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(54) SUBMARINE DCDC CONVERTER, METHOD FOR CONTROLLING SUBMARINE DCDC CONVERTER, AND SUBMARINE CABLE SYSTEM

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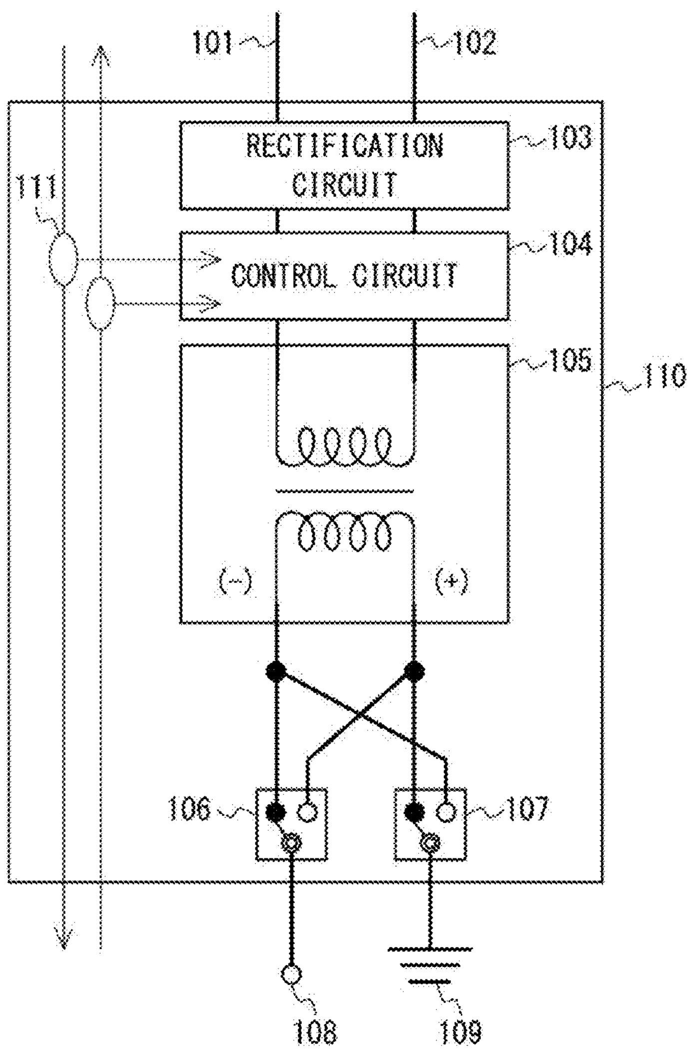
(57) **ABSTRACT**

To share, i.e., to use, a common submarine DCDC converter for both a submarine DCDC converter for positive outputting and one for negative outputting. A submarine DCDC converter according to the present disclosure includes: a DCDC conversion circuit configured to supply a first constant current input to an input terminal from a land feeding apparatus through a first submarine cable to a first output terminal, generate a second constant current using the first constant current, and supply the generated second constant current to a second output terminal; a control circuit configured to switch a polarity of the second constant current output from the second output terminal; a first switch; and a second switch.



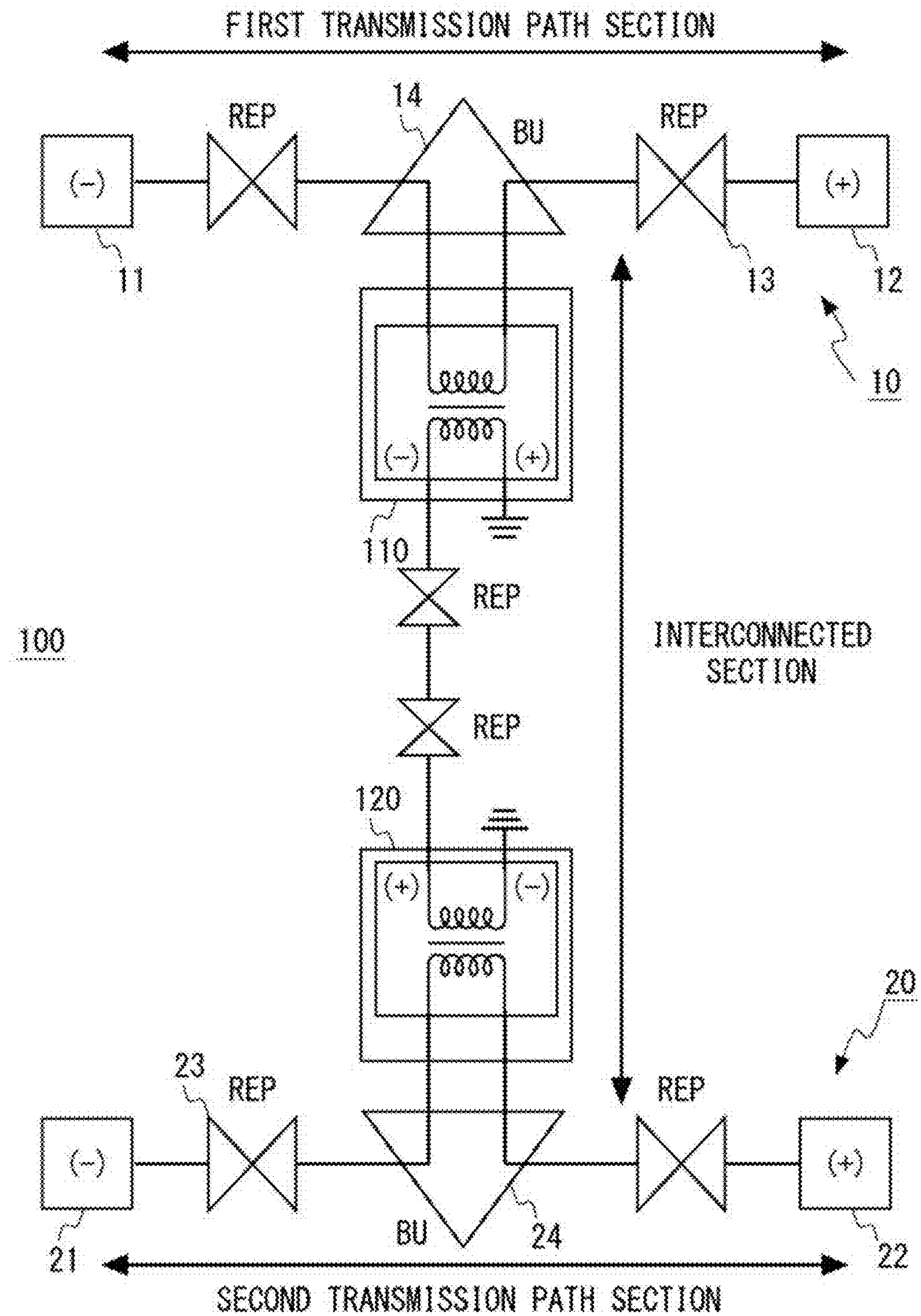

FIRST TRANSMISSION PATH SECTION
14
BU
REP
REP
(−)
(+)
11
13
12
10
110
REP
100
INTERCONNECTED SECTION
REP
120
(+)
(−)
(−)
(+)
20
23
REP
REP
(−)
(+)
BU
24
21
22
SECOND TRANSMISSION PATH SECTION

Fig. 1

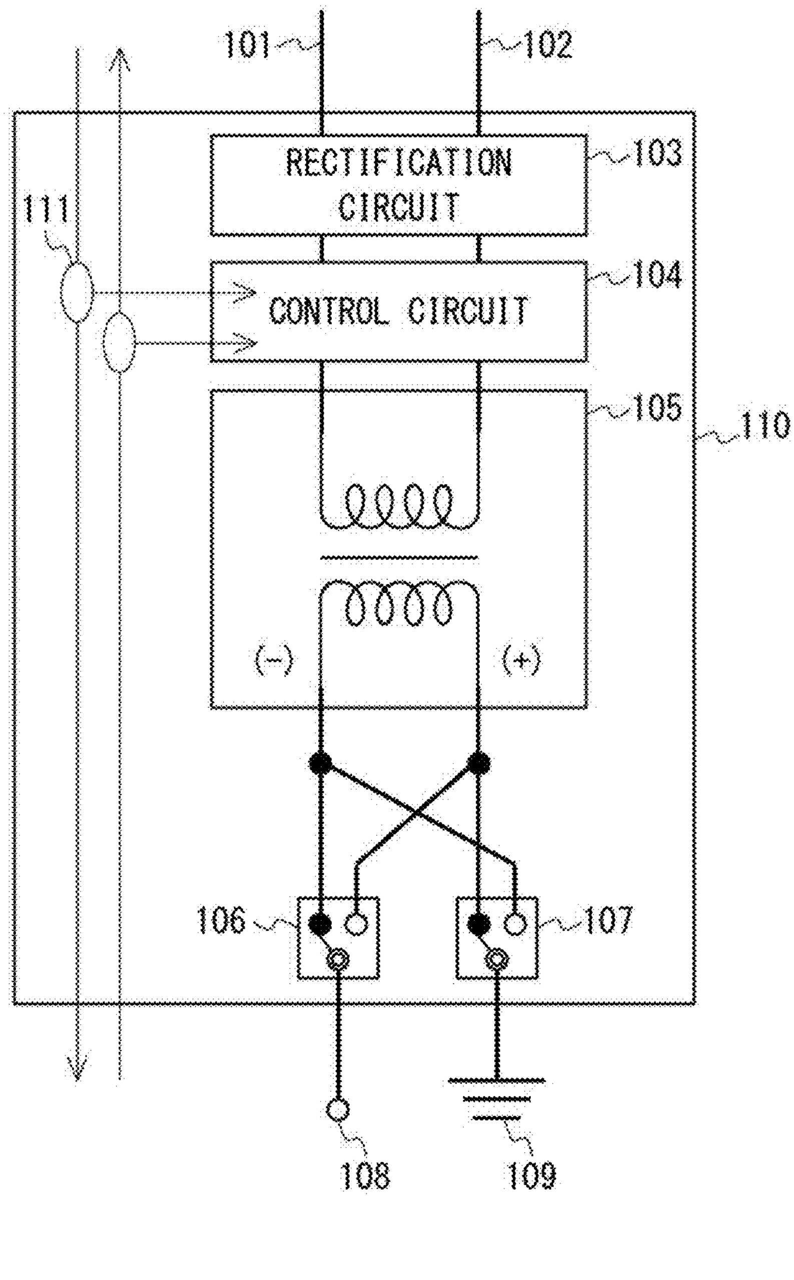
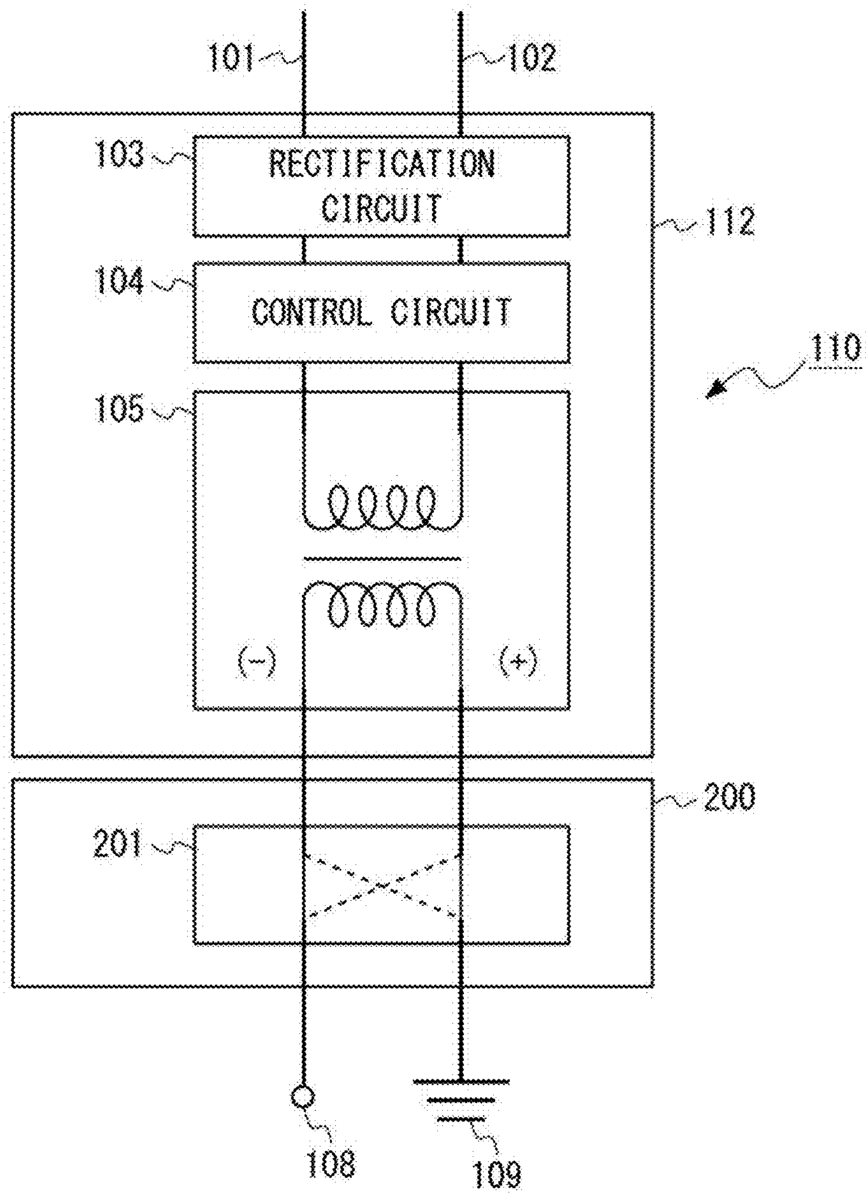

101
102
RECTIFICATION CIRCUIT
103
111
CONTROL CIRCUIT
104
105
110
(−)
(+)
106
107
108
109

Fig. 2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102
103
RECTIFICATION CIRCUIT
112
104
CONTROL CIRCUIT
110
105
(-)
(+)
200
201
108
109

Fig. 3

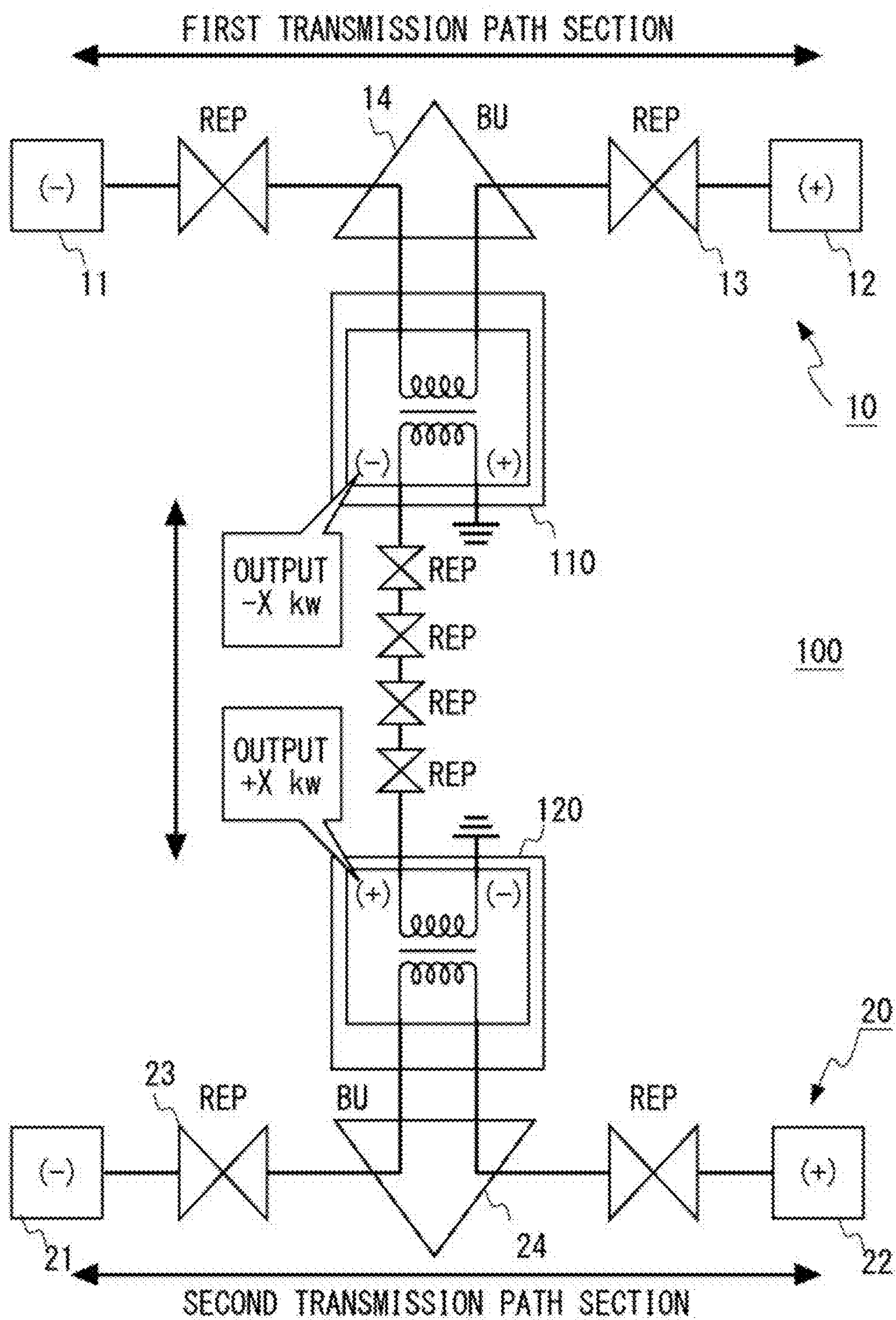
FIRST TRANSMISSION PATH SECTION
REP
14
BU
REP
(−)
(+)
11
13
12
10
(−)
(+)
110
OUTPUT
−X kw
REP
REP
100
REP
REP
OUTPUT
+X kw
120
(+)
(−)
20
23
REP
BU
REP
(−)
(+)
21
24
22
SECOND TRANSMISSION PATH SECTION

Fig. 4

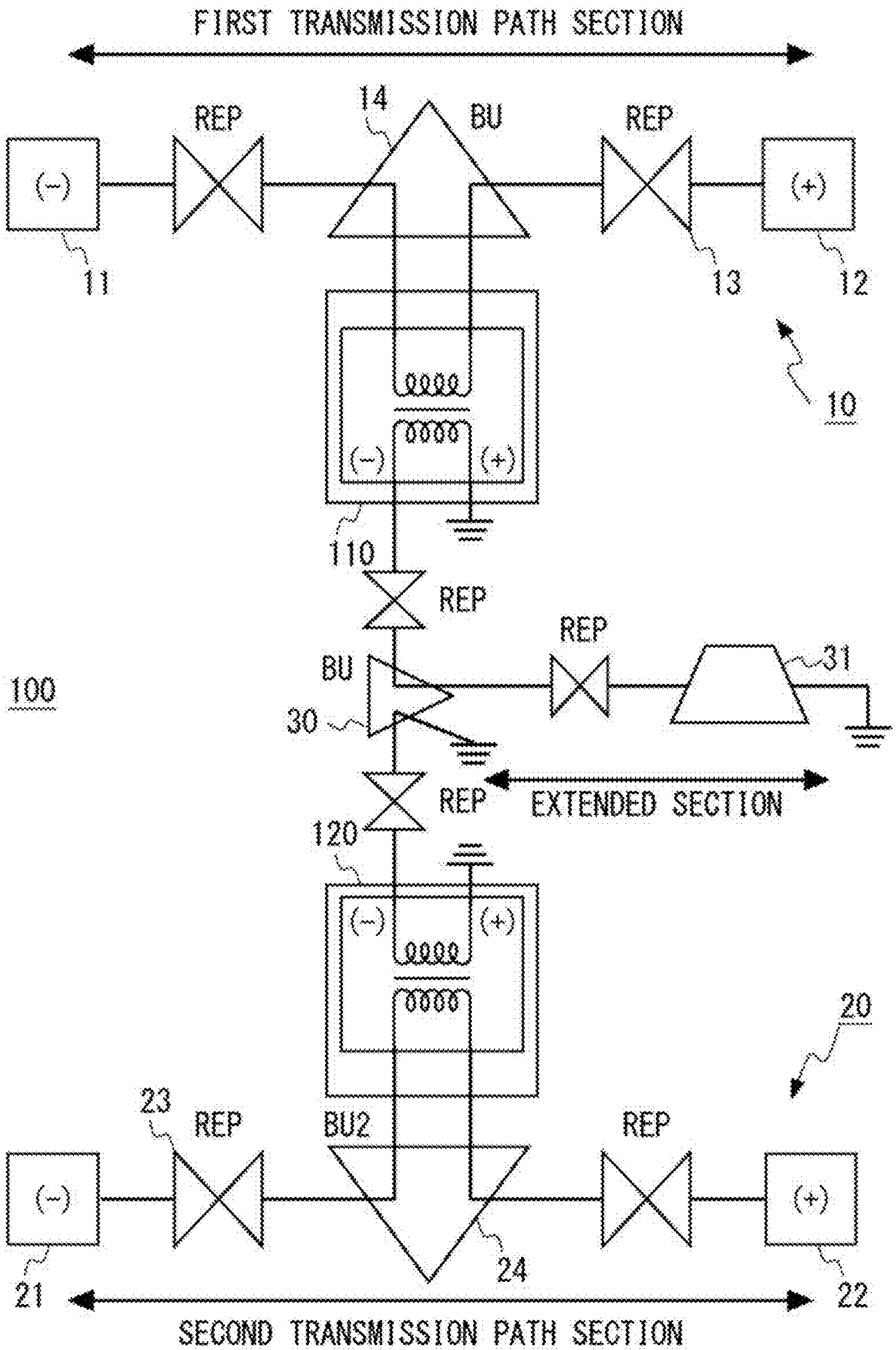
FIRST TRANSMISSION PATH SECTION
14
BU
REP
REP
(−)
(+)
11
13
12
10
(−)
(+)
110
REP
REP
BU
31
100
30
REP
EXTENDED SECTION
120
(−)
(+)
20
23
REP
BU2
REP
(−)
(+)
21
24
22
SECOND TRANSMISSION PATH SECTION

Fig. 5

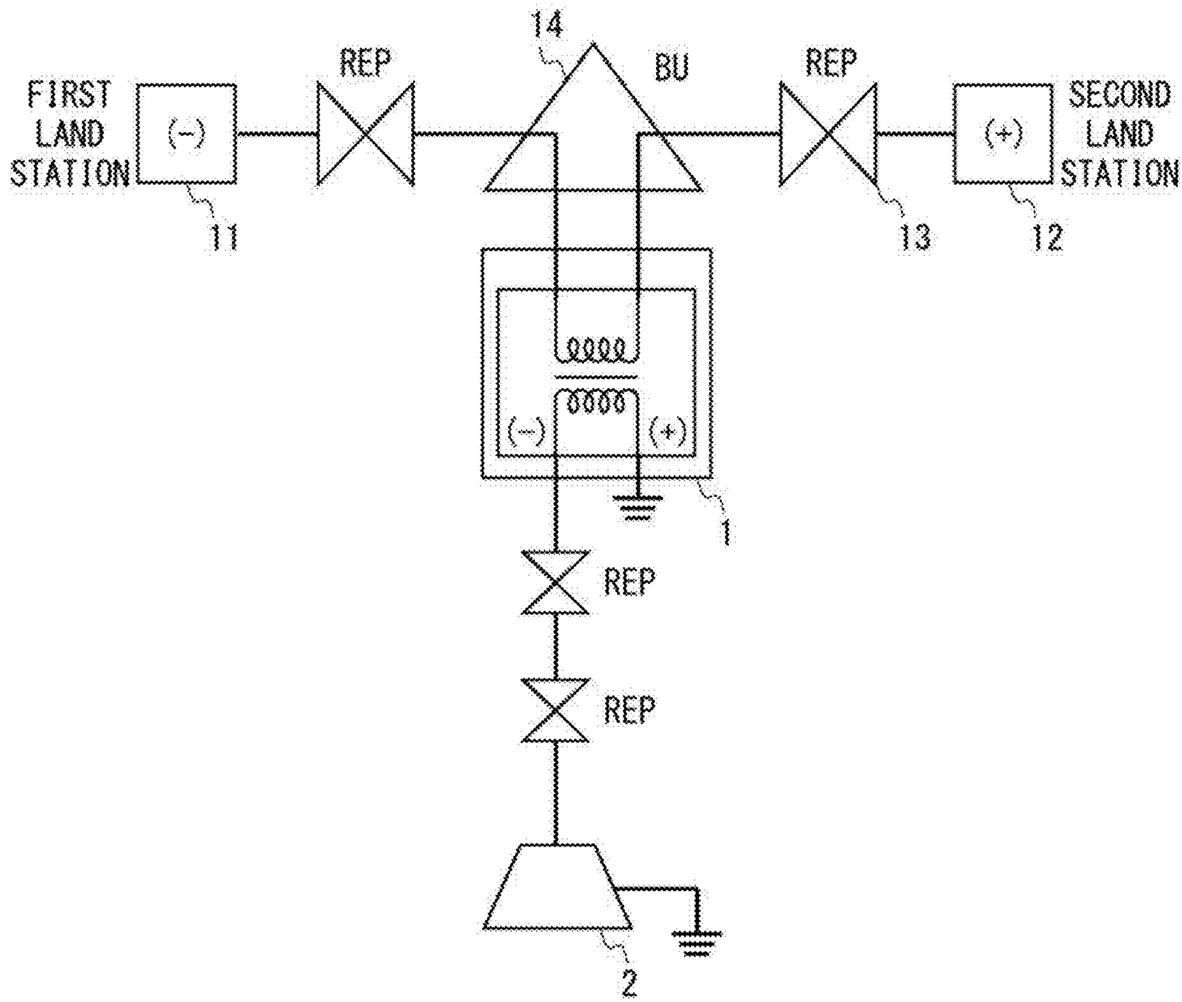
14
REP
BU
REP
FIRST
LAND
STATION
(-)
(+)
SECOND
LAND
STATION
11
13
12
(-)
(+)
1
REP
REP
2

Fig. 6

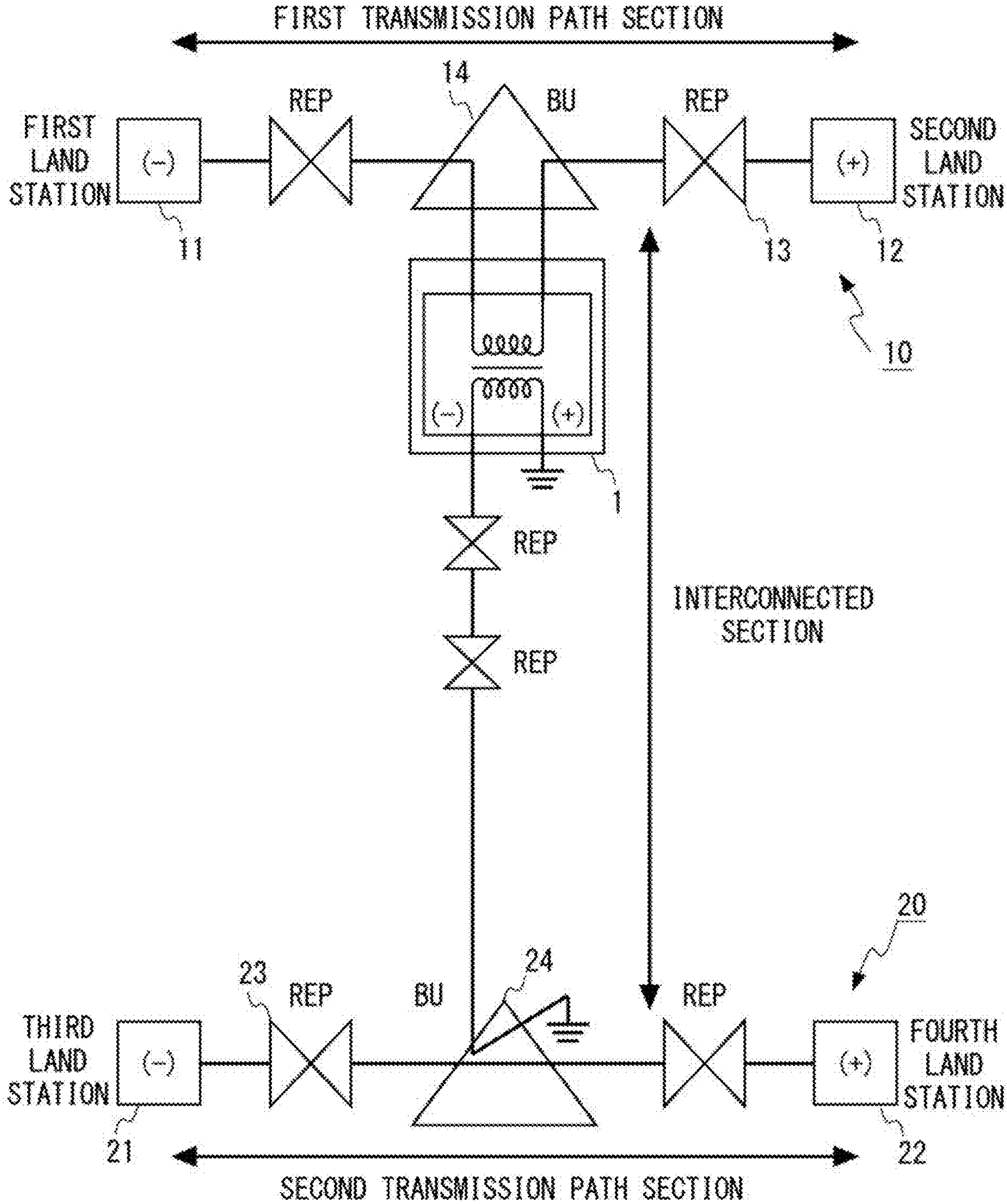
FIRST TRANSMISSION PATH SECTION
14
REP
BU
REP
FIRST LAND STATION
(−)
(+)
SECOND LAND STATION
11
13
12
10
(−)
(+)
1
REP
REP
INTERCONNECTED SECTION
20
23
24
REP
BU
REP
THIRD LAND STATION
(−)
(+)
FOURTH LAND STATION
21
22
SECOND TRANSMISSION PATH SECTION

Fig. 7

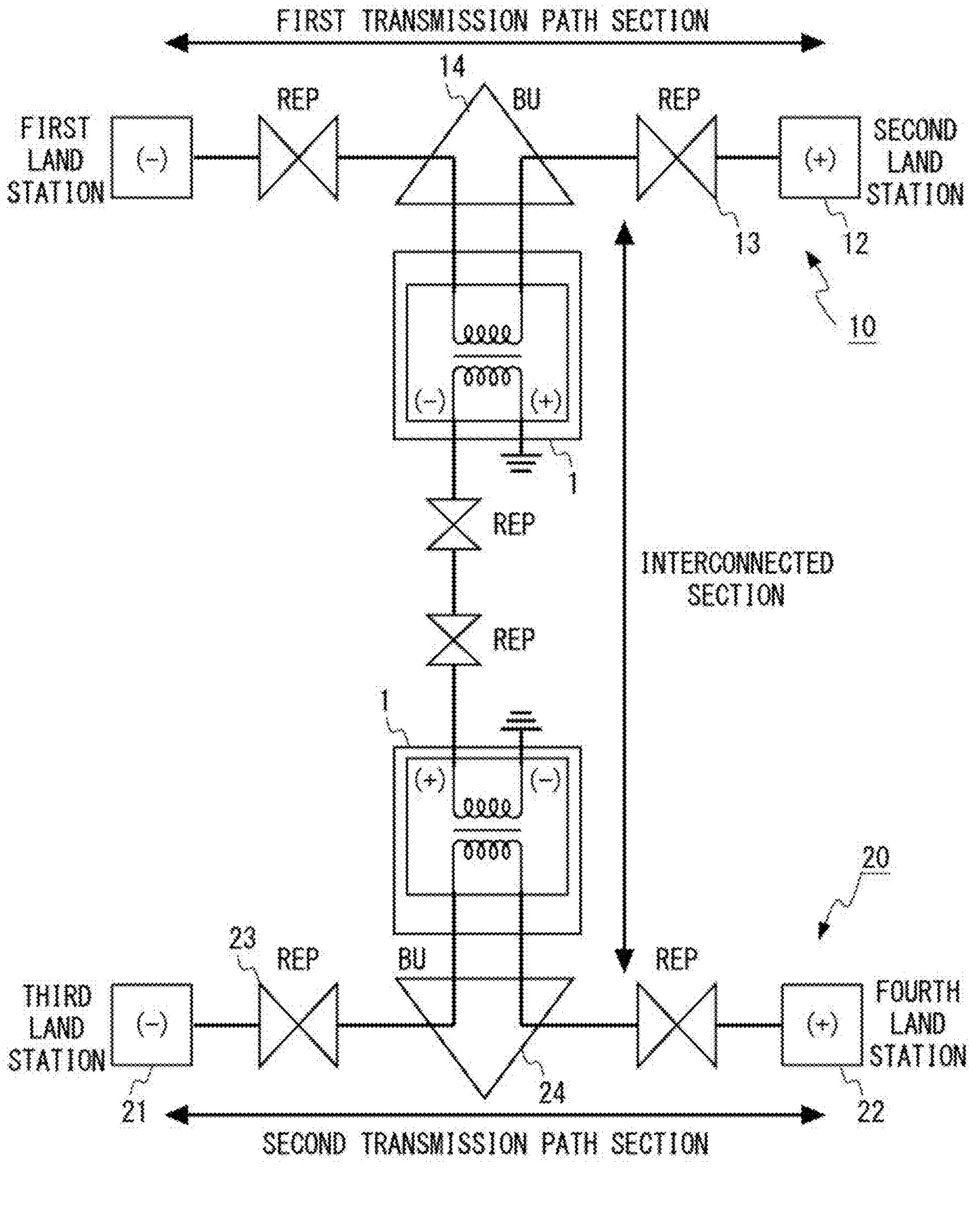
FIRST TRANSMISSION PATH SECTION
14
BU
REP
REP
FIRST LAND STATION
(−)
(+)
SECOND LAND STATION
13
12
10
(−)
(+)
1
REP
REP
INTERCONNECTED SECTION
1
(+)
(−)
20
23
REP
BU
REP
THIRD LAND STATION
(−)
(+)
FOURTH LAND STATION
21
24
22
SECOND TRANSMISSION PATH SECTION

Fig. 8

SUBMARINE DCDC CONVERTER, METHOD FOR CONTROLLING SUBMARINE DCDC CONVERTER, AND SUBMARINE CABLE SYSTEM

INCORPORATION BY REFERENCE

[0001] This application is based upon and claims the benefit of priority from Japanese patent application No. 2024-019563, filed on Feb. 13, 2024, the disclosure of which is incorporated herein in its entirety by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to a submarine DCDC converter, a method for controlling a submarine DCDC converter, and a submarine cable system.

BACKGROUND ART

[0003] In general, a submarine cable system has a configuration in which a plurality of submarine apparatuses such as repeaters and branching units are connected one after another in a chain-like manner by submarine cables. Such submarine cables are equipped with respective feeder lines. A power supply circuit of each submarine apparatus is connected to the respective feeder line so as to form a series circuit. A constant feeding current is supplied to this feeder line from feeding apparatuses provided at land stations located at both ends of the feeder line. Each submarine apparatus uses electric power corresponding to the voltage drop of the feeding current (which is disclosed, for example, in Japanese Unexamined Patent Publication No. 2017-184473 (Patent Literature 1)).

[0004] According to Patent Literature 1, each submarine apparatus includes a plurality of main DC/DC converters each of which converts first DC power supplied from the land feeding apparatus through the submarine cable into second DC power. The second DC power supplied from each main DC/DC converter is converted into third DC power by an output DC/DC converter and is then output to a respective one of a plurality of observation apparatuses. Further, on the primary side of each main DC/DC converter, a switch for switching the state on the primary side between an open state and a closed state is connected in parallel therewith. The land control apparatus switches each switch between the open state and the closed state, and by doing so, prevents electric power from being wastefully consumed.

[0005] Regarding submarine cable systems, there are cases where if a submarine cable is branched by using a submarine branching unit (BU: Branching Unit) to supply electric power to a node or the like disposed on the seabed, or if a feeding apparatus cannot be installed at the end of a branched cable, a submarine DCDC converter is provided on the branched side. The submarine DCDC converter supplies electric power to a submarine cable or a submarine apparatus disposed on the branched side.

[0006] Further, there are cases where if two submarine cable systems are connected to each other (hereinafter also expressed as “being interconnected”), a DCDC converter is provided under the sea in order to supply electric power to the interconnected section of the two submarine cables. In recent years, there has been a demand for adopting a configuration in which electric power is supplied from both ends of a feeder line (hereinafter also referred to as “both-end power supply configuration”) to such an interconnected section of two submarine cable systems as in the case of the configuration in which electric power is supplied from feeding apparatuses provided in land stations. To adopt such a both-end power supply configuration, it is necessary to arrange two DCDC converters so as to face each other in the interconnected section, and perform constant-current control so that one of the DC converters performs positive (+) outputting and the other of the DC converters performs negative (−) outputting.

[0007] As a result, there is a problem that it is necessary to prepare each of a DCDC converter for positive outputting and a DCDC converter for negative outputting. Further, it is necessary to prepare a spare apparatus for each submarine apparatus so that the submarine apparatus is replaced with the spare apparatus in case where the submarine apparatus is broken and repaired. Therefore, it is necessary to prepare a spare apparatus for each of the DCDC converter for positive outputting and the one for negative outputting.

SUMMARY

[0008] In view of the problems described above, an object of the present disclosure is to provide a submarine DCDC converter, a method for controlling a submarine DCDC converter, and a submarine cable system using them, capable of making it possible to share, i.e., to use, a common DCDC converter for both a DCDC converter for positive outputting and one for negative outputting.

[0009] A submarine DCDC converter according to the present disclosure includes a DCDC conversion circuit and a polarity switching unit. The DCDC conversion circuit supplies a first constant current input to an input terminal from a land feeding apparatus through a first submarine cable to a first output terminal, generates a second constant current using the first constant current, and supplies the generated second constant current to a second output terminal. The polarity switching unit switches a polarity of the second constant current output from the second output terminal.

[0010] A method for controlling a submarine DCDC converter according to the present disclosure includes: supplying a first constant current input to an input terminal from a land feeding apparatus through a first submarine cable to a first output terminal, generating a second constant current using the first constant current, and supplying the generated second constant current to a second output terminal; and switching a polarity of the second constant current output from the second output terminal.

[0011] A submarine cable system according to the present disclosure includes:

[0012] a first submarine cable sub-system including: two land feeding apparatuses each of which is configured to supply a first constant current to a submarine cable; a submarine branching unit configured to branch the submarine cable; and a DCDC converter to which the first constant current is supplied from the branched submarine cable. The DCDC converter includes a DCDC conversion circuit and a polarity switching unit. The DCDC conversion circuit supplies the first constant current input to an input terminal to a first output terminal, generates a second constant current using the first constant current, and supplies the generated second constant current to a second output terminal. The polarity switching unit switches a polarity of the second constant current output from the second output terminal.

BRIEF DESCRIPTION OF DRAWINGS

[0013] The above and other aspects, features and advantages of the present disclosure will become more apparent from the following description of certain exemplary example embodiments when taken in conjunction with the accompanying drawings, in which:

[0014] FIG. **1** shows an example of a configuration of a submarine cable system according to the present disclosure;

[0015] FIG. **2** shows an example of a configuration of a submarine DCDC converter shown in FIG. **1**;

[0016] FIG. **3** shows another example of a configuration of the submarine DCDC converter shown in FIG. **1**;

[0017] FIG. **4** is a diagram for explaining features of the submarine cable system shown in FIG. **1**;

[0018] FIG. **5** shows another example of a configuration of a submarine cable system according to the present disclosure;

[0019] FIG. **6** shows a configuration of a comparative submarine cable system;

[0020] FIG. **7** shows a configuration of a submarine cable system according to a comparative example; and

[0021] FIG. **8** shows the configuration of the submarine cable system according to the comparative example.

EXAMPLE EMBODIMENT

[0022] An example embodiment will be described hereinafter with reference to the drawings. Note that in the example embodiment, the same or equivalent elements are assigned the same reference numerals (or symbols), and redundant descriptions thereof will be omitted. The example embodiment relates to a submarine cable system that is laid on the seabed and supplies electric power from a feeding apparatus provided in a land station to a submarine apparatus through a submarine cable.

[0023] Firstly, a submarine cable system according to a comparative example will be described with reference to FIGS. **6** to **8**. FIGS. **6** to **8** shows the configuration of the submarine cable system according to the comparative example. As shown in FIG. **6**, in the submarine cable system according to the comparative example, a first land station and a second land station disposed on land are connected to each other by submarine cables. The submarine cable contains an optical fiber and a feeder line. The optical fiber includes a plurality of cores and transmits optical signals in both directions. Through the submarine cables, optical communication data and electric power are transmitted from the first land station located at one end of the submarine cables to the second land station located at the other end thereof. Submarine repeaters (REPs) **13** and a submarine branching unit (BU) **14** connected one after another in a chain-like manner by submarine cables are provided in a transmission path section between a first land feeding apparatus **11** and a second land feeding apparatus **12**.

[0024] The first land feeding apparatus **11** is provided in the first land station, and the second land feeding apparatus **12** is provided in the second land station. The first and second land feeding apparatuses **11** and **12** perform both-end power supply using polarities different from each other. In the example shown in FIG. **6**, the polarity of the first land feeding apparatus **11** is negative (−), and the polarity of the second land feeding apparatus **12** is positive (+). For a submarine apparatus such as the submarine repeater **13**, electric power necessary for its operation is supplied through a feeder contained in the submarine cable. A constant current supplied between the first and second land stations is called a feeding current.

[0025] The submarine branching unit **14** branches the submarine cable and supplies electric power to a submarine node **2** disposed located on the seabed. As described above, if the submarine cable is branched in order to supply electric power to the submarine node **2** by using the submarine branching unit **14**, a submarine DCDC converter **1** is provided between the submarine branching unit **14** and the submarine node **2**. The submarine DCDC converter **1** includes a transformer for converting a first constant current supplied through the submarine cable on the branched side into a second constant current. The output electric power output from the submarine DCDC converter **1** is supplied to the submarine node **2** through the submarine repeater **13**. Such a submarine DCDC converter **1** may also be provided even in a case where the end, i.e., the destination, of the branched cable is in an isolated island or the like and hence the construction work thereof is restricted, so that a feeding apparatus cannot be provided there.

[0026] Further, as shown in FIG. **7**, there is a case where a first submarine cable sub-system **10** and a second submarine cable sub-system **20** are interconnected, i.e., connected to each other. Note that the configurations of a first land feeding apparatus **11**, a second land feeding apparatus **12**, a submarine repeater **13**, and a submarine branching unit **14** of the first submarine cable sub-system **10** and the configurations of a third land feeding apparatus **21**, a fourth land feeding apparatus **22**, a submarine repeater **23**, and a submarine branching unit **24** of the second submarine cable sub-system **20** may be identical to each other. As described above, the submarine DCDC converter **1** may be used in order to supply electric power to the interconnected section of two submarine cables.

[0027] There is a demand for adopting a both-end power supply configuration even to such an interconnected section of two submarine cable systems as in the case of the configuration in which electric power is supplied from the first and second land feeding apparatuses **11** and **12** provided in the land stations. To adopt such a both-end power supply configuration, it is necessary to arrange two submarine DCDC converters **1** so as to face each other in the interconnected section, and perform constant-current control so that one of the DC converters **1** performs positive (+) outputting and the other of the DC converters **1** performs negative (−) outputting.

[0028] By adopting the both-end power supply configuration as described above, even if a ground fault failure occurs in the interconnected section of submarine cables, electric power is supplied from each of the two submarine DCDC converters **1** to the failed part, thus making it possible to maintain the supply of electric power in the interconnected section. However, as shown in FIG. **8**, there is a problem that it is necessary to prepare each of a submarine DCDC converter for positive outputting and one for negative outputting. Further, it is necessary to prepare a spare apparatus for each submarine apparatus so that the submarine apparatus is replaced with the spare apparatus if the submarine apparatus is broken and repaired. Therefore, it is necessary to prepare a spare apparatus for each of the marine DCDC converter for positive outputting and the one for negative outputting. Therefore, the inventors of the present disclosure have conceived a configuration described below in order to share, i.e., to use, a common submarine DCDC converter for both a DCDC converter for positive outputting and one for negative outputting.

[0029] A submarine cable system **100** according to the present disclosure will be described hereinafter with reference to the drawings. Note that in the example of the submarine cable system **100** shown below, it is assumed that a first land station and a second land station both of which are located on land are connected to each other by submarine cables, and thereby forming a first transmission path section of a first submarine cable sub-system **10**, and a third land station and a fourth land station are connected to each other by submarine cables, and thereby forming a second transmission path section of a second submarine cable sub-system **20**.

[0030] The first land station includes the first land feeding apparatus **11**; the second land station includes the second land feeding apparatus **12**; the third land station includes the submarine repeater **13**; and the fourth land station includes the submarine branching unit **14**. In the first transmission path section, optical communication data and electric power are transmitted between the first land station located at one end and the second land station located at the other end. Further, in the second transmission path section, optical communication data and electric power are transmitted from the third land station located at one end to the fourth land station located at the other end.

[0031] FIG. **1** shows an example of a configuration of the submarine cable system **100** according to the present disclosure. As shown in FIG. **1**, the submarine cable system **100** includes a first submarine cable sub-system **10** and a second submarine cable sub-system **20**. Similarly to the configuration described above, each of the first and second submarine cable sub-systems **10** and **20** performs both-end power supply. The first submarine cable sub-system **10** includes the first land feeding apparatus **11**, the second land feeding apparatus **12**, the submarine repeater **13**, the submarine branching unit **14**, and a first submarine DCDC converter **110**. The first and second land feeding apparatuses **11** and **12** are connected to each other by submarine cables. The submarine repeater **13** and the submarine branching unit **14** connected one after another in a chain-like manner by a submarine cable are provided in a transmission path section between the first and second land feeding apparatuses **11** and **12**.

[0032] The second submarine cable sub-system **20** includes the third land feeding apparatus **21**, the fourth land feeding apparatus **22**, the submarine repeater **23**, the submarine branching unit **24**, and a second submarine DCDC converter **120**. The submarine repeater **23** and the submarine branching unit **24** connected one after another in a chain-like manner by a submarine cable are provided in a transmission path section between the third and fourth land feeding apparatuses **21** and **22** connected to each other by submarine cables.

[0033] As described above, the first and second submarine cable sub-systems **10** and **20** may have configurations roughly identical to each other. The configuration of the first submarine cable sub-system **10** will be described hereinafter while omitting redundant descriptions for simplifying the explanation.

[0034] In a case where the submarine repeater **13** transmits an optical signal from one of the land stations to the other land station, it compensates for the attenuation or degradation of the optical signal that occurs during the propagation thereof by reamplifying, regenerating, and reshaping the optical signal. Note that the number of components such as the submarine repeater **13** in the first submarine cable sub-system **10** is not limited to the number in this example. Further, the submarine cable system **100** may include other components not shown in FIG. **1**.

[0035] The first and second submarine cable sub-systems **10** and **20** are interconnected between the submarine branching unit **14** and the submarine branching unit **24**. The transmission path section in which the first and second submarine cable sub-systems **10** and **20** are interconnected is referred to as an interconnected section. Electric power is supplied to the interconnected section by the submarine branching unit **14** and the submarine branching unit **24**, and the first submarine DCDC converter **110** and the second submarine DCDC converter **120** provided between the submarine branching unit **14** and the submarine branching unit **24**.

[0036] The first submarine DCDC converter **110** performs negative outputting under constant-current control, and the second submarine DCDC converter **120** performs positive outputting under constant-current control. The output terminals of the first and second submarine DCDC converters **110** and **120** are connected to each other with two submarine repeaters interposed therebetween. In this way, both-end power supply can be performed in the interconnected section.

[0037] FIG. **2** shows a configuration of the first submarine DCDC converter **110**. Note that the second submarine DCDC converter **120** may have a configuration similar to that shown in FIG. **2**. The first submarine DCDC converter **110** includes an input terminal **101**, a first output terminal **102**, a rectification circuit **103**, a control circuit **104**, a DCDC conversion circuit **105**, a first switch **106**, a second switch **107**, a second output terminal **108**, a ground terminal **109**, and an optical coupler **111**. The feeding current supplied from the first submarine cable sub-system **10** is input to the input terminal **101** through the submarine branching unit **14**.

[0038] The feeding current input to the input terminal **101** is rectified by the rectification circuit **103** irrespective of the direction of the feeding. The rectified current is input to the control circuit **104**. The control circuit **104** controls the DCDC conversion circuit **105**, the first switch **106**, and the second switch **107**. The DCDC conversion circuit **105** includes a transformer including a primary winding provided on the side on which the first output terminal **102** is located and a secondary winding provided on the side on which the second output terminal **108** is located. The DCDC conversion circuit **105** supplies a first constant current input to the primary winding side to the first output terminal **102**, converts this first constant current into a second constant current, and outputs the second constant current to the secondary winding side. Electric power is supplied to the submarine cable under the constant-current control using a DC current, so that electric power equivalent to a value obtained by multiplying the electric power input to the primary winding of the DCDC conversion circuit **105** by the conversion efficiency thereof is obtained as the electric power on the secondary winding side.

[0039] One of the positive and negative outputs of the power supply on the secondary side is connected to the second output terminal **108** and the other is connected to the ground terminal **109**. The second output terminal **108** is connected to the submarine cable in the interconnected section, and the ground terminal **109** is connected to the underwater ground electrode (sea earth). The first and second switches **106** and **107** are switches for switching the polarity of the output current output from the second output terminal **108** according to the control by the control circuit **104**. That is, the first switch **106**, the second switch **107**, and the control circuit **104** constitute a polarity switching unit.

[0040] The first switch **106** is provided between the first terminal (negative (−) terminal in this example) on the secondary winding side of the DCDC conversion circuit **105** and the second output terminal **108**. The second switch **107** is provided between the second terminal (positive (+) terminal in this example) on the secondary winding side of the DCDC conversion circuit **105** and the ground terminal **109**. A high-voltage relay for switching a feeding path can be used as each of the first and second switches **106** and **107**. Note that since the first and second switches **106** and **107** operate simultaneously with each other, a double-pole double-throw switch is preferably used for them.

[0041] The optical coupler **111** branches a remote-control signal transmitted from the land station through an optical fiber for communication contained in the submarine cable in the interconnected section, and outputs the branched remote-control signal to the control circuit **104**. The control circuit **104** switches the connection state of the first and second switches **106** and **107** based on the remote-control signal. Specifically, the control circuit **104** switches the connection state between a first state in which the first switch **106** connects the negative terminal to the second output terminal **108** and the second switch **107** connects the positive terminal to the ground terminal **109**, and a second state in which the first switch **106** connects the negative terminal to the ground terminal **109** and the second switch **107** connects the positive terminal to the second output terminal **108**.

[0042] The first and second submarine DCDC converters **110** and **120** have configurations identical to each other. In the case of the first submarine DCDC converter **110** for negative outputting shown in FIG. **1**, the control circuit **104** connects the negative terminal to the second output terminal **108** and connects the positive terminal to the ground terminal **109** (first state) by switching the first and second switches **106** and **107**. Further, in the case of the second submarine DCDC converter **120** for positive outputting shown in FIG. **1**, the control circuit **104** connects the positive terminal to the second output terminal **108** and connects the negative terminal to the ground terminal **109** (second state) by switching the first and second switches **106** and **107**. Since the control circuit **104** switches the first and second switches **106** and **107** as described above, it becomes possible to share, i.e., to use, the configuration of a common submarine DCDC converter for both a DCDC converter for positive outputting and one for negative outputting.

[0043] FIG. **3** shows another example of the configuration of the submarine DCDC converter shown in FIG. **1**. In the example shown in FIG. **3**, the first submarine DCDC converter **110** includes a conversion unit **112** including a rectification circuit **103**, a control circuit **104**, and a DCDC conversion circuit **105**, and also includes a cable connection part **200**. The cable connection part **200** is disposed outside the conversion unit **112**.

[0044] A unit in which an electric circuit is provided, such as the conversion unit **112**, is usually housed in a housing such as a metal pressure-resistant container capable of dissipating heat therethrough as in the case of the submarine repeater **13** or the like, covered with a pressure-resistant lid, sealed by welding, and then shipped from the factory. The cable connection part **200** serves as a connection part between such a conversion unit **112** and a submarine cable. The cable connection part **200** may be a cable coupling part or a cable joint part.

[0045] The cable coupling part is a connection part including a flexible wire called a tail cable, which is obtained by combining an optical fiber and a feeder line, and is made so as to withstand a high water pressure in the deep sea. Further, the cable joint part is a Universal Joint or the like specified and supplied by an industrial organization called Universal Jointing (UJ) Consortium. A cable coupling part used for the connection with a submarine cable may be connected to the conversion unit **112**. Further, a cable joint part may be connected to the joint part of a connection between cables. A switching unit **201** for switching the polarity of a constant current output from the second output terminal is provided in the cable connection part **200**.

[0046] In a case where a feeding current is input from a land feeding apparatus of the first submarine cable sub-system **10** or the second submarine cable sub-system **20** to the input terminal **101**, the rectification circuit **103** rectifies the feeding current irrespective of the direction of the feeding. The rectified current is input to the control circuit **104**. The control circuit **104** controls the DCDC conversion circuit **105**.

[0047] The DCDC conversion circuit **105** includes a transformer including a primary winding provided on the side on which the first output terminal **102** is located and a secondary winding provided on the side on which the second output terminal **108** is located. The DCDC conversion circuit **105** supplies a first constant current input to the primary winding side to the first output terminal **102**, converts this first constant current into a second constant current, and outputs the second constant current to the secondary winding side. Electric power is supplied to the submarine cable under the constant-current control using a DC current, so that electric power equivalent to a value obtained by multiplying the electric power input to the primary winding of the DCDC conversion circuit **105** by the conversion efficiency thereof is obtained as the electric power on the secondary winding side. One of the positive and negative outputs of the power supply on the secondary side is connected to the second output terminal **108** and the other is connected to the ground terminal **109**.

[0048] In the example shown in FIG. **3**, the switching unit **201** provided in the cable connection part **200** functions as a polarity switching unit. The switching unit **201** can switch the polarity of an output current output from the second output terminal **108**. Specifically, the polarity of the output current output from the second output terminal **108** is switched by switching the connection of the feeder line provided in the above-described cable coupling part or the cable joint part. In the case of the first submarine DCDC converter **110** for negative outputting shown in FIG. **1**, the switching unit **201** connects the negative terminal to the second output terminal **108** and connects the positive terminal to the ground terminal **109** (first state). Further, in the case of the second submarine DCDC converter **120** for positive outputting shown in FIG. **1**, the switching unit **201** connects the positive terminal to the second output terminal **108** and connects the negative terminal to the ground terminal **109** (second state).

[0049] As described above, according to the configuration shown in FIG. **3**, it is possible to switch the destination of the connection of the output on the secondary side of the DCDC conversion circuit **105** between the second output terminal **108** and the ground terminal **109** by switching the connection of the feeder line in the switching unit **201** provided in the cable connection part **200** disposed outside the housing without adding any other configuration in the first submarine DCDC converter **110** housed in the housing, and thereby to share, i.e., to use, the configuration of a common submarine DCDC converter for both a DCDC converter for positive outputting and one for negative outputting. In this case, the current apparatus, i.e., the existing apparatus, can also be used as the conversion unit **112**. It is sufficient if the switching unit **201** is provided in the cable connection part **200** disposed outside the conversion unit **112** in a laying construction work which will be carried out later.

[0050] Note that the cable connection part **200** described above with reference to FIG. **3** is usually located several kilometers away from the first submarine DCDC converter **110**. In a case where the polarity of the output current is to be changed, there is no need to pull up the first submarine DCDC converter **110** from the seabed. That is, only the cable connection part **200** is pulled up onto a ship and disassembled, and the connection of the feeder line of the switching unit **201** is switched. After the connection of the feeder line is switched, the switching unit **201** is sealed again in the cable connection part **200**, and the cable connection part **200** is submerged to the seabed. In this way, it is possible to switch the polarity of the current output from the second output terminal **108** without pulling up the first submarine DCDC converter **110** itself.

[0051] FIG. **4** is a diagram for explaining features of the submarine cable system shown in FIG. **1**. Assuming that the limit of the output of one submarine DCDC converter **1** is X kW. Then, if one submarine DCDC converter **1** is provided in an interconnected section as shown in FIG. **7**, the maximum electric power that can be supplied to the submarine cable and the repeater in the interconnected section is X kW. Note that it is conceivable that if the distance between the first and second submarine cable sub-systems **10** and **20** is large, the maximum power feeding capacity, which is X kW, is insufficient.

[0052] As shown in FIG. **4**, if the submarine cable system **100** adopts a both-end power supply configuration using two submarine DCDC converters, i.e., first and second submarine DCDC converters **110** and **120**, it is possible to supply electric power twice as much as that can be supplied by one submarine DCDC converter, i.e., to supply electric power that can be supplied by two submarine DCDC converters, even if the limit of the output of one first submarine DCDC converter **110** is X kW. In this way, it is possible to supply electric power to a submarine cable in a longer interconnected section. That is, in the case where the distance between the first and second submarine cable sub-systems **10** and **20** is large and the power feeding capacity of one submarine DCDC converter is not sufficient, it is possible to supply electric power to a longer interconnected section by adopting the configuration shown in FIG. **4**.

[0053] FIG. **5** shows another example of a configuration of a submarine cable system according to the present disclosure. In the example shown in FIG. **5**, a submarine branching unit **30** is provided between first and second submarine DCDC converters **110** and **120** in an interconnected section. In an extended part branched from the submarine branching unit **30**, a submarine node **31** is provided at the end of the submarine cable.

[0054] As shown in FIG. **5**, the submarine branching unit **30** and the submarine node **31** are connected to an underwater ground electrode. Note that the underwater ground electrode must be fed with negative electric power. This is because if the underwater ground electrode is fed with positive electric power, the underwater ground electrode is gradually dissolved. As shown in FIG. **5**, even if the configuration of the submarine cable system **100** is extended in the future, it is possible to continuously use the submarine cable system **100** as it is by changing the output polarities of the first and second submarine DCDC converters **110** and **120** without replacing the apparatus.

[0055] As described above, according to the present disclosure, it is possible to share, i.e., to use, the configuration of a common submarine DCDC converter as both of two submarine DCDC converters used for both-end power supply to an interconnected section between two submarine cable sub-systems. As a result, it is possible to reduce the cost for a spare apparatus for a submarine DCDC converter. Further, the spare apparatus can be used as either a submarine DCDC converter having a positive polarity or one having a negative polarity. Therefore, even in the case where a submarine DCDC converter is broken or damaged before being laid, it is possible to reduce the occurrence of a delay from the schedule related to the laying of the submarine cable system.

[0056] Further, in the case where the distance between two submarine cable sub-systems is large and the power feeding capacity of one submarine DCDC converter is insufficient, it is possible to increase the power feeding capacity by adding a submarine DCDC converter according to the present disclosure in an interconnected section, and thereby to supply electric power to a longer interconnected section. Further, even in the case where the submarine cable system is expanded in the future, it is possible to continuously use the apparatus already-laid on the seabed as it is without replacing the submarine DCDC converter.

[0057] Note that the present invention is not limited to the above-described example embodiment, and it can be modified as appropriate without departing from the scope and sprit of the invention.

[0058] According to the present disclosure, it is possible to share, i.e., to use, a common DCDC converter for both a DCDC converter for positive outputting and one for negative outputting.

[0059] While the disclosure has been particularly shown and described with reference to example embodiments thereof, the disclosure is not limited to these example embodiments. It will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present disclosure as defined by the claims. The whole or part of the exemplary example embodiments disclosed above can be described as, but not limited to, the following supplementary notes.

(Supplementary Note 1)

[0060] A submarine DCDC converter comprising:

[0061] a DCDC conversion circuit configured to supply a first constant current input to an input terminal from a land feeding apparatus through a first submarine cable to a first output terminal, generate a second constant current using the first constant current, and supply the generated second constant current to a second output terminal; and

[0062] a polarity switching unit configured to switch a polarity of the second constant current output from the second output terminal.

(Supplementary Note 2)

[0063] The submarine DCDC converter described in Supplementary note 1, wherein

[0064] the DCDC conversion circuit comprises a transformer including a primary winding provided on a side on which the first output terminal is located and a secondary winding provided on a side on which the second output terminal is located, and

[0065] the polarity switching unit comprises:

[0066] a first switch disposed between a first terminal of the secondary winding and the second output terminal; and

[0067] a second switch disposed between a second terminal of the secondary winding and the second output terminal.

(Supplementary Note 3)

[0068] The submarine DCDC converter described in Supplementary note 2, wherein the polarity switching unit switches a state of the submarine DCDC converter between

[0069] a first state in which the first switch connects the first terminal to the second output terminal, and the second switch connects the second terminal to an underwater ground electrode, and

[0070] a second state in which the first switch connects the first terminal to the underwater ground electrode, and the second switch connects the second terminal to the second output terminal.

(Supplementary Note 4)

[0071] The submarine DCDC converter described in Supplementary note 1, wherein the polarity switching unit is disposed outside the DCDC conversion circuit and is disposed in a cable connection part configured to connect an output of the DCDC conversion circuit to the second output terminal.

(Supplementary Note 5)

[0072] The submarine DCDC converter described in Supplementary note 2, further comprising a rectification circuit connected to both ends of the primary winding of the transformer and configured to rectify a current flowing through the primary winding.

(Supplementary Note 6)

[0073] A method for controlling a submarine DCDC converter, comprising:

[0074] supplying a first constant current input to an input terminal from a land feeding apparatus through a first submarine cable to a first output terminal, generating a second constant current using the first constant current, and supplying the generated second constant current to a second output terminal; and

[0075] switching a polarity of the second constant current output from the second output terminal.

(Supplementary Note 7)

[0076] A submarine cable system comprising:

[0077] a first submarine cable sub-system comprising:

[0078] two land feeding apparatuses each of which is configured to supply a first constant current to a submarine cable;

[0079] a submarine branching unit configured to branch the submarine cable; and

[0080] a DCDC converter to which the first constant current is supplied from the branched submarine cable, wherein

[0081] the DCDC converter comprising:

[0082] a DCDC conversion circuit configured to supply the first constant current input to an input terminal to a first output terminal, generate a second constant current using the first constant current, and supply the generated second constant current to a second output terminal; and

[0083] a polarity switching unit configured to switch a polarity of the second constant current output from the second output terminal.

(Supplementary Note 8)

[0084] The submarine cable system described in Supplementary note 7, further comprising a second submarine cable sub-system having a configuration similar to that of the first submarine cable sub-system, wherein

[0085] DCDC converters are arranged so as to face each other in an interconnected section between the first and second submarine cable sub-systems, and

[0086] a polarity of a current output from one of the DCDC converters is different from that of a current output from the other DCDC converter.

(Supplementary Note 9)

[0087] The submarine cable system described in Supplementary note 8, wherein

[0088] the DCDC conversion circuit comprises a transformer including a primary winding provided on a side on which the first output terminal is located and a secondary winding provided on a side on which the second output terminal is located,

[0089] the polarity switching unit comprises:

[0090] a first switch disposed between a first terminal of the secondary winding and the second output terminal; and

[0091] a second switch disposed between a second terminal of the secondary winding and the second output terminal,

[0092] the polarity switching unit switches a state of the submarine DCDC converter between

[0093] a first state in which the first switch connects the first terminal to the second output terminal, and the second switch connects the second terminal to an underwater ground electrode, and

[0094] a second state in which the first switch connects the first terminal to the underwater ground electrode, and the second switch connects the second terminal to the second output terminal, and

[0095] the first submarine cable sub-system is in one of the first and second states, and the second submarine cable sub-system is in the other of the first and second states.

(Supplementary Note 10)

[0096] The submarine cable system described in Supplementary note 8, further comprising:

[0097] a branching unit configured to branch a connection cable connecting two DCDC converters to each other; and

[0098] a submarine apparatus to which electric power is supplied through the branching unit.

What is claimed is:

1. A submarine DCDC converter comprising:

a DCDC conversion circuit configured to supply a first constant current input to an input terminal from a land feeding apparatus through a first submarine cable to a first output terminal, generate a second constant current using the first constant current, and supply the generated second constant current to a second output terminal; and

a polarity switching unit configured to switch a polarity of the second constant current output from the second output terminal.

2. The submarine DCDC converter according to claim **1**, wherein

the DCDC conversion circuit comprises a transformer including a primary winding provided on a side on which the first output terminal is located and a secondary winding provided on a side on which the second output terminal is located, and

the polarity switching unit comprises:

a first switch disposed between a first terminal of the secondary winding and the second output terminal; and

a second switch disposed between a second terminal of the secondary winding and the second output terminal.

3. The submarine DCDC converter according to claim **2**, wherein the polarity switching unit switches a state of the submarine DCDC converter between

a first state in which the first switch connects the first terminal to the second output terminal, and the second switch connects the second terminal to an underwater ground electrode, and

a second state in which the first switch connects the first terminal to the underwater ground electrode, and the second switch connects the second terminal to the second output terminal.

4. The submarine DCDC converter according to claim **1**, wherein the polarity switching unit is disposed outside the DCDC conversion circuit and is disposed in a cable connection part configured to connect an output of the DCDC conversion circuit to the second output terminal.

5. The submarine DCDC converter according to claim **2**, further comprising a rectification circuit connected to both ends of the primary winding of the transformer and configured to rectify a current flowing through the primary winding.

6. A method for controlling a submarine DCDC converter, comprising:

supplying a first constant current input to an input terminal from a land feeding apparatus through a first submarine cable to a first output terminal, generating a second constant current using the first constant current, and supplying the generated second constant current to a second output terminal; and

switching a polarity of the second constant current output from the second output terminal.

7. A submarine cable system comprising:

a first submarine cable sub-system comprising:

two land feeding apparatuses each of which is configured to supply a first constant current to a submarine cable;

a submarine branching unit configured to branch the submarine cable; and

a DCDC converter to which the first constant current is supplied from the branched submarine cable, wherein

the DCDC converter comprising:

a DCDC conversion circuit configured to supply the first constant current input to an input terminal to a first output terminal, generate a second constant current using the first constant current, and supply the generated second constant current to a second output terminal; and

a polarity switching unit configured to switch a polarity of the second constant current output from the second output terminal.

8. The submarine cable system according to claim **7**, further comprising a second submarine cable sub-system having a configuration similar to that of the first submarine cable sub-system, wherein

DCDC converters are arranged so as to face each other in an interconnected section between the first and second submarine cable sub-systems, and

a polarity of a current output from one of the DCDC converters is different from that of a current output from the other DCDC converter.

9. The submarine cable system according to claim **8**, wherein

the DCDC conversion circuit comprises a transformer including a primary winding provided on a side on which the first output terminal is located and a secondary winding provided on a side on which the second output terminal is located,

the polarity switching unit comprises:

a first switch disposed between a first terminal of the secondary winding and the second output terminal; and

a second switch disposed between a second terminal of the secondary winding and the second output terminal,

the polarity switching unit switches a state of the submarine DCDC converter between

a first state in which the first switch connects the first terminal to the second output terminal, and the second switch connects the second terminal to an underwater ground electrode, and

a second state in which the first switch connects the first terminal to the underwater ground electrode, and the second switch connects the second terminal to the second output terminal, and

the first submarine cable sub-system is in one of the first and second states, and the second submarine cable sub-system is in the other of the first and second states.

10. The submarine cable system according to claim **8**, further comprising:

a branching unit configured to branch a connection cable connecting two DCDC converters to each other; and

a submarine apparatus to which electric power is supplied through the branching unit.

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