(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 December 2020 (30.12.2020)

WIPO | PCT

(10) International Publication Number
WO 2020/259801 A1

(51) International Patent Classification:
H02M 3/158 (2006.01) *H02J 7/35* (2006.01)

(21) International Application Number:
PCT/EP2019/066760

(22) International Filing Date:
25 June 2019 (25.06.2019)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: HUAWEI TECHNOLOGIES CO., LTD. [CN/CN]; Huawei Administration Building Bantian Longgang District, Shenzhen, Guangdong 518129 (CN).

(72) Inventor; and
(71) Applicant *(for US only)*: WIJEKOON, Piniwan Thiwanka Bandara [LK/DE]; Huawei Technologies Duesseldorf GmbH, Riesstr. 25, 80992 Munich (DE).

(74) Agent: KREUZ, Georg; Huawei Technologies Duesseldorf GmbH, Riesstr. 25, 80992 Munich (DE).

(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, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, 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, SA, 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, ST, 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, KM, ML, MR, NE, SN, TD, TG).

(54) Title: A DC-TO-DC POWER CONVERTER

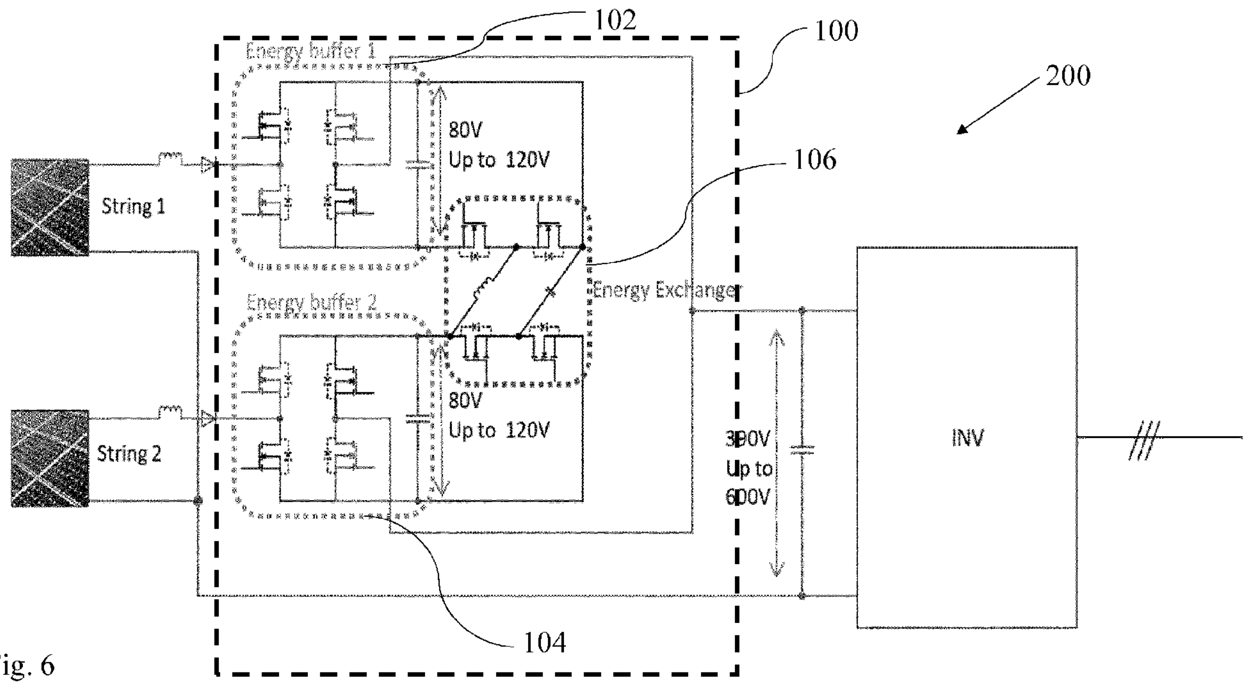

Fig. 6

(57) Abstract: The present invention relates to a DC-to-DC power converter (100), comprising at least two energy buffer units (102, 104), wherein each energy buffer unit (102, 104) is configured to receive a first-type voltage component and to respectively produce a voltage Vb at an output of the DC-to-DC power converter (100), and at least one energy exchanger (106), wherein the at least one energy exchanger (106) is connected to the at least two energy buffer units (102, 104) and is configured to exchange energy between the at least two energy buffer units (102, 104).

WO 2020/259801 A1

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Published:

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

A DC-to-DC POWER CONVERTER

TECHNICAL FIELD

The present invention relates to a DC-to-DC power converter. In particular, the DC-to-DC power converter is for an electrical energy conversion system, which is, for example, configured to convert electrical energy provided by at least one solar panel. The invention also relates to the electrical energy conversion system.

BACKGROUND

Solar photovoltaic (PV) panels (or “solar panels” for short, and also commonly known as “solar modules”) are used to convert solar energy into direct current (DC) power. Because solar panels are a limited source of energy, they behave differently than a conventional DC power supply.

The output voltage from the PV cells that make up a solar panel varies depending on the current being drawn from the panel. The solar panel power (i.e., the product of panel voltage and panel current) is not constant for all combinations of voltages and currents. There is one operating point where the product of the panel voltage and the panel current is highest. This point is called the maximum power point (MPP).

The amount of power, which can be harvested from solar panels, varies in real time as solar panels are exposed to different lighting intensity levels, clouds, or dirt. In addition, solar panels show a tendency to age, which reduces the power-harvesting ability of the panels. The panel performance also depends on operating temperature. These factors cause the MPP to vary over time.

A system or circuit designed to track the MPP in real time is referred to as a MPP tracker (MPPT) or power-point tracker.

In an application, in which the output power of a solar panel is used to store energy in a battery or other storage element, once the MPPT locates the MPP, the output should be translated into a voltage level that matches the battery specifications (or storage element specifications). A system or circuit that performs this translation is referred to as a battery charger. The battery charger ensures that charging requirements of the battery (e.g., as specified in the battery specifications) are met.

The battery nominal voltage requirement can be higher or lower than the MPP voltage of the solar panel (i.e., the output voltage of the solar panel at the MPP) by system design or due to variation of electrical parameters of the solar panel. DC-to-DC conversion is performed to provide the desired charging voltage level for the battery. Buck and/or boost techniques may be used in performing this DC-to-DC conversion. In Fig. 1, an example of such a system comprising a MPPT and a battery is shown.

However, nowadays technologies for such MPPT DC-to-DC converters either use high voltage semiconductor devices or multiple low voltage devices in series or parallel to form the converter circuitry, which in turn increases the cost and reduces reliability. Moreover, these applications need higher efficiency in terms of electrical efficiency (output power vs. input power), weight efficiency (output power vs. weight), and size efficiency (output power vs. size).

Thus, there is a need for an improved DC-to-DC power converter.

SUMMARY

In view of the above-mentioned problems and disadvantages, embodiments of the present invention aim to improve the conventional DC-to-DC power converters and their productions methods. An object is thereby to provide an improved DC-to-DC power converter, in particular for a solar panel system.

The object is achieved by the embodiments provided in the enclosed independent claims. Advantageous implementations of the embodiments are further defined in the dependent claims.

According to a first aspect, a DC-to-DC power converter is provided, comprising at least two energy buffer units, wherein each energy buffer unit is configured to receive a first-type voltage component and to respectively produce a voltage Vb at an output of the DC-to-DC power converter; and at least one energy exchanger, wherein the at least one energy exchanger is connected to the at least two energy buffer units and is configured to exchange energy between the at least two energy buffer units.

This has the advantage that an improved DC-to-DC power converter is provided. The power converter can be is highly integrated, comprises a low number of components, and efficiently combines energy buffer units together with an energy exchanger in order to obtain a DC-to-DC power conversion. Moreover, the DC-to-DC power converter has a low cost and converts a DC energy to another form of DC energy in an efficient manner. The power converter can, for example, be used to convert the power provided by a solar panel system.

In an implementation form of the first aspect, each energy buffer unit is based on a half-bridge or a full-bridge structure.

This provides the advantage that well known structures, such as a half-bridge and a full-bridge structure, can be used in order to implement the energy buffer unit.

In a further implementation form of the first aspect, the full-bridge structure comprises four low-voltage semiconductor switches.

This provides the advantage that low-voltage and low-cost semiconductor devices, in particular switches, can be used in the DC-to-DC converter. Moreover, the switches can be characterized by very low static and dynamic losses and can be operated at high switching frequencies.

In a further implementation form of the first aspect, the half- or full-bridge structure comprises a capacitor, wherein for a voltage Vc across the capacitor:

$$Vb = \begin{cases} Va \\ Va \pm Vc \end{cases},$$

wherein Va is the first-type voltage component received by the energy buffer unit.

This provides the advantage that the voltage Vb at an output of the DC-to-DC power converter can be estimated and implemented in an easy way.

In a further implementation form of the first aspect, each first-type voltage component is a positive voltage component or a negative voltage component.

This has the advantage that a certain flexibility is provided in the choice of the first-type voltage component.

In a further implementation form of the first aspect, the at least one energy exchanger is based on a resonant balancer circuitry.

This has the advantage that the resonant balancer circuitry operates high efficiently with soft switching and with no switching losses.

In a further implementation form of the first aspect, the resonant balancer circuitry has a configuration comprising at least four switches, two capacitors, and an inductor, and wherein the two resonant capacitors and the inductor are excitable to exchange energy between the capacitors.

This has the advantage that a low size of the circuitry can be achieved by moving towards a high frequency operation. Moreover, this embodiment provides the advantage that simplified gate drivers and a simplified control hardware can be used. Moreover, during the energy exchange between the capacitors, a soft switching can be achieved and this results in almost no switching losses.

In a further implementation form of the first aspect, the at least one energy exchanger is comprised between the at least two energy buffer units.

According to a second aspect, an electrical energy conversion system comprising a DC-to-DC power converter according to the first aspect or any one of the implementation forms thereof is provided.

In an implementation form of the second aspect, the electrical energy conversion system further comprises a DC-to-AC inverter, and wherein the output of the DC-to-DC power converter is connected to the DC-to-AC inverter.

In a further implementation form of the second aspect, the electrical energy conversion system further comprises a DC transmission system, and wherein the output of the DC-to-DC power converter is connected to the DC transmission system.

In a further implementation form of the second aspect, the electrical energy conversion system further comprises a solid state transformer, and wherein the output of the DC-to-DC power converter is connected to the solid state transformer.

In a further implementation form of the second aspect, the electrical energy conversion system further comprises a battery, wherein the battery is configured to store an energy in excess generated from a solar panel.

This has the advantage that the battery facilitates the maximization of the harvest during a long time, and provides flexibility in the usage of the stored energy in the case the solar energy is not available or minimal.

In a further implementation form of the second aspect, the electrical energy conversion system further comprises ultra-capacitors, wherein the ultra-capacitors are configured to store an energy in excess generated from the solar panel.

This has the advantage that the ultra-capacitors facilitate the maximization of the harvest during a long time, and provides flexibility in the usage of the stored energy in the case the solar energy is not available or minimal.

According to a third aspect a method for a DC-to-DC power converter comprising at least two energy buffer units and at least one energy exchanged is provided, the method comprising the steps of receiving, by each energy buffer unit, a first-type voltage component; producing, by each energy buffer unit, a voltage Vb at an output of the DC-to-DC power converter; and exchanging, by the at least one energy exchanger, energy between at least two energy buffer units.

In an implementation form of the third aspect, each energy buffer unit is based on a half-bridge or a full-bridge structure.

In a further implementation form of the third aspect, the full-bridge structure comprises four low-voltage semiconductor switches.

In a further implementation form of the third aspect, the half- or full-bridge structure comprises a capacitor, wherein for a voltage Vc across the capacitor:

$$\mathrm{Vb} = \begin{cases} Va \\ Va \pm Vc \end{cases},$$

wherein Va is the first-type voltage component received by the energy buffer unit.

In a further implementation form of the third aspect, each first-type voltage component is a positive voltage component or a negative voltage component.

In a further implementation form of the third aspect, the at least one energy exchanger is based on a resonant balancer circuitry.

In a further implementation form of the third aspect, the resonant balancer circuitry has a configuration comprising at least four switches, two capacitors, and an inductor, and wherein the two resonant capacitors and the inductor are excitable to exchange energy between the capacitors.

In a further implementation form of the third aspect, the at least one energy exchanger is comprised between the at least two energy buffer units.

The method of the third aspect and its respective implementation forms provide the same advantages and effects as described above for the device of the first aspect and its respective implementation forms.

It has to be noted that all devices, elements, units and means described in the present application could be implemented in the software or hardware elements or any kind of combination thereof. All steps which are performed by the various entities described in the present application as well as the functionalities described to be performed by the various entities are intended to mean that the respective entity is adapted to or configured to perform the respective steps and functionalities. Even if, in the following description of specific embodiments, a specific functionality or step to be performed by external entities is not reflected in the description of a specific detailed element of that entity which performs that specific step or functionality, it should be clear for a skilled person that these methods and functionalities can be implemented in respective software or hardware elements, or any kind of combination thereof.

BRIEF DESCRIPTION OF DRAWINGS

The above described aspects and implementation forms of the present invention will be explained in the following description of specific embodiments in relation to the enclosed drawings, in which:

FIG. 1 shows a schematic representation of an exemplary electrical energy conversion system comprising a DC-to-DC converter;

FIG. 2 shows a schematic representation of a DC-to-DC-power converter according to an embodiment;

FIG. 3 shows a schematic representation of an electrical energy conversion system comprising a Dc-to-DC converter according to an embodiment;

FIG. 4 shows a schematic representation of an energy buffer unit for a DC-to-DC converter according to an embodiment;

FIG. 5 shows a schematic representation of an energy exchanger unit for a DC-to-DC converter according to an embodiment;

FIG. 6 shows a schematic representation of an electrical energy conversion system comprising a DC-to-DC converter according to an embodiment;

FIG. 7 shows a schematic representation of an electrical energy conversion system comprising a DC-to-DC converter according to an embodiment;

FIG. 8 shows a schematic representation of an electrical energy conversion system comprising a DC-to-DC converter according to an embodiment; and

FIG. 9 shows a schematic representation of a method for a DC-to-DC power converter according to an embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

Fig. 2 shows schematically a DC-to-DC-power converter 100 according to an embodiment of the invention.

The DC-to-DC-power converter 100 comprises at least two energy buffer units 102, 104, wherein each energy buffer unit 102, 104 is configured to receive a first-type voltage component and to respectively produce a voltage Vb at an output of the DC-to-DC power converter 100; and at least one energy exchanger 106, wherein the at least one energy exchanger 106 is connected to the at least two energy buffer units 102, 104 and is configured to exchange energy between the at least two energy buffer units 102, 104.

Each first-type voltage component can be either a positive voltage component or a negative voltage component.

Fig. 3 shows a schematic representation of an electrical energy conversion system 200 comprising a DC-to-DC converter 100 according to an embodiment of the invention.

In particular, the DC-to-DC converter 100 may be the one shown in Fig. 1.

In this embodiment, the electrical energy conversion system 200 comprises the DC-to-DC converter 100, wherein the DC-to-DC converter 100 comprises the energy buffer units 102…102m, 104…, 104m and the energy exchangers 106,…, 106m-1, wherein the energy exchangers 106,…, 106m-1 are placed between the energy buffer units 102…102m, 104…, 104m, respectively.

In this embodiment, a DC-to-DC power converter topology and control mechanism (referred to as "converter") as used in solar PV electrical energy conversion applications is exemplarily described. In particular, the converter DC-to-DC 100 can be configured to translate DC electrical power generated from one or more solar panels, string1,…, string(m), to another form of DC electrical power. The input of the DC-to-Dc converter 100 can directly be connected to multiple solar panels or strings, string1,…, string(m), (e.g. many panels in series or parallel).

The output of the DC-to-DC converter 100 can be connected to either a DC-to-AC inverter, which translates the DC power to AC power, or to a DC transmission system, or to a solid state transformer.

The DC-to-DC converter 100 provides the advantage that a low voltage can be used. Moreover, low cost semiconductor devices can be used to operate at higher DC voltages by means of the circuit arrangement according to this embodiment.

Thereby, the DC-to-DC power converter 100 advantageously enables the design of modular PV inverters with high electrical efficiency, due to lower voltage semiconductor devices, and by means of the integration of control and driving circuits in close proximity to the switching power cells. Thereby delays and latencies in the control loop are minimized.

This embodiment is based on processing only the minimal amount of differential power. This improves the overall efficiency and power density. The MPPT of each input may be achieved based on a maximum average output voltage. Moreover, there are no bulky energy storage elements, thus providing the potential for highly integrated and scalable converters 100 for multiple MPPT strings.

The energy exchanger 106 can based on a resonant balancer, which operates with soft switching and with no switching losses for high efficiency operation. Moreover, the operation may be with 50% fixed duty operation, which simplifies the gate driver and controller requirements with high potential for low cost production.

Furthermore, this embodiment provides the advantage that a highly integrated, low component energy buffer 102, 104, and an energy exchanger 106, which work together to form a DC-to-DC power converter 106, are provided.

Fig. 4 shows a schematic representation of an energy buffer unit 102 for a DC-to-DC converter 100 according to an embodiment of the invention.

In this embodiment, the energy unit 102 is based on a H-bridge circuit structure with low voltage semiconductor switches, such as MOSFETs (i.e. 150V OptiMOS5), wherein a, b, c, and d indicate different configurations of the energy unit 102.

The H-bridge structure can be a half-bridge structure or a full-bridge structure.

In this embodiment, the buffer unit 102 is connected in series with an incoming DC source, as it is in the case of solar panels for example.

The function of the buffer units 102 is to add or subtract additional voltage buffer in the capacitor VC from the voltage VA, where necessary. Based on the status of the switches S1, S2, S3 and S4, the ideal (i.e. the best possible) voltage VB can be synthesized as:

- for the configuration (a) or (b) VB =VA,
- for the configuration (c) VB =VA-VC; and
- for the configuration (d) VB =VA+VC.

These switches can be operated at relatively low frequency to synthesise VB.

The option to use 0, $+V_C$ or $-V_C$ can be based on the input voltage and the output common DC link. Any voltage level between $-V_C$ and $+V_C$ can be synthesized on average between the ports ‘A’ and ‘B’, for instance, based on the duty cycle of each of the switching states (a)/(b), (c) or (d).

The energy in each buffer capacitors can be supplied by energy exchangers/balancer unit(s) 106.

Fig. 5 shows a schematic representation of an energy exchanger unit 106 for a DC-to-DC converter 100 according to an embodiment in different operation states (e) and (f).

The energy exchanger unit 106 can be based on a resonant balancer circuitry, wherein a resonant capacitor and inductor are excited to exchange energy between two ports, i.e. in this embodiment, between two capacitors, VC1 and VC2 in the energy buffer 102 and 104.

In this embodiment, in the state (e), the energy exchange occurs between Cf, Lf and VC2, while, in the state (f), the energy exchange occurs between Cf, Lf and VC1.

The switching between the two possible states (e) and (f) occurs ideally at a resonant frequency of the Lf and Cf. Therefore, advantageously, a lower size of the circuit can be achieved by moving towards a high frequency operation. A duty cycle between two possible states can be fixed at e.g. 50% duty. Therefore, simplified gate drivers and control hardware can be sufficient. During the state changes, a soft switching can be achieved, resulting in almost no switching losses.

Fig. 6 shows a schematic representation of an electrical energy conversion system 200 comprising a DC-to-DC converter 100 according to an embodiment;

In particular, in Fig. 6 a possible embodiment for a residential solar PV inverter is represented.

In this embodiment, two energy buffer units 102 and 104 are connected in series with solar PV strings, string1 and string2. One energy exchanger 106 is connected between the two energy buffer units 102 and 104.

All circuit elements in the above embodiment may be based on low voltage semiconductor devices, such as MOSFETs. They are typically characterised by very low static and dynamic losses, low costs, and can be operated at higher switching frequencies.

Fig. 7 shows a schematic representation of an electrical energy conversion system 200 comprising a DC-to-DC converter 100 according to an embodiment.

In particular, in Fig. 7 the embodiment shown in Fig. 6 is extended to a multi PV string scenario, wherein the energy buffer units 102m and 104m+1 can be similar to those of the embodiment of Fig. 6. However, the energy exchanger units 106 are here three port converters.

Fig. 8 shows a schematic representation of an electrical energy conversion system 200 comprising a DC-to-DC converter 100 according to an embodiment

Embodiments of this invention can include energy storage elements, if for example there is an excess in energy generated from PV strings. In this case, some energy can be stored and reused when the energy generation is low, as shown in Fig. 8. These energy storage elements can be a battery, ultra-capacitors or a similar device. This facilitates to maximise the harvest in a long time, and provide flexibility to use the stored energy in case the solar energy is not available or minimal.

Fig. 9 shows a schematic representation of a method 900 for a DC-to-DC power converter 100, comprising at least two energy buffer units 102 and 104 and at least one energy exchanger 106, according to an embodiment.

The method 900 comprises the following steps: receiving 902, by each energy buffer unit 102, 104, a first-type voltage component; producing 904, by each energy buffer unit 102, 104, a voltage Vb at an output of the DC-to-DC power converter 100; and exchanging 906, by the at least one energy exchanger 106, energy between at least two energy buffer units 102 and 104.

The present invention has been described in conjunction with various embodiments as examples as well as implementations. However, other variations can be understood and effected by those persons skilled in the art and practicing the claimed invention, from the studies of the drawings, this disclosure and the independent claims. In the claims as well as in the description the word “comprising” does not exclude other elements or steps and the indefinite article “a” or “an” does not exclude a plurality. A single element or other unit may fulfill the functions of several entities or items recited in the claims. The mere fact that certain measures are recited in the mutual different dependent claims does not indicate that a combination of these measures cannot be used in an advantageous implementation.

Claims

1. A DC-to-DC power converter (100), comprising:
   - at least two energy buffer units (102, 104), wherein each energy buffer unit (102, 104) is configured to receive a first-type voltage component and to respectively produce a voltage Vb at an output of the DC-to-DC power converter (100); and
   - at least one energy exchanger (106), wherein the at least one energy exchanger (106) is connected to the at least two energy buffer units (102, 104) and is configured to exchange energy between the at least two energy buffer units (102, 104).

2. The DC-to-DC power converter (100) of claim 1, wherein each energy buffer unit (102, 104) is based on a half-bridge or a full-bridge structure.

3. The DC-to-DC power converter (100) of claim 2, wherein the full-bridge structure comprises four low-voltage semiconductor switches.

4. The DC-to-DC power converter (100) of claim 2 or 3, wherein the half- or full-bridge structure comprises a capacitor, wherein for a voltage Vc across the capacitor:

$$Vb = \begin{cases} Va \\ Va \pm Vc \end{cases},$$

wherein Va is the first-type voltage component received by the energy buffer unit (102, 104).

5. The DC-to-DC power converter (100) of any one of the claims 1 to 4, wherein each first-type voltage component is a positive voltage component or a negative voltage component.

6. The DC-to-DC power converter (100) of any one of the preceding claims, wherein the at least one energy exchanger (106) is based on a resonant balancer circuitry.

7. The DC-to-DC power converter (100) of claim 6, wherein the resonant balancer circuitry has a configuration comprising at least four switches, two capacitors, and an inductor, and wherein the two resonant capacitors and the inductor are excitable to exchange energy between the capacitors.

8. The DC-to-DC power converter (100) of any one of the preceding claims, wherein the at least one energy exchanger (106) is comprised between the at least two energy buffer units (102, 104).

9. An electrical energy conversion system (200) comprising a DC-to-DC power converter (100) according to one of the claims 1 to 8.

10. The electrical energy conversion system (200) of claim 9, wherein the electrical energy conversion system (200) further comprises a DC-to-AC inverter, and wherein the output of the DC-to-DC power converter is connected to the DC-to-AC inverter.

11. The electrical energy conversion system (200) of claim 9, wherein the electrical energy conversion system (200) further comprises a DC transmission system, and wherein the output of the DC-to-DC power converter is connected to the DC transmission system.

12. The electrical energy conversion system (200) of claim to 9, wherein the electrical energy conversion system (200) further comprises a solid state transformer, and wherein the output of the DC-to-DC power converter (100) is connected to the solid state transformer.

13. The electrical energy conversion system (200) of any one of the claims 9 to 12, wherein the electrical energy conversion system (200) further comprises a

battery, wherein the battery is configured to store an energy in excess generated from a solar panel.

14. The electrical energy conversion system (200) according to claim 13, wherein the electrical energy conversion system (200) further comprises ultra-capacitors, wherein the ultra-capacitors are configured to store an energy in excess generated from the solar panel.

15. Method (900) for a DC-to-DC power converter (100) comprising at least two energy buffer units (102, 104) and at least one energy exchanged (106), the method (900) comprising the steps of:
- receiving (902), by each energy buffer unit (102, 104), a first-type voltage component;
- producing (904), by each energy buffer unit (102, 104), a voltage Vb at an output of the DC-to-DC power converter (100); and
- exchanging (906), by the at least one energy exchanger (106), energy between at least two energy buffer units (102, 104).

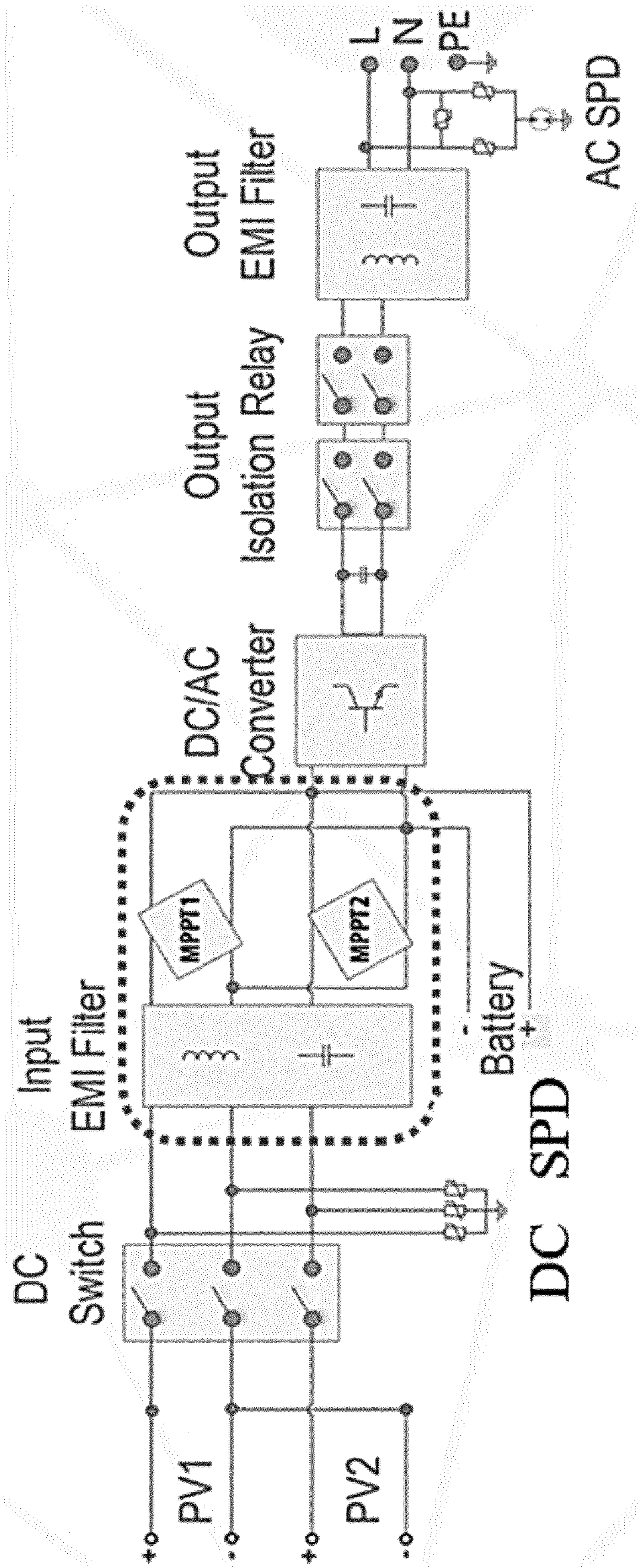

PV1
PV2
DC
Switch
Input
EMI Filter
MPPT1
MPPT2
Battery
DC SPD
DC/AC
Converter
Output
Isolation Relay
Output
EMI Filter
L
N
PE
AC SPD

Fig. 1

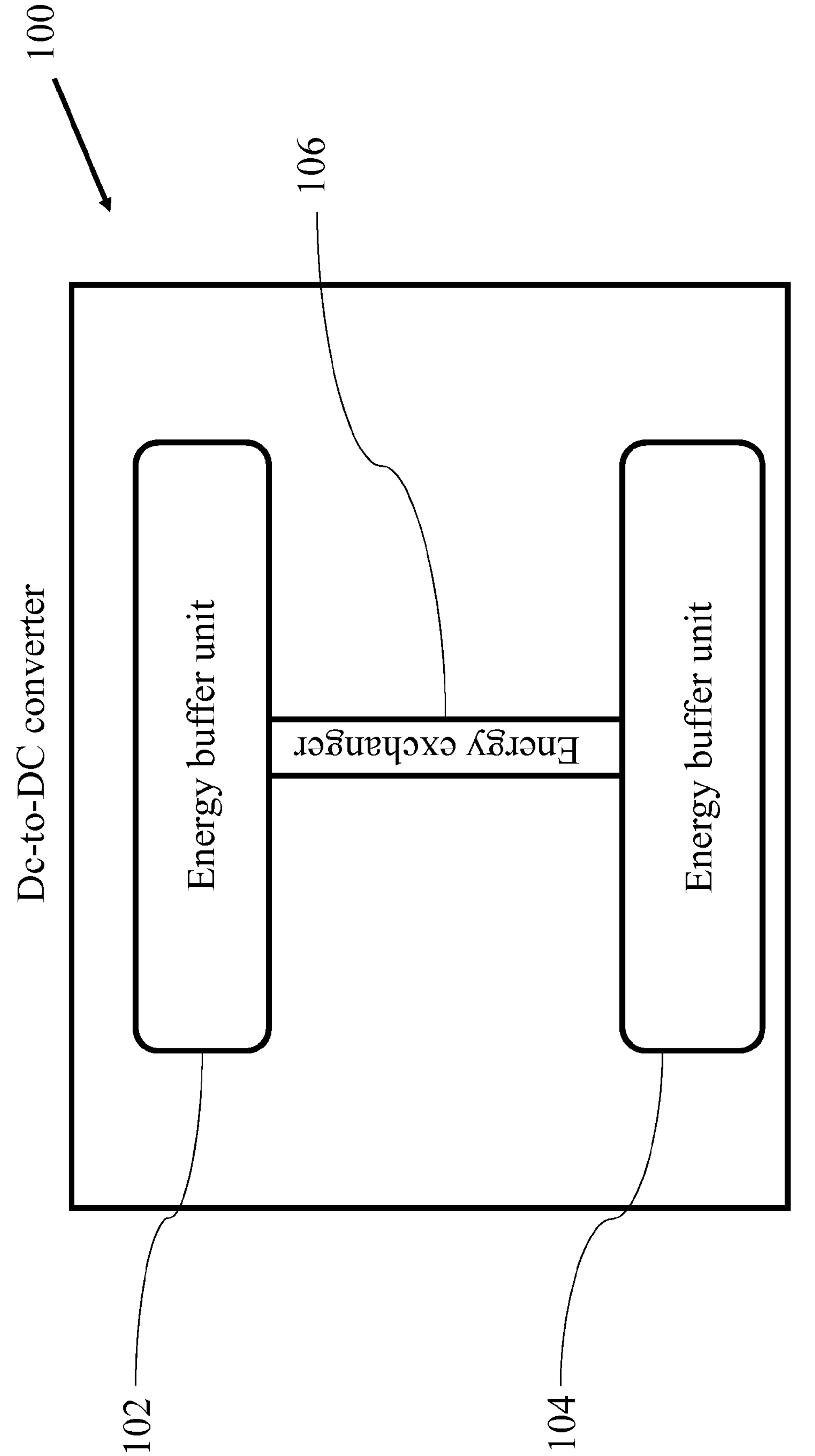

100
106
Dc-to-DC converter
Energy buffer unit
Energy exchanger
Energy buffer unit
102
104

Fig. 2

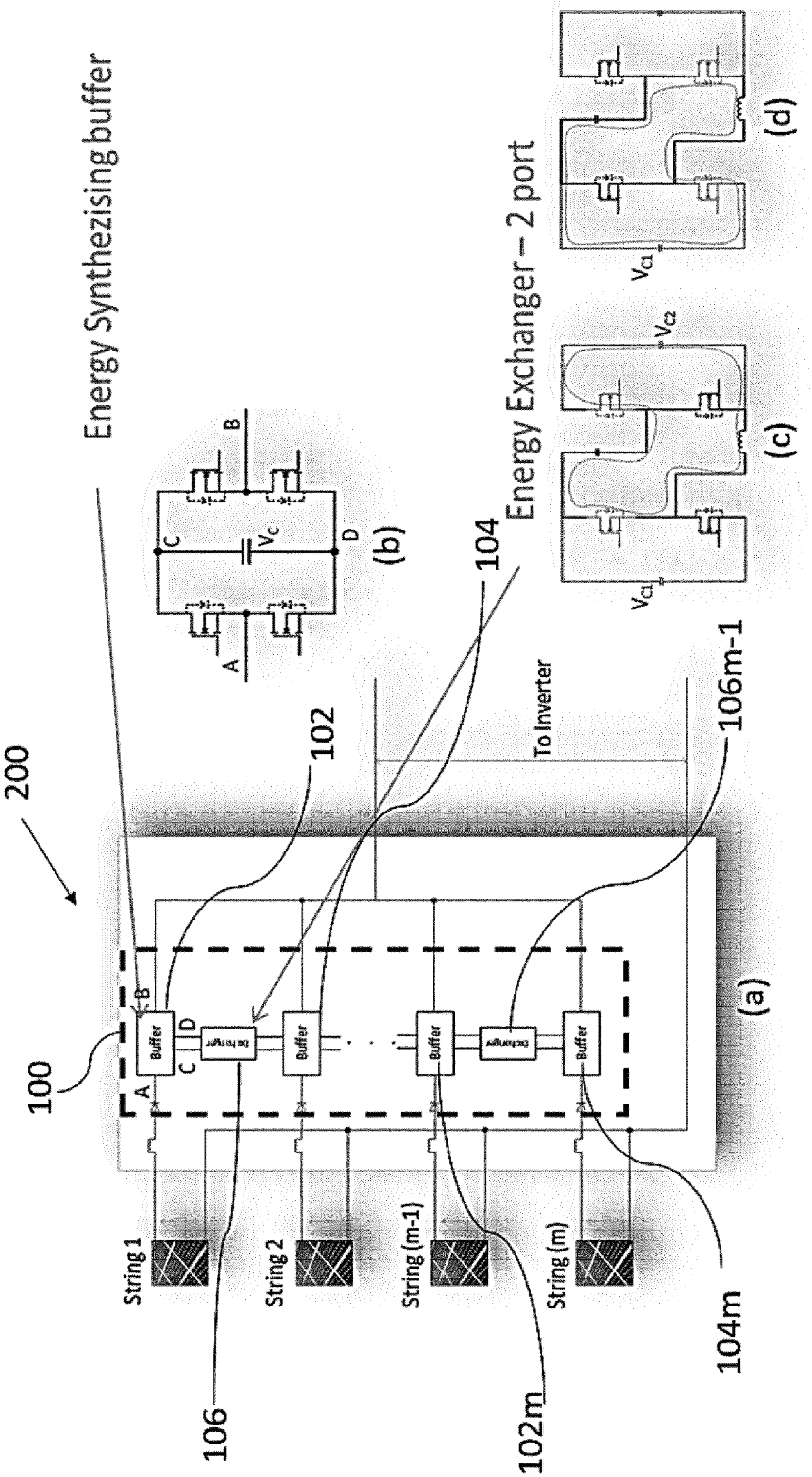
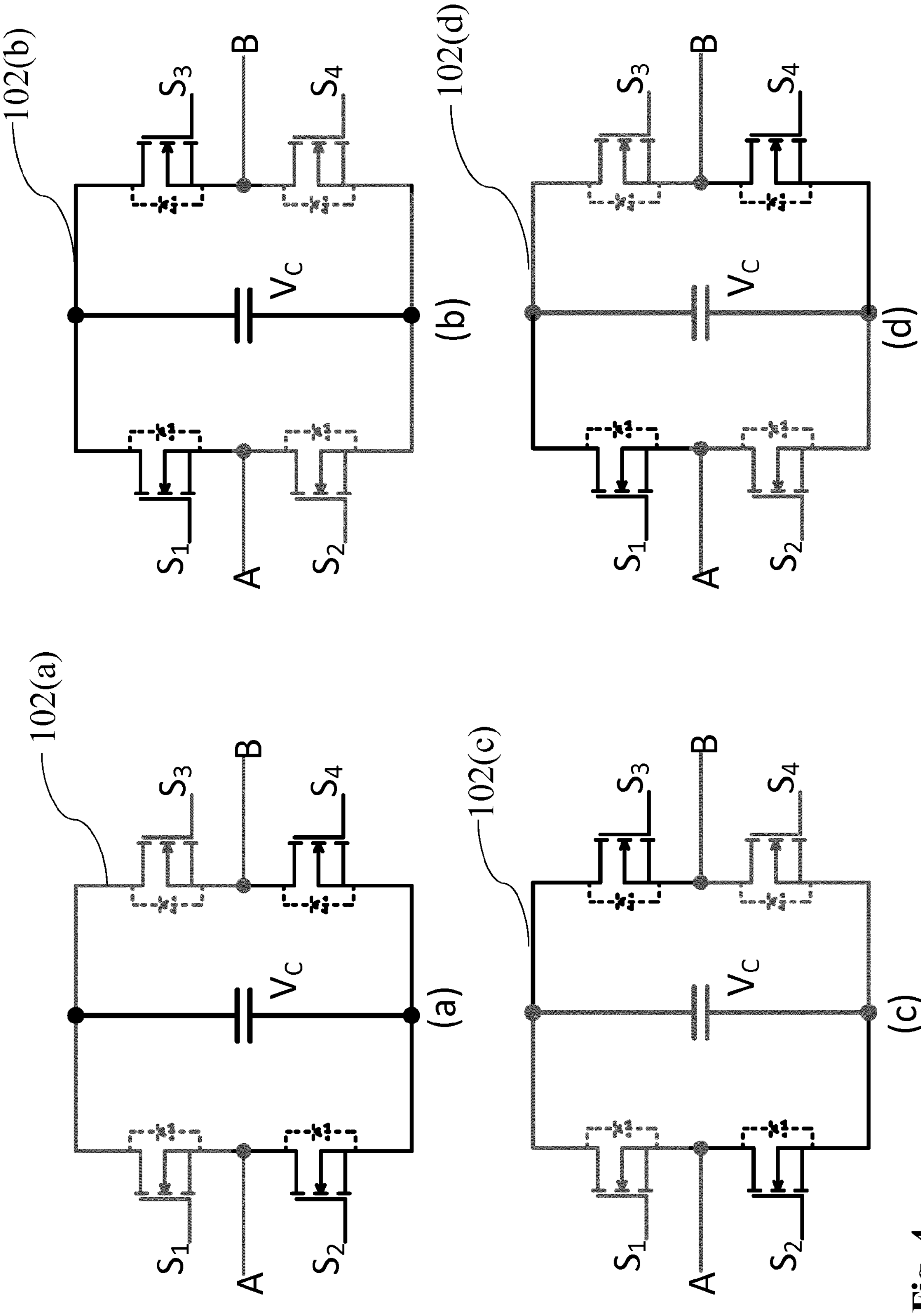

Energy Synthezising buffer
Energy Exchanger – 2 port
200
100
102
104
106
102m
104m
106m-1
String 1
String 2
String (m-1)
String (m)
Buffer
A
B
C
D
To Inverter
(a)
(b)
(c)
(d)
V_C
V_{C1}
V_{C2}

Fig. 3


102(b)
S3
B
S4
Vc
(b)
S1
A
S2
102(d)
S3
B
S4
Vc
(d)
S1
A
S2
102(a)
S3
B
S4
Vc
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(c)
S1
A
S2

Fig. 4

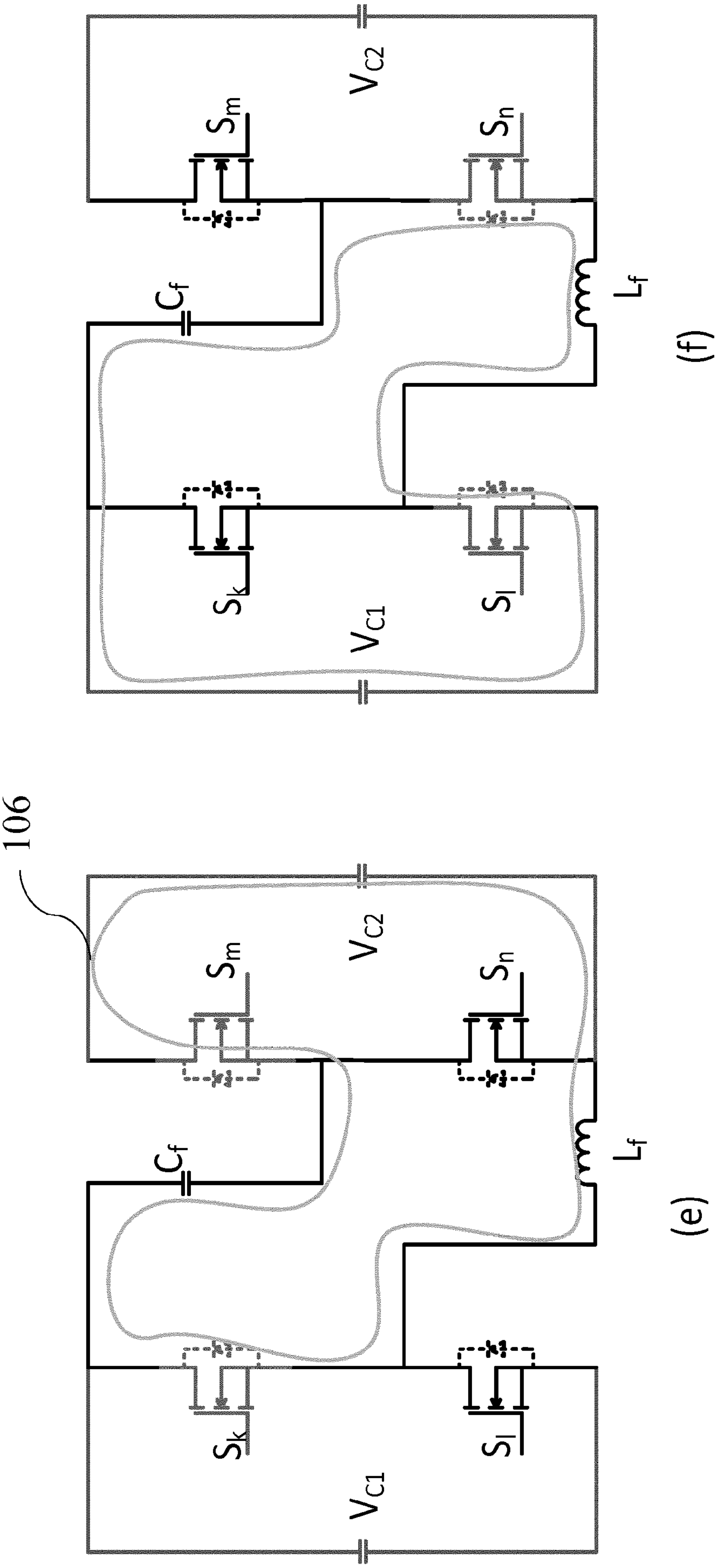

Fig. 5

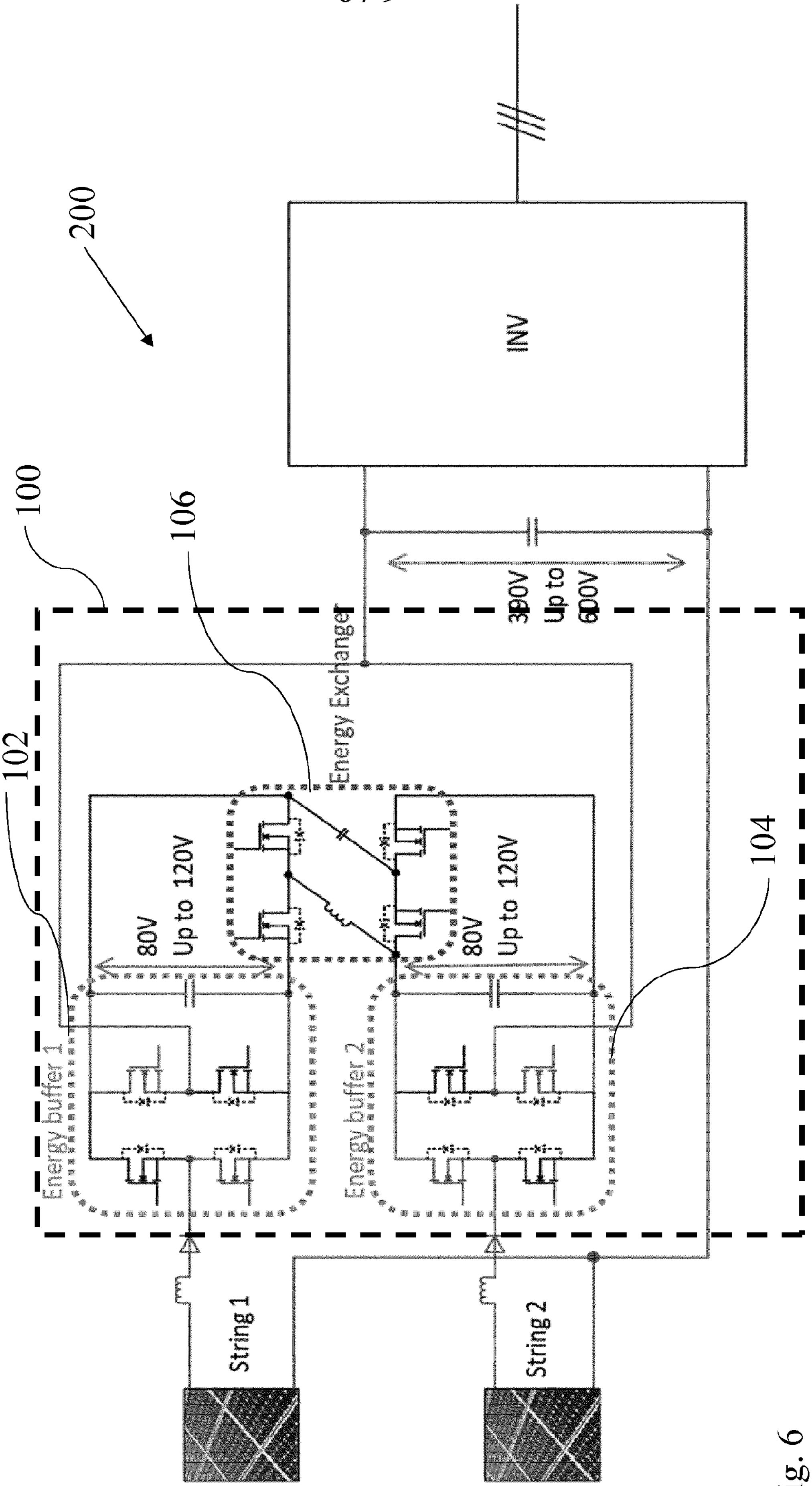
200
100
106
102
104
INV
Energy Exchanger
Energy buffer 1
Energy buffer 2
80V
Up to 120V
80V
Up to 120V
300V
Up to
600V
String 1
String 2

Fig. 6

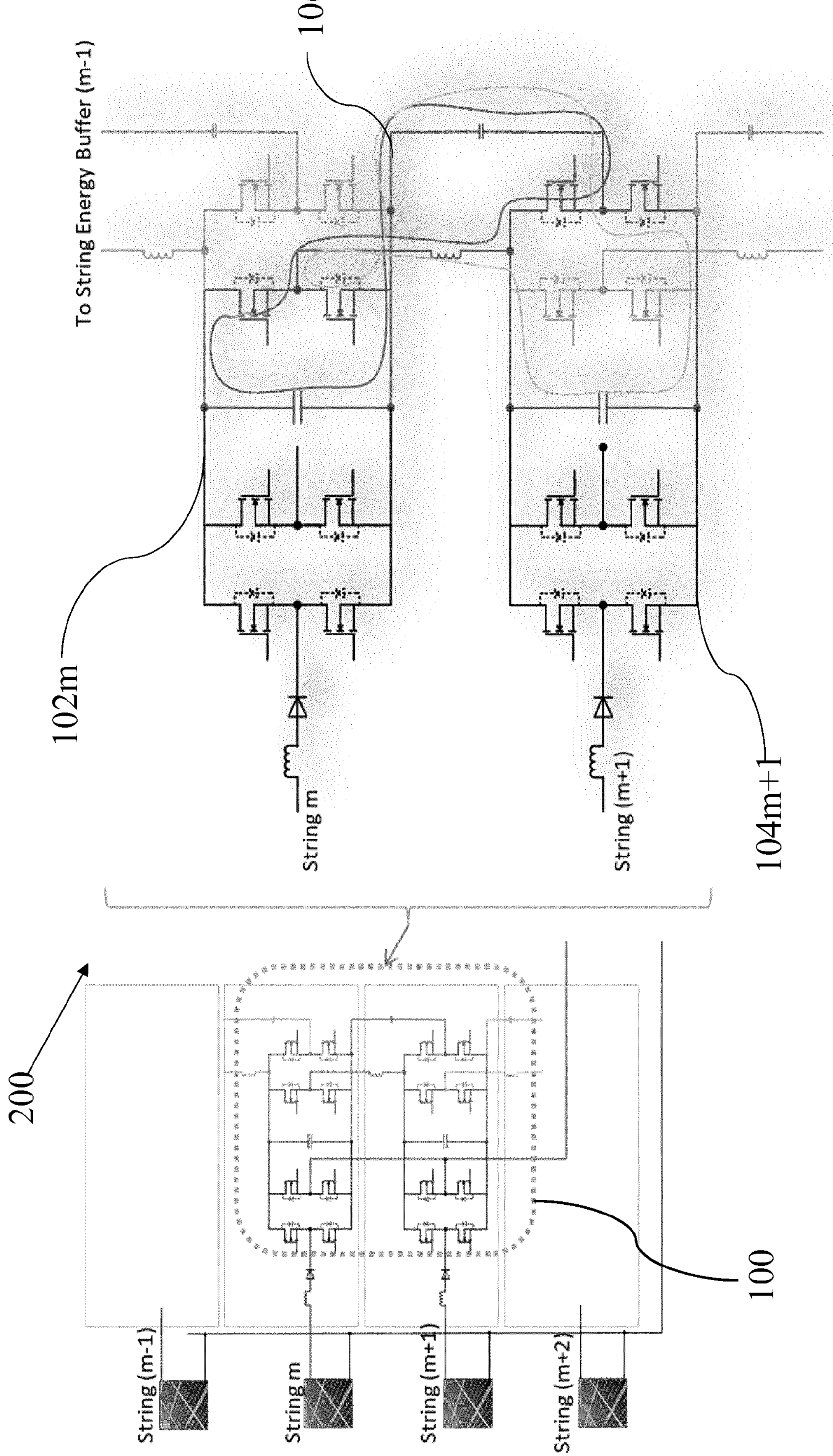
106
To String Energy Buffer (m-1)
To String Energy Buffer (m+2)
102m
String m
String (m+1)
104m+1
200
100
String (m-1)
String m
String (m+1)
String (m+2)

Fig. 7

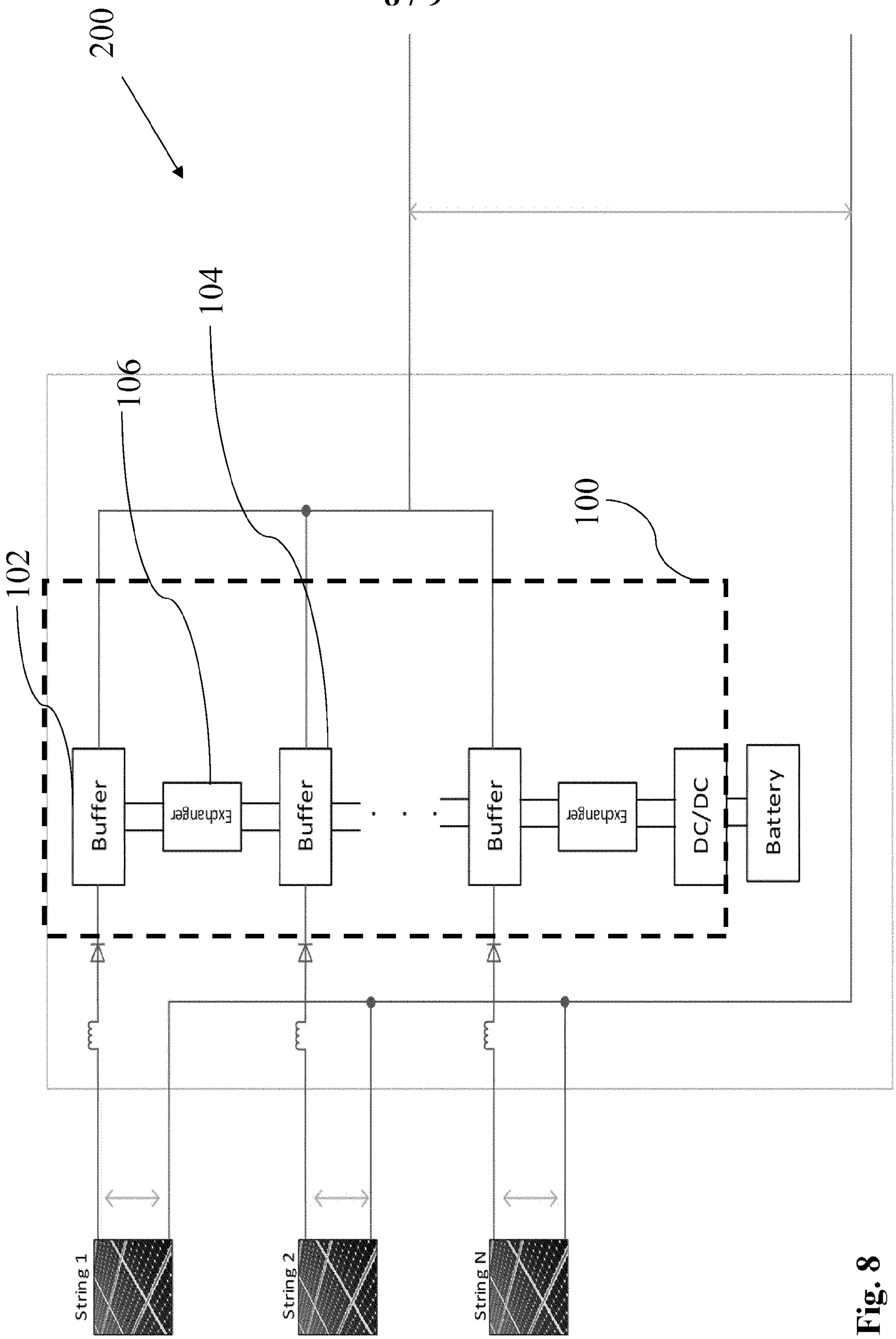
200
102
106
104
100
Buffer
Exchanger
Buffer
Buffer
Exchanger
DC/DC
Battery
String 1
String 2
String N

Fig. 8

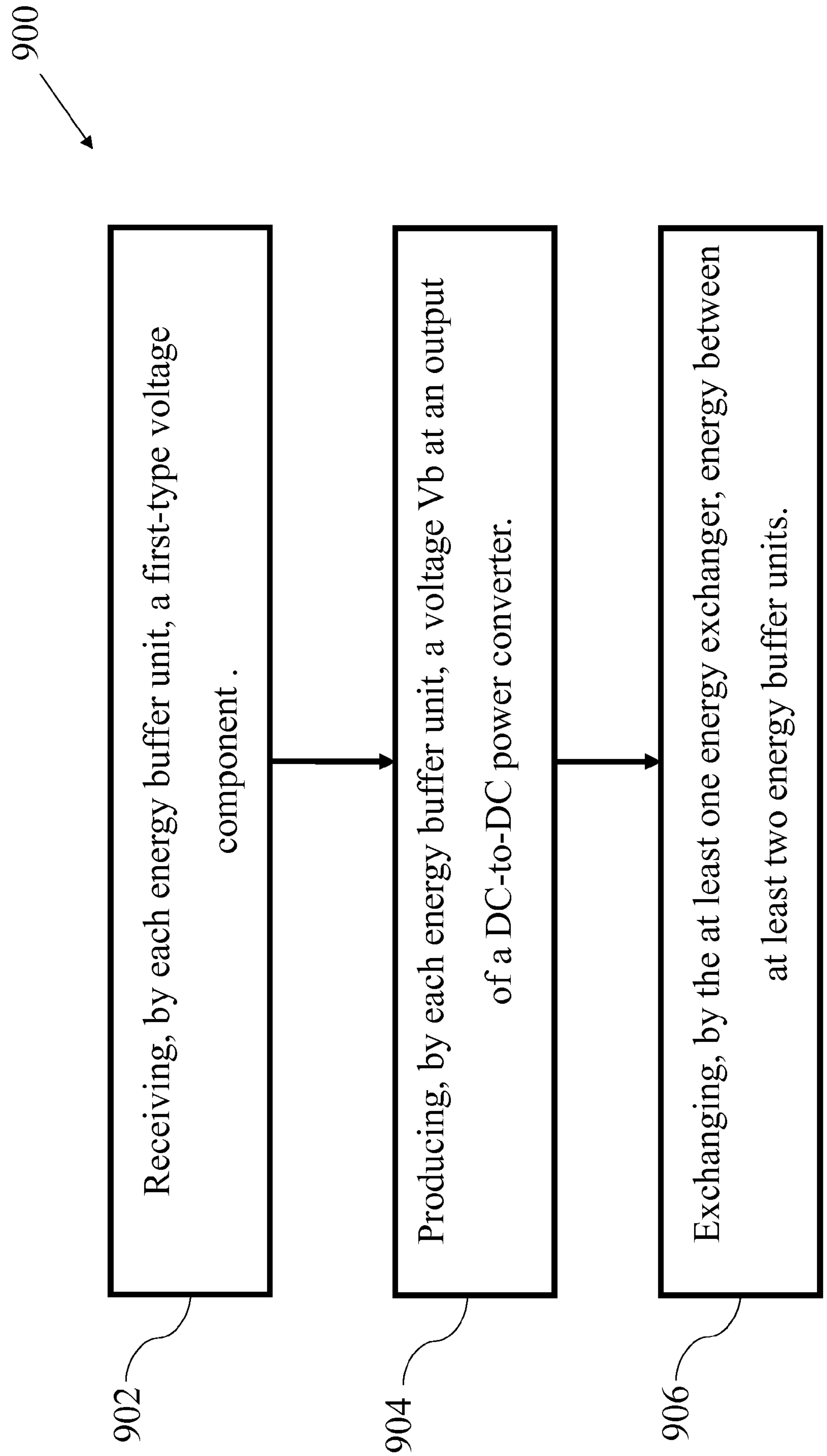
900
Receiving, by each energy buffer unit, a first-type voltage component .
902
Producing, by each energy buffer unit, a voltage Vb at an output of a DC-to-DC power converter.
904
Exchanging, by the at least one energy exchanger, energy between at least two energy buffer units.
906

Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/066760

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02M3/158 H02J7/35
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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	EP 2 595 291 A1 (SCHNEIDER TOSHIBA INVERTER [FR]) 22 May 2013 (2013-05-22) figure 1	1-5,8,9,12-15 7
X	US 2018/026450 A1 (MORIYAMA YUICHI [JP]) 25 January 2018 (2018-01-25) figure 2	1,10,11
X	DE 10 2014 002592 A1 (KARLSRUHER INST FÜR TECHNOLOGIE [DE]) 27 August 2015 (2015-08-27) figure 9B	1,6,15
X	US 2011/121661 A1 (KAWAKAMI TOMOYUKI [JP] ET AL) 26 May 2011 (2011-05-26) figure 11	1,15

-/--

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

[X] See patent family annex.

* Special categories of cited documents :

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 March 2020	07/04/2020

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	Gotzig, Bernhard

1

International application No
PCT/EP2019/066760

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2019/066760

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