating operation of the power converter assembly of Figs 3-4.

DETAILED DESCRIPTION

- 10 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
15 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 of a power converter 1 for converting between DC and AC. The power converter 1 converts power in either direction between
20 a high voltage DC connection and a high voltage AC connection. The high voltage DC connection 71 comprises a positive terminal DC⁺ and a negative terminal DC⁻. The high voltage AC connection comprises a phase terminal 70 and an AC ground terminal (not shown). Power can flow from DC to AC or vice versa. The power converter 1 comprises a power converter assembly 9
25 which performs the actual power conversion. This division between the power converter 1 and the power converter assembly does not need to be represented by physical objects, whereby the power converter 1 and the power converter assembly 9 can in practice be the same device.

Fig 2 is a schematic diagram of a three phase power converter 1 for converting between DC and AC. The three phase power converter 1 here comprises three power converter assemblies 9a-c. In this way, the AC connection here comprises three phase terminals AC_1 , AC_2 and AC_3 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 AC_0 is also provided (not shown).

Fig 3 is a schematic diagram of a first embodiment of a power converter assembly 9 which may be used to implement any of the power converter assemblies, 9, 9a, 9b and 9c of Figs 1-2. The power converter assembly 9 comprises an upper converter arm 3a, an outer upper director switch S2, an inner upper director switch S1, an inner lower director switch S1', an outer lower director switch S2', and a lower converter arm 3b, connected serially in the mentioned order between the positive and negative terminals DC^+ , DC^- of the DC connection 71. Positive and negative are here to be interpreted as relative terms and not absolute. For example, the positive terminal or the negative terminal could be at ground potential. The voltage difference between the positive and negative terminals DC^+ , DC^- is here denoted $2U$.

The high voltage AC connection 70 is provided between the inner upper director switch S1 and the inner lower director switch S1'.

Two DC side capacitors 12a-b are serially arranged between the positive and negative terminals DC^+ , DC^- of the DC connection 71 to allow an AC current to circulate with minimal effect on the DC terminals DC^+ , DC^- . A neutral point C is provided between the two DC side capacitors 12a-b.

Furthermore, a clamping link 7 is arranged between an upper point A and a lower point B to achieve a type of neutral point clamped (NPC) structure. The upper point A is provided between the outer upper director switch S2 and the inner upper director switch S1, and the lower point B is provided between the inner lower S1' and the outer lower director switch S2'. A mid point D of the clamping link 7 is connected to the neutral point C. It is to be noted that the

mid point D is a logical mid point, i.e. in relation to the components of the clamping link. In general, the mid point D corresponds to a potential mid point of the clamping link 7. In other words, the mid point D does not need to be physically in the middle of the clamping link 7. The clamping link 7
5 provides the ability to synthesise multiple voltage levels between the upper and lower converter arms 3a, 3b using the director switches S1, S2, S1', S2', the significance of which will be explained in more detail below with reference to Fig 8.

In this embodiment, the clamping link 7 comprises a first clamping diode 15a
10 and a second clamping diode 15b, serially arranged between the lower point B and the upper point A. A centre converter arm 3c is connected between the mid point D of the clamping link 7 and the neutral point C. When the inner upper director switch S1 and the inner lower director switch S1' are in a conducting state, this effectively connects the centre converter arm 3c to the
15 high voltage AC connection AC, allowing the centre converter arm 3c to control the voltage on the high voltage AC connection.

As will be shown in more detail below with reference to Fig 6, each one of the converter arms 3a-c comprises a plurality of converter cells. The converter cells can be individually controlled to achieve a finer granularity in the
20 conversion, e.g. to achieve a more sinusoidal (or square, saw tooth shaped, etc.) power conversion. A controller 50 controls the operation of the converter arms 3a-c and the director switches S1, S2, S1', S2'. The controller 50 can be a single controller or divided into a central controller and local controllers for each converter arm 3a-c and/or converter cell. While the
25 controller 50 is here shown as being part of the power converter assembly 9, part or all of the controller 50 may also be provided externally to the power converter assembly, but still part of any encompassing power converter 1 (see Figs 1-2).

Fig 4 is a schematic diagram of a second example embodiment of the power
30 converter assemblies, 9, 9a, 9b and 9c of Figs 1-2. This embodiment is similar to the embodiment shown in Fig 3 and only those elements that differ will be

described. Here, the clamping link 7 comprises an upper centre converter arm 3d serially connected to a lower centre converter arm 3e. The upper centre converter arm 3d and the lower centre converter arm 3e are of the same type as the centre converter arm 3c of Fig 3. The logical mid point D is
5 here provided at a point between the upper centre converter arm 3d and a lower centre converter arm 3e. In this embodiment, the logical mid point D is directly connected to the neutral point C. The lower and upper centre converter arms 3d-3e provide the controllability of the AC voltage in analogy with the centre converter arm 3c of the embodiment shown in Fig 3.

10 Figs 5A-B are schematic diagrams illustrating alternative embodiments of the director switches of Figs 3-4. Either one of the director switches S1, S2, S1', S2' is here represented as a director switch S. In Fig 5A, the director switch S comprises a transistor 26 and an antiparallel diode 60. The transistor 26 is any suitable high power transistor, e.g. an IGBT (Insulated Gate Bipolar
15 Transistor) or power FET (Field Effect Transistor). The transistor operation is controlled by a controller 50 according to what is shown in Fig 8 and explained in more detail below.

In Fig 5B, the switching element of the director switch S is implemented using a thyristor 21 and an antiparallel diode 61. The thyristor 21 can be any
20 type of suitable high power semiconductor of thyristor type, such as an Integrated Gate-Commutated Thyristor (IGCT), or a Gate Turn-Off thyristor (GTO). The thyristor 21 is controlled by the controller 50 according to what is shown in Fig 8 and explained in more detail below.

Fig 6 is a schematic diagram illustrating possible converter cell arrangements
25 of converter arms of Figs 3-4. Fig 6 illustrates the structure of any one of the converter arms 3a-e, here represented by a single converter arm 3. The converter arm 3 is a multi level converter and comprises a plurality of converter cells 32a-d, wherein each converter cell 32a-d is controlled by the controller 50.

The converter cells 32a-d can be connected in series to increase voltage rating or in parallel to increase current rating. The serially connected converter cells 32a-d can be individually controlled to achieve a finer granularity in the conversion, e.g. to achieve a more sinusoidal (or square, saw tooth shaped, etc.) power conversion. Also, by controlling the serially connected converter cells in this way, the switching frequency of each converter cell is relatively low, which results in low switching losses when compared to higher switching frequencies. While the converter arm 3 is here illustrated to have four converter cells 32a-d, any number of converter cells is possible, including one, two, three or more. In one embodiment, the number of converter cells in each converter arm 3 is in the range from 30 to 1000 converter cells.

Optionally, a smoothing inductor 33 is serially provided in the converter arm 3 to provide a smoother current

Figs 7A-C are schematic diagrams illustrating embodiments of converter cells 32a-d of the converter arm of Fig 6. Any one of the converter cells 32a-d is here represented as a single converter cell 32. A converter cell 32 is a combination of one or more semiconductor switching elements, such as transistors or thyristors, and one or more energy storing elements 41, such as capacitors, supercapacitors, inductors, batteries, flywheels etc. Optionally, a converter cell can be a multilevel converter structure in itself, such as a flying capacitor or MPC (Multi-Point-Clamped) or ANPC (Active – Neutral-Point-Clamped) multilevel structure.

Fig 7A illustrates a converter cell comprising an active component in the form of a switching element 40 and an energy storage element 41 in the form of a capacitor. The switching element 40 can for example be implemented using an insulated gate bipolar transistor (IGBT), Integrated Gate-Commutated Thyristor (IGCT), a Gate Turn-Off thyristor (GTO), or any other suitable high power semiconductor component. In fact, the converter cell 32 of Fig 7A can be considered to be a more general representation of the converter cell shown in Fig 7B, which will be described here next.

Fig 7B illustrates a converter cell 32 implementing a half bridge structure. The converter cell 32 here comprises a leg of two serially connected active components in the form of switching elements 40a-b, e.g. IGBTs, IGCTs, GTOs, etc. Optionally, there is an antiparallel diode connected across each switching element 40a-b (not shown). An energy storage element 41 is also provided in parallel with the leg of switching elements 40a-b. The voltage synthesised by the converter cell can thus either be zero or the voltage of the energy storage element 41.

Fig 7C illustrates a converter cell 32 implementing a full bridge structure. The converter cell 32 here comprises four switching elements 40a-d, e.g. IGBTs, IGCTs, GTOs, etc. Optionally, there is an antiparallel diode connected across each switching element 40a-d (not shown). An energy storage element 41 is also provided in parallel across a first leg of two switching elements 40a-b and a second leg of two switching elements 40c-d. Compared to the half bridge of Fig 7B, the full bridge structure allows the synthesis of a voltage capable of assuming both signs, whereby the voltage of the converter cell can either be zero, the voltage of the energy storage element 41, or a reversed voltage of the energy storage element 41.

Fig 8 is a schematic graph illustrating the operation of the power converter assembly 9 of Figs 3-4. Time flows along the horizontal axis from left to right and the vertical axis represents voltage. The straight line indicates a director switch voltage 62 resulting from the operation of the director switches. In other words, the director switches are used to connect the upper, centre, or lower converter arms to provide a resulting voltage 65, which can be sinusoidal as shown in Fig 8.

In other words, by controlling the director switches at various points in time t_1 - t_7 , the director switch state is changed, resulting in DC bias variations which provide a basic approximation of the sinusoidal resulting voltage 65. This relieves the converter arms 3a-e of handling the entire voltage span (from ground). The sinusoidal resulting voltage 65 is subsequently achieved by superimposing the effects of the converter arms 3a-e.

One example of director switch states for the director switches S_1 - S_2 , S_1' - S_2' is shown in Table 1 below, where a '0' represents a blocking state and '1' represents a conducting state:

State id	S_1	S_2	S_1'	S_2'	Active converter arm(s)	Resulting voltage
I	1	0	1	0	Centre	Positive cycle $< U/2$
II	1	1	0	0	Upper	Positive cycle $> U/2$
III	1	0	1	0	Centre	Negative cycle $> -U/2$
IV	0	0	1	1	Lower	Negative cycle $< -U/2$

Table 1: example of a switching scheme for the director switches

- 5 Looking to Fig 8 again, the switching schedule of states is there I-II-I-III-IV-III, using the state id column from Table 1. Significantly, switching of the director switches S_1 - S_2 , S_1' - S_2' can then occur under zero voltage, which will now be explained in some detail. Zero voltage is here to be interpreted as negligible voltage, where switching losses are low in the director switch in question during switching.

In state I between times t_1 and t_2 , the centre converter arm(s) is active to gradually increase the resulting voltage 65 from zero to $U/2$. This implies that the centre converter arm(s) generate a positive voltage during this state.

- 15 In the transition from state I to state II, the changes are that the outer upper director switch S_2 is made to conduct and the inner lower director switch S_1' is made to block. The centre and lower converter arms are controlled such that there is no voltage over the inner lower director switch S_1' . Also, the centre and upper converter arms are controlled to be at the same voltage during the switching, whereby there is no voltage over the outer upper switch 20 S_2 , allowing zero voltage switching of both S_1' and S_2 .

In state II, the upper converter arm is active, first generating a negative voltage to meet the $U/2$ voltage at time t_2 . Over time, the converter arm increases its output to a positive voltage (representing the peak of the sinus wave), and then gradually decreases to a negative voltage such that the
5 resulting voltage 65 is again $U/2$ at time t_3 .

In the transition from state II to state I, the changes are that the outer upper director switch S2 is made to block and the inner lower director switch S1' is made to conduct. In analogy with the transition from I to II, the centre and lower converter arms are controlled such that there is no voltage over the
10 inner lower director switch S1'. Moreover, the centre and upper converter arms can be controlled to be at the same voltage during the switching, whereby there is no voltage over the outer upper switch S2, allowing zero voltage switching of both S1' and S2.

In state I from time t_3 to t_4 , the centre converter arm(s) is active to gradually
15 decrease the resulting voltage 65 from $U/2$ to zero. This implies that the centre converter arm(s) generate a positive voltage during this state.

In the transition from state I to state III, there is no change in the director switches and the voltage is controlled by the centre converter arm(s).

In state III between times t_3 and t_4 , the centre converter arm(s) is active to
20 gradually decrease the resulting voltage 65 from zero to $-U/2$. This implies that the centre converter arm(s) generate a negative voltage during this state.

In the transition from state III to state IV, the changes are that the outer lower director switch S2' is made to conduct and the inner upper director switch S1 is made to block. The centre and upper converter arms are
25 controlled such that there is no voltage over the inner upper director switch S1. Moreover, the centre and lower converter arms can be controlled to be at the same voltage during the switching, whereby there is no voltage over the outer lower switch S2', allowing zero voltage switching of both S1 and S2'.

In state IV, the lower converter arm is active, first generating a positive voltage to meet the $-U/2$ voltage at time t_5 . Over time, the lower converter arm decreases its voltage to a negative voltage (representing the negative peak of the sinus wave), and then gradually increases to a positive voltage
5 such that the resulting voltage 65 is again $-U/2$ at time t_6 .

In the transition from state IV to state III, the changes are that the outer lower director switch $S2'$ is made to block and the inner upper director switch $S1$ is made to conduct. In analogy with the transition from III to IV, the centre and upper converter arms are controlled such that there is no voltage
10 over the inner upper director switch $S1$. Moreover, the centre and lower converter arms can be controlled to be at the same voltage during the switching, whereby there is no voltage over the outer lower switch $S2'$, allowing zero voltage switching of both $S1$ and $S2'$.

In state III between times t_6 and t_7 , the centre converter arm(s) is active to
15 gradually increase the resulting voltage 65 from $-U/2$ to zero. This implies that the centre converter arm(s) generate a negative voltage during this state.

In the transition from state III to state I, there is no change in the director switches and the voltage is controlled by the centre converter arm(s).

Thanks to the zero voltage switching, the timings can be changed. In
20 particular, if the same frequency is to be maintained, the times related to state II and state IV can be adjusted, i.e. times t_2 , t_3 , t_5 and t_6 , to increase or decrease the time in states II and IV. A longer time in states II and IV results in a higher AC voltage and a shorter time in states II and IV results in a lower AC voltage. Hence, by altering these timings, the AC voltage can be adjusted.
25 In one embodiment, it has been found that the AC amplitude can be freely adjusted between 14.6% and 27% of U .

Some balancing is thus required to ensure zero voltage switching to and from states II and IV.

In one embodiment, the upper and lower converter arms 3a-b can be balanced with respect to energy balance e.g. using a series of full bridge converter cells which provide both a positive and negative voltage and are able to reverse the current.

- 5 The centre converter arm(s) 3c-e can also be balanced when there is a small reactive power transfer e.g. using a full bridge structure, which is the case in HVDC where there is often some reactive power transfer during operation.

- When there is a pure active power transfer, the centre converter arm(s) 3c-e can be balanced using other measures. For example, extra converter cells can
10 be added to be able to reverse the current in some of the cells. Also, third harmonics can be injected. Optionally, one or both of the outer director switches S2, S2' can be set to conduct to provide a path from the centre converter arm(s) to the upper and/or lower arm converter arm in order to exchange the energy.

- 15 Furthermore, the DC side capacitors 12a-b can be balanced in any one or more of the following ways:

- Firstly, a small number of extra full bridge cells (not shown) can be added in series with the two DC side capacitors 12a-b so that the neutral point C can be dynamically regulated by charging and/or discharging the extra full bridge
20 cells with positive or negative voltage polarity. Secondly, e.g. with reference to the embodiment shown in Fig 4, the two centre converter arms 3d-e can be combined to the small number of extra full bridge cells at the neutral point C, whereby the centre converter arms 3d-e shape output AC voltages under consideration of the mid point voltage variation.

- 25 Thirdly, the two DC side capacitor 12a-b voltages can be self balanced. This is the case e.g. in the embodiment shown in Fig 4, where the two centre converter arms 3d-e can be active while the AC current flows positively and negatively in a symmetrical fashion.

Ratings of components will be as follows (where pole to pole DC voltage is $2U$). Each one of the upper and lower converter arms need to have a voltage rating of $U/2$. Analogously, the centre converter arm(s) 3c-e need to have a voltage rating of $U/2$. All director switches $S1-S2$, $S1'-S2'$ need to have a
5 voltage rating of $2U/\Pi$ and the clamping diodes need to have a voltage rating of $\left(\frac{4}{\Pi} - \frac{1}{2}\right) * U$. The current rating is the AC current for all components. This rating is low compared to other structures in the prior art, which reduces cost.

The zero voltage switching (i.e. essentially zero voltage over the director
10 switch at the time of switching) of the director switches $S1-S2$, $S1'-S2'$ is a significant improvement over the prior art. This provides a flexibility of timings, since the non-zero voltage results in significant switching losses.

Using this flexibility, the timings $t2$, $t3$ for state II and the timings $t5$, $t6$ for state IV can be adjusted to control the AC side voltage amplitude. This
15 flexibility can also be used to control the timing difference between voltage and current to thereby control reactive power flow to and from the high voltage AC connection.

Moreover, the voltage stress on the director switches is reduced and the number of components in the conduction path is low, which reduces losses.

20 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 (1) for transferring power between a high voltage DC connection (71) and a high voltage AC connection (70, 70a-c), the power converter (1) comprising a power converter assembly (9) comprising:
 - 5 an upper converter arm (3a), an outer upper director switch (S2), an inner upper director switch (S1), an inner lower director switch (S1'), an outer lower director switch (S2'), and a lower converter arm (3b), connected serially in the mentioned order between the positive and negative terminals of the DC connection (71); and
 - 10 a clamping link (7) comprising at least one centre converter arm (3c, 3d, 3e), the clamping link (7) being arranged between an upper point (A) and a lower point (B), the upper point (A) being provided between the outer upper director switch (S2) and the inner upper director switch (S1), and the lower point (B) being provided between the inner lower director switch (S1') and
 - 15 the outer lower director switch (S2'), wherein a mid point (D) of the clamping link (7) is connected to a neutral point (C);
wherein the high voltage AC connection (70, 70a-c) is provided between the inner upper director switch (S1) and the inner lower director switch (S1'); and
 - 20 each one of the converter arms (3a-e) comprises a plurality of converter cells (32a-d, 32) and each one of the converter cells (32a-d, 32) comprises a switching element (40, 40a-d) and an energy storage element (41).
2. The power converter (1) according to claim 1, wherein the at least one centre converter arms is of a type which is capable of both positive and
- 25 negative voltage output.
3. The power converter (1) according to claim 1 or 2, further comprising a controller (50) configured to, prior to switching any one of the director switches, control converter arms (3c, 3d, 3e) on either side of the director switch to be switched such that the voltage across the director switch to be
- 30 switched is negligible.

4. The power converter (1) according to claim 3, wherein the converter arms on either side of the director switch to be switched comprises one of the at least one centre converter arm (3c, 3d, 3e).
5. The power converter (1) according to any one of the preceding claims,
5 wherein each one of the director switches (S1, S2, S1', S2') comprises a switching element (60, 61) and a diode (26).
6. The power converter (1) according to claim 5, wherein the switching element of each one of the director switches is a thyristor (61).
7. The power converter (1) according to claim 5 or 6, wherein each one of
10 the director switches (S1, S2, S1', S2') omits any energy storage element.
8. The power converter (1) according to any one of the preceding claims, further comprising two DC side capacitors (12a-b) serially arranged between the positive and negative terminals (DC⁺, DC⁻) of the DC connection and wherein the neutral point (C) is provided between the two DC side capacitors
15 (12a-b).
9. The power converter (1) according to claim 8, wherein the clamping link (7) comprises two serially connected clamping diodes (15a-b) and wherein the centre converter arm (3c) of the clamping link (7) is connected between the neutral point (C) and the mid point (D) of the clamping link, the mid
20 point (D) being provided between the two serially connected clamping diodes (15a-b).
10. The power converter (1) according to claim 8, wherein the clamping link (7) comprises an upper centre converter arm (3d) serially connected to a lower centre converter arm (3e), and wherein the mid point (D) is provided at
25 a point between the upper centre converter arm (3d) and a lower centre converter arm (3e).
11. The power converter (1) according to any one of the preceding claims, wherein each one of the converter arms comprises at least one full bridge converter cell.

12. The power converter (1) according to any one of the preceding claims,
wherein each one of the converter arms comprises at least one half bridge
converter cell.
13. The power converter (1) according to any one of the preceding claims,
5 wherein all converter cells (32, 32a-d) are full bridge converter cells.
14. The power converter (1) according to any one of the preceding claims,
wherein all converter cells (32, 32a-d) are half bridge converter cells.
15. The power converter (1) according to any one of the preceding claims,
comprising three of the power converter assemblies (9) for connection
10 between a common high voltage DC connection and a three phase high
voltage AC connection (70a-c).

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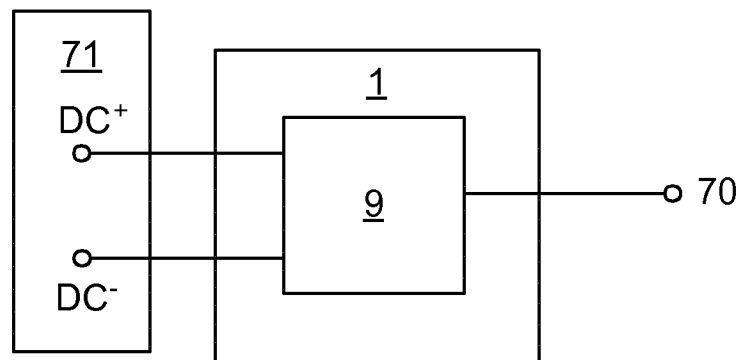


Fig. 1

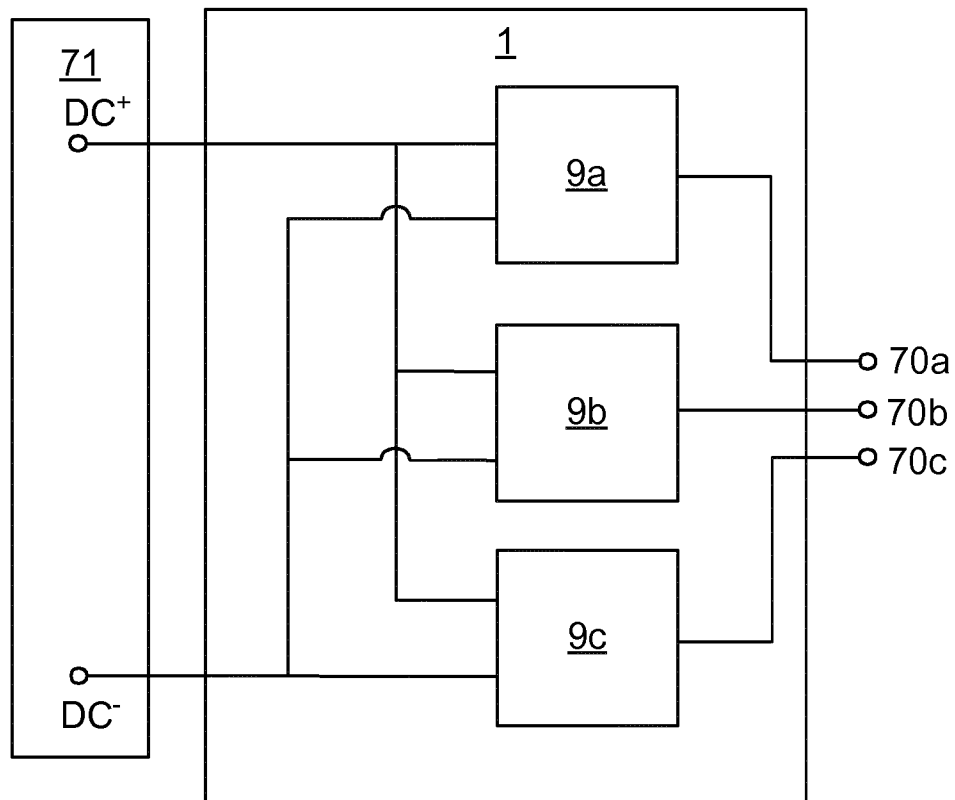


Fig. 2

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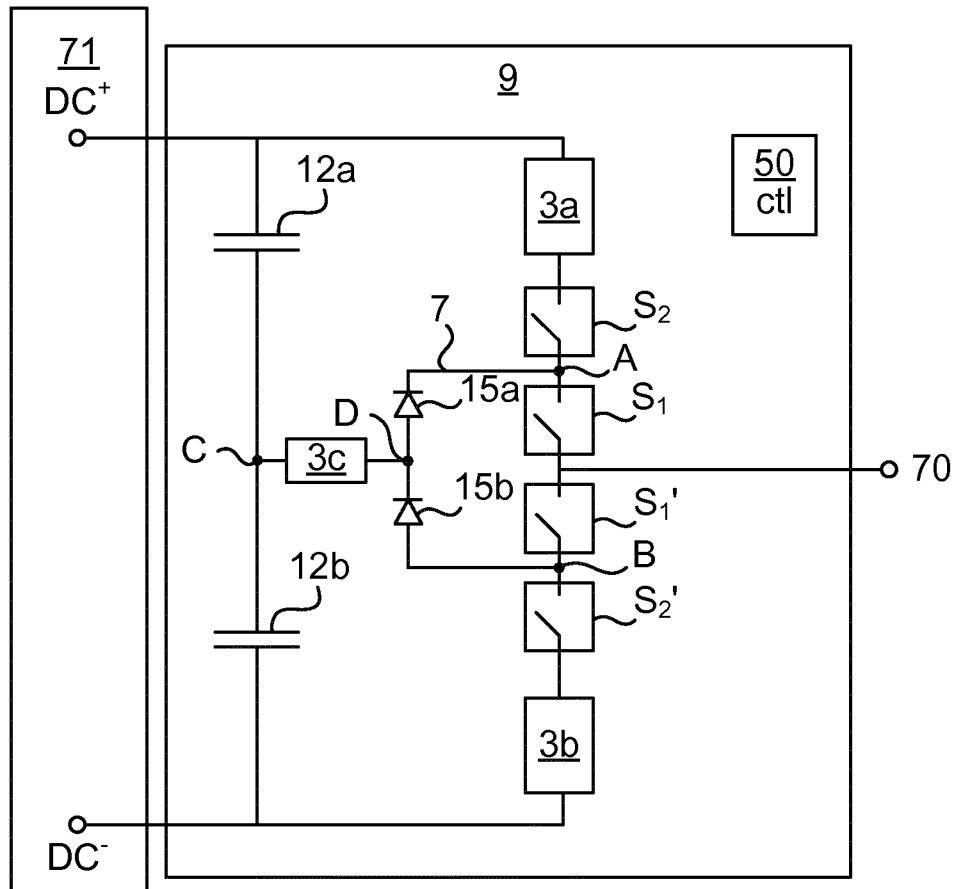


Fig. 3

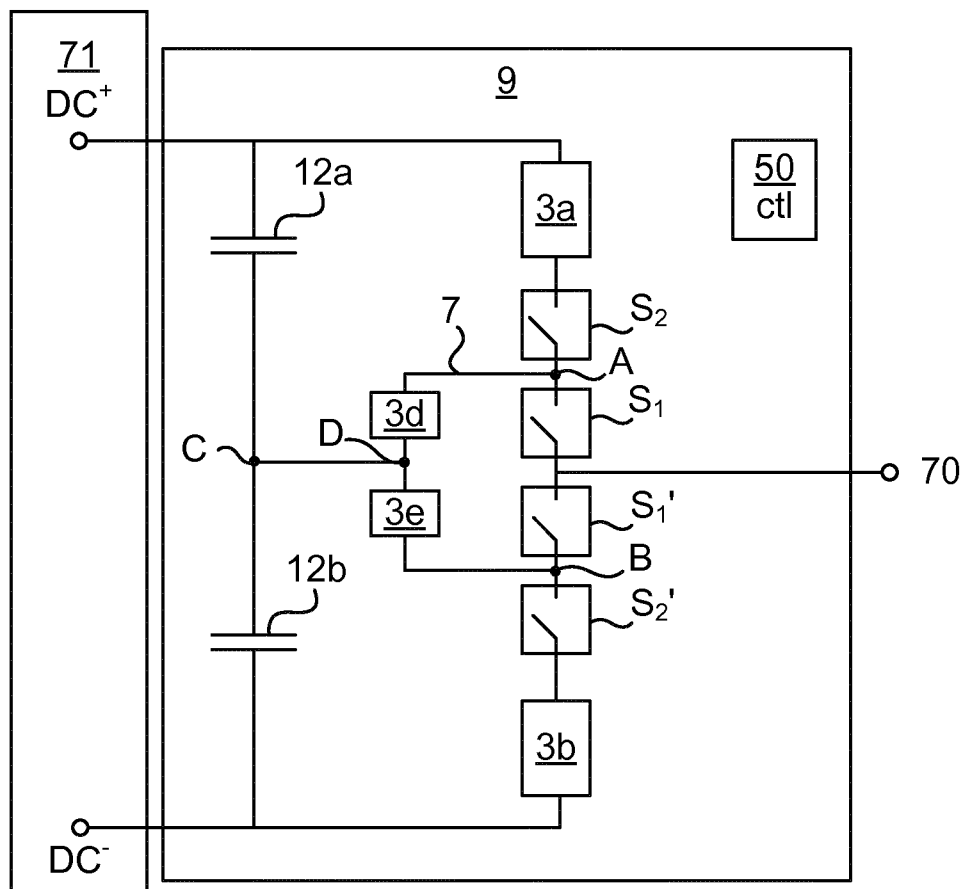


Fig. 4

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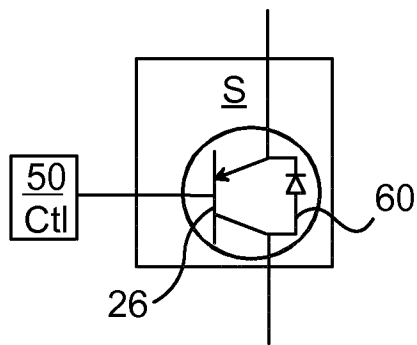


Fig. 5A

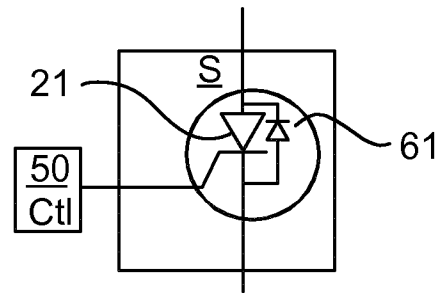


Fig. 5B

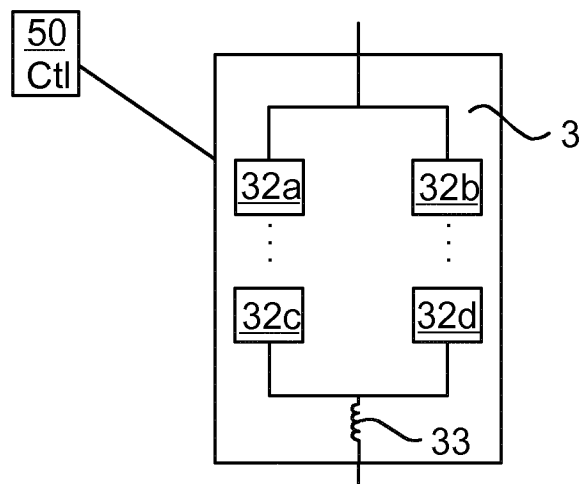


Fig. 6

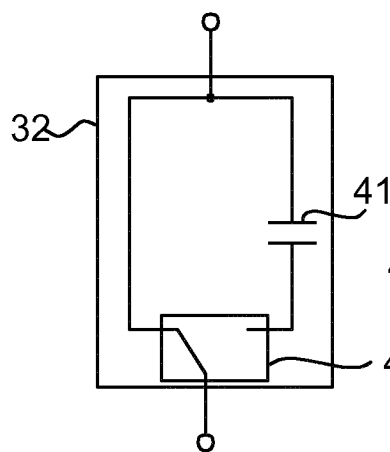


Fig. 7A

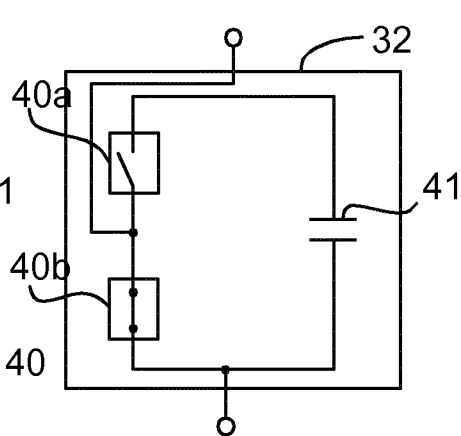


Fig. 7B

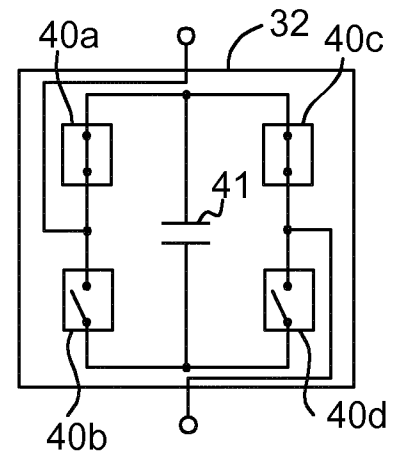


Fig. 7C

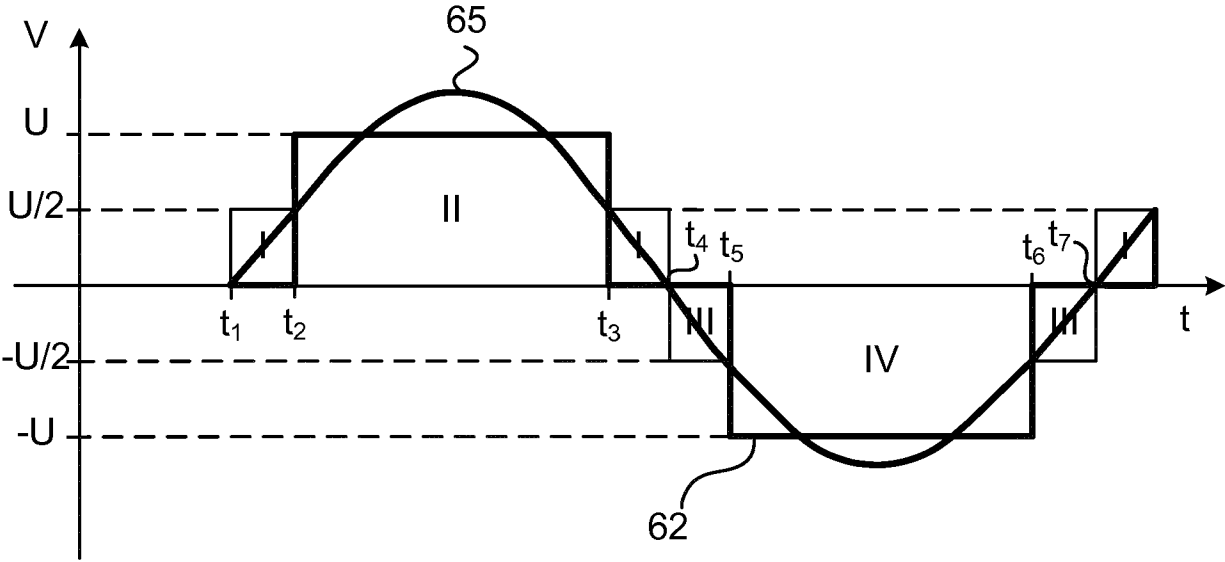


Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/056556

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02M7/487 H02M7/49
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

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, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	WO 2011/012171 A1 (AREVA T & D UK LTD [GB]; CROOKES WILLIAM [GB]; TRAINER DAVID [GB]; OAT) 3 February 2011 (2011-02-03) figures 4b,5a,5b,8 page 1 page 4, lines 3-18 page 6 page 7, lines 14-25 page 8, lines 14-17 page 13, line 8 - page 14, line 5 page 15, line 7 - page 16, line 16 -----	1-9, 11-15 10
Y A	WO 2011/050847 A1 (AREVA T & D UK LTD [GB]; TRAINER DAVID [GB]; CROOKES WILLIAM [GB]; OAT) 5 May 2011 (2011-05-05) figures 2, 7 page 1 page 11, line 10 - page 13, line 26 pages 4,5 -----	1-9, 11-15 10



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

11 November 2013

Date of mailing of the international search report

22/11/2013

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Authorized officer

Kail, Maximilian

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2013/056556

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