

(12) 按照专利合作条约所公布的国际申请

(19) 世界知识产权组织
国际局

(43) 国际公布日
2021 年 10 月 21 日 (21.10.2021)



(10) 国际公布号
WO 2021/208141 A1

(51) 国际专利分类号:

H02J 3/38 (2006.01)

(21) 国际申请号: PCT/CN2020/087324

(22) 国际申请日: 2020 年 4 月 27 日 (27.04.2020)

(25) 申请语言: 中文

(26) 公布语言: 中文

(30) 优先权:

PCT/CN2020/085212

2020年4月16日 (16.04.2020) CN

(71) 申请人: 华为技术有限公司 (HUAWEI TECHNOLOGIES CO., LTD.) [CN/CN]; 中国广东省深圳市龙岗区坂田华为总部办公楼, Guangdong 518129 (CN)。

(72) 发明人: 张彦忠 (ZHANG, Yanzhong); 中国广东省深圳市龙岗区坂田华为总部办公楼, Guangdong 518129 (CN)。高拥兵 (GAO, Yongbing); 中国广东省深圳市龙岗区坂田华为总部办

公楼, Guangdong 518129 (CN)。王勋 (WANG, Xun); 中国广东省深圳市龙岗区坂田华为总部办公楼, Guangdong 518129 (CN)。欣普夫纳罗兰 (HUEMPFNER, Roland); 中国广东省深圳市龙岗区坂田华为总部办公楼, Guangdong 518129 (CN)。

(74) 代理人: 深圳市深佳知识产权代理事务所 (普通合伙) (SHENPAT INTELLECTUAL PROPERTY AGENCY); 中国广东省深圳市罗湖区南湖街道春风路庐山大厦B座18C2、18D、18E、18E2, Guangdong 518001 (CN)。

(81) 指定国 (除另有指明, 要求每一种可提供的国家保护): 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,

(54) Title: POWER SUPPLY SYSTEM

(54) 发明名称: 一种电源系统

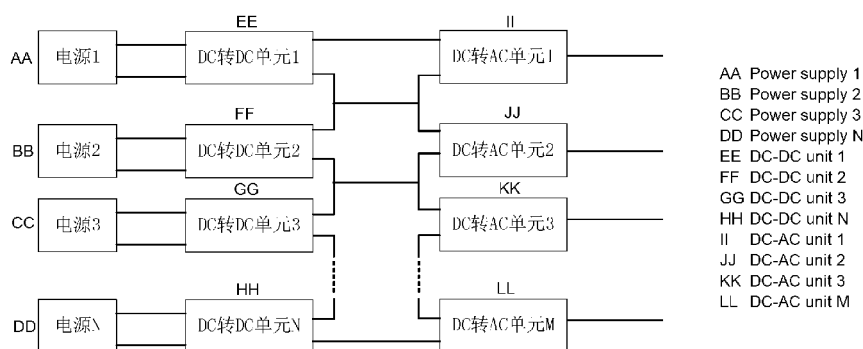


图 16

(57) Abstract: Embodiments of the present application provide a power supply system. By means of cascade of output ends of power supplies or DC-DC units, the output voltage is increased, the current between the power supplies or DC-DC units and DC-AC units is decreased, and the problems of costs and losses of cables from the power supplies or DC-DC units to the DC-AC units are solved. Moreover, the power supply system provided by the embodiments of the present application can also reduce the number of the cables from the power supplies or DC-DC units to the DC-AC units by means of cascade of the output ends of the power supplies or DC-DC units and input cascade of the DC-AC units, thereby reducing system costs. Moreover, in the power supply system provided by the embodiments of the present application, the input cascade and output isolation of the DC-AC units can reduce the specifications of a power conversion device. The problems of inadequate specifications and high cost of power conversion devices in existing industry are solved. In addition, the power supply system provided in some embodiments can also solve the problem of Potential Induced Degradation (PID) caused by a negative voltage of a battery plate to the ground when the system is running.

PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL,
ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US,
UZ, VC, VN, WS, ZA, ZM, ZW。

- (84) 指定国(除另有指明, 要求每一种可提供的地区
保护): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ,
NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), 欧亚 (AM,
AZ, BY, KG, KZ, RU, TJ, TM), 欧洲 (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)。

本国际公布:

- 包括国际检索报告(条约第21条(3))。

(57) 摘要: 本申请实施例提供一种电源系统, 通过电源或DC转DC单元的输出端级联的方式, 提高输出电压, 降低电源或DC转DC单元与DC转AC单元之间的电流, 解决电源或DC转DC单元到DC转AC单元线缆成本 and 损耗问题。同时, 本申请实施例提供的电源系统还可以通过电源或DC转DC单元的输出端级联、DC转AC单元输入级联的方式, 减少电源或DC转DC单元到DC转AC单元线缆数量, 从而降低系统成本。并且, 本申请实施例提供的电源系统中, DC转AC单元的输入级联, 输出隔离, 能够降低功率转换器件规格。解决现有行业功率变换器件规格不够, 成本高的问题。此外, 一些实施例中提供的电源系统还可以解决系统运行时, 电池板对地存在负电压导致的电势诱导衰减(Potential Induced Degradation, PID)问题。

POWER SYSTEM

[0001] This application claims priority to PCT Patent Application No. PCT/CN2020/085212, filed with the China National Intellectual Property Administration on April 16, 2020 and entitled "POWER SYSTEM", which is incorporated herein by reference in its entirety.

5

TECHNICAL FIELD

[0002] This application relates to the field of circuit technologies, and in particular, to a power system.

BACKGROUND

[0003] Photovoltaic power generation is more widely used because it has less pollution than conventional fossil energy. In power generation systems, three-phase grid-connected photovoltaic inverters are mainly used during application due to mature technologies in terms of performance, reliability, management, and the like of connected photovoltaic arrays. With the adjustment of grid-connected photovoltaic power price policies, higher requirements are raised for an input-output ratio of photovoltaic power generation, and it is essential to reduce costs of photovoltaic power generation.

10

15

[0004] Currently, there are three three-phase grid-connected photovoltaic inverter architectures: a centralized architecture, a distributed architecture, and a decentralized architecture. Centralized and decentralized inverters have high conversion power, but low input and grid-connected voltages, resulting in higher input and output currents, larger diameters of DC/AC cables, increased costs, and increased losses. A distributed inverter has low conversion power. Although an input voltage can reach 1500 V and a grid-connected voltage can reach 800 V AC, as the power increases, the distributed inverter also has problems of higher input and output currents, larger diameters of DC/AC cables, increased costs, and increased losses.

20

SUMMARY

[0005] Embodiments of this application provide a power system, to resolve the foregoing technical problems of a high current in a cable, a high cable diameter specification, and high costs.

[0006] According to a first aspect, an embodiment of this application provides a power system, including N power modules and M DC-to-AC units. N is an integer greater than 1. M is an integer greater than 1. The power module is configured with a positive output terminal and a negative output terminal. The DC-to-AC unit is configured with a positive input terminal, a negative input terminal, and an output terminal. A positive output terminal of a first power module is coupled to a positive input terminal of a first DC-to-AC unit. A negative output terminal of an n^{th} power module is coupled in series to a positive output terminal of an $(n+1)^{\text{th}}$ power module to form a first node, where n is an integer greater than 0 and less than N, for example, a negative output terminal of the first power module is coupled in series to a positive output terminal of a second power module to form a first node, a negative output terminal of the second power module is coupled in series to a positive output terminal of a third power module to form a first node, ..., and a negative output terminal of an N^{th} power module is coupled to a negative input terminal of an M^{th} DC-to-AC unit. A negative input terminal of an m^{th} DC-to-AC unit is coupled in series to a positive input terminal of an $(m+1)^{\text{th}}$ DC-to-AC unit to form a second node, where m is an integer greater than 0 and less than M, for example, a negative input terminal of the first DC-to-AC unit is coupled to a positive input terminal of a second DC-to-AC unit to form a second node, a negative input terminal of the second DC-to-AC unit is coupled to a negative input terminal of a third DC-to-AC unit to form a second node, ..., and at least one first node and at least one second node are coupled. An output of an output terminal of the DC-to-AC unit is isolated.

[0007] In the power system according to the first aspect, the power module is cascaded to increase an output voltage of the power module, so as to reduce a current between the power module and the DC-to-AC unit, so that a cable with a low wire diameter specification may be used between the power module and the DC-to-AC unit, to resolve a cost problem of the cable from the power module to the DC-to-AC unit.

[0008] According to a second aspect, an embodiment of this application provides a power system, including a first power supply, a second power supply, a first-stage DC-to-AC unit, and a second-stage DC-to-AC unit. A positive output terminal of the first power supply is coupled to a

positive input terminal of the first-stage DC-to-AC unit. A negative output terminal of the first power supply is coupled to a positive output terminal of the second power supply to form a first node. A negative output terminal of the second power supply is coupled to a negative input terminal of the second-stage DC-to-AC unit. A negative input terminal of the first-stage DC-to-AC unit is coupled to a positive input terminal of the second-stage DC-to-AC unit to form a second node. Outputs of output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are isolated.

[0009] In the power system according to the second aspect, the first power supply and the second power supply are cascaded to increase an output voltage of the power supply (including the first power supply and the second power supply), so as to reduce a current between the power supply and the DC-to-AC unit (including the first-stage DC-to-AC unit and the second-stage DC-to-AC unit), so that a cable with a low wire diameter specification may be used between the power supply and the DC-to-AC unit, to resolve a cost problem of the cable from the power supply to the DC-to-AC unit.

[0010] With reference to the power system according to the second aspect, in a possible implementation, the positive output terminal of the first power supply is coupled to the positive input terminal of the first-stage DC-to-AC unit by using a first conducting wire. The negative output terminal of the second power supply is coupled to the negative input terminal of the second-stage DC-to-AC unit by using a second conducting wire. The first node is coupled to the second node by using a third conducting wire. A current value of the third conducting wire is less than or equal to a current value of the first conducting wire or the second conducting wire. Because the current value of the third conducting wire is small, a cable specification of the third conducting wire may be reduced, and costs of the third conducting wire may be further reduced. In addition, when output powers/voltages of the first power supply and the second power supply are asymmetric, or when input powers/voltages of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are asymmetric, a current loop can be provided to achieve voltage equalization.

[0011] According to a third aspect, an embodiment of this application provides a power system, including N power modules, N DC-to-DC units, and M DC-to-AC units. An output terminal of the power module is coupled to an input terminal of the DC-to-DC unit. A positive output terminal of a first DC-to-DC unit is coupled to a positive input terminal of a first DC-to-AC unit. A negative output terminal of an n^{th} DC-to-DC unit is coupled in series to a positive output terminal of an

(n+1)th DC-to-DC unit to form a first node, where n is an integer greater than 0 and less than N. A negative output terminal of an Nth DC-to-DC unit is coupled to a negative input terminal of an Mth DC-to-AC unit. A negative input terminal of an mth DC-to-AC unit is coupled in series to a positive input terminal of an (m+1)th DC-to-AC unit to form a second node, where m is an integer greater than 0 and less than M. At least one first node and at least one second node are coupled. An output of an output terminal of the DC-to-AC unit is isolated.

[0012] In the power system according to the third aspect, the DC-to-DC unit is cascaded to increase an output voltage of the DC-to-DC unit, so as to reduce a current between the DC-to-DC unit and the DC-to-AC unit, so that a cable with a low wire diameter specification may be used between the DC-to-DC unit and the DC-to-AC unit, to resolve a cost problem of the cable from the DC-to-DC unit to the DC-to-AC unit.

[0013] According to a fourth aspect, an embodiment of this application provides a power system, including a first power supply, a second power supply, a first-stage DC-to-DC unit, a second-stage DC-to-DC unit, a first-stage DC-to-AC unit, and a second-stage DC-to-AC unit. An output terminal of the first power supply is coupled to an input terminal of the first-stage DC-to-DC unit. An output terminal of the second power supply is coupled to an input terminal of the second-stage DC-to-DC unit. A positive output terminal of the first-stage DC-to-DC unit is coupled to a positive input terminal of the first-stage DC-to-AC unit. A negative output terminal of the first-stage DC-to-DC unit is coupled to a positive output terminal of the second-stage DC-to-DC unit to form a first node. A negative output terminal of the second-stage DC-to-DC unit is coupled to a negative output terminal of the second-stage DC-to-AC unit. A negative input terminal of the first-stage DC-to-AC unit is coupled to a positive input terminal of the second-stage DC-to-AC unit to form a second node. Outputs of output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are isolated.

[0014] In the power system according to the fourth aspect, the DC-to-DC unit (the first-stage DC-to-DC unit and the second-stage DC-to-DC unit) is cascaded to increase an output voltage of the DC-to-DC unit, so as to reduce a current between the DC-to-DC unit and the DC-to-AC unit (the first-stage DC-to-AC unit and the second-stage DC-to-AC unit), so that a cable with a low wire diameter specification may be used between the DC-to-DC unit and the DC-to-AC unit, to resolve a cost problem of the cable from the DC-to-DC unit to the DC-to-AC unit.

[0015] With reference to the power system according to the fourth aspect, in a possible

implementation, the positive output terminal of the first DC-to-DC unit is coupled to the positive input terminal of the first-stage DC-to-AC unit by using a first conducting wire. The negative output terminal of the second DC-to-DC unit is coupled to the negative output terminal of the second-stage DC-to-AC unit by using a second conducting wire. The first node is coupled to the second node by using a third conducting wire. A current value of the third conducting wire is less than or equal to a current value of the first conducting wire or the second conducting wire. Because the current value of the third conducting wire is small, a cable specification of the third conducting wire may be reduced, and costs of the third conducting wire may be further reduced. In addition, when output powers/voltages of the first-stage DC-to-DC unit and the second-stage DC-to-DC unit are asymmetric, or when input powers/voltages of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are asymmetric, a current loop can be provided to achieve voltage equalization.

[0016] According to a fifth aspect, an embodiment of this application provides a power system, including a power supply, a DC-to-DC unit, and N DC-to-AC units. An output terminal of the power supply is coupled to an input terminal of the DC-to-DC unit. A positive output terminal of the DC-to-DC unit is coupled to a positive input terminal of a first DC-to-AC unit. A negative output terminal of the DC-to-DC unit is coupled to a negative input terminal of an N^{th} DC-to-AC unit. A negative input terminal of an n^{th} DC-to-AC unit is coupled in series to a positive input terminal of an $(n+1)^{\text{th}}$ DC-to-AC unit to form a first node, where n is an integer greater than 0 and less than N. An output terminal of the DC-to-AC unit is isolated.

[0017] In the power system according to the fifth aspect, the DC-to-AC unit is cascaded to increase an input voltage of the DC-to-AC unit, so as to reduce a current between the DC-to-DC unit and the DC-to-AC unit, so that a cable with a low wire diameter specification may be used between the DC-to-DC unit and the DC-to-AC unit, to resolve a cost problem of the cable from the DC-to-DC unit to the DC-to-AC unit. When the DC-to-DC unit is connected to a plurality of power supplies, the DC-to-DC unit may be used to increase an output voltage, to reduce the current between the DC-to-DC unit and the DC-to-AC unit, and resolve cost and loss problems of the cable from the DC-to-DC unit to the DC-to-AC unit.

[0018] According to a sixth aspect, an embodiment of this application provides a power system, including a power supply, a DC-to-DC unit, a first-stage DC-to-AC unit, and a second-stage DC-to-AC unit. An output terminal of the power supply is coupled to an input terminal of the DC-to-

DC unit. A positive output terminal of the DC-to-DC unit is coupled to a positive input terminal of the first-stage DC-to-AC unit. A negative output terminal of the DC-to-DC unit is coupled to a negative input terminal of the second-stage DC-to-AC unit. A negative input terminal of the first-stage DC-to-AC unit is coupled to a positive input terminal of the second-stage DC-to-AC unit.

5 Outputs of output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are isolated.

[0019] In the power system according to the sixth aspect, input terminals of the DC-to-AC units are cascaded, to reduce a current between the DC-to-DC unit and the DC-to-AC unit, and resolve cost and loss problems of a cable from the DC-to-DC unit to the DC-to-AC unit. When the
10 DC-to-DC unit is connected to a plurality of power supplies, the DC-to-DC unit may be used to increase an output voltage, to reduce the current between the DC-to-DC unit and the DC-to-AC unit, and resolve cost and loss problems of the cable from the DC-to-DC unit to the DC-to-AC unit.

[0020] With reference to the power system according to the sixth aspect, in a possible
15 implementation, a middle point of an output terminal potential of the DC-to-DC unit is a first node. The negative input terminal of the first-stage DC-to-AC unit is coupled to the positive input terminal of the second-stage DC-to-AC unit to form a second node. The positive output terminal of the DC-to-DC unit is coupled to the positive input terminal of the first-stage DC-to-AC unit by using a first conducting wire. The negative output terminal of the DC-to-DC unit is coupled to the
20 negative output terminal of the second-stage DC-to-AC unit by using a second conducting wire. The first node is coupled to the second node by using a third conducting wire. A current value of the third conducting wire is less than or equal to a current value of the first conducting wire or the second conducting wire. Because the current value of the third conducting wire is small, a cable specification of the third conducting wire may be reduced, and costs of the third conducting wire
25 may be further reduced. In addition, when output power/voltage of the DC-to-DC unit is asymmetric, or when input powers/voltages of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are asymmetric, a current loop can be provided to achieve voltage equalization.

[0021] According to a seventh aspect, an embodiment of this application provides a power system, including N first power supplies, M second power supplies, N DC-to-DC units, and S DC-
30 to-AC units. An output terminal of the first power supply is coupled to an input terminal of the DC-to-DC unit. A positive terminal formed by serially connecting output terminals of the N DC-

to-DC units and output terminals of the M second power supplies is coupled to a positive terminal formed by serially connecting input terminals of the S DC-to-AC units. A negative terminal formed by serially connecting output terminals of the N DC-to-DC units and output terminals of the M second power supplies is coupled to a negative terminal formed by serially connecting input
5 terminals of the S DC-to-AC units. The output terminals of the N DC-to-DC units and the output terminals of the M second power supplies are coupled in series, and series coupling points form a first node. The input terminals of the S DC-to-AC units are coupled in series, and series coupling points form a second node. At least one first node and at least one second node are coupled by using at least one cable. An output terminal of the DC-to-AC unit is isolated.

10 **[0022]** In the power system according to the seventh aspect, the DC-to-DC unit and the second power supply are cascaded to increase output voltages of the DC-to-DC unit and the second power supply, so as to reduce a current between the DC-to-DC unit or the second power supply and the DC-to-AC unit, so that a cable with a low wire diameter specification may be used between the DC-to-DC unit or the second power supply and the DC-to-AC unit, to resolve a cost problem of
15 the cable from the DC-to-DC unit or the second power supply to the DC-to-AC unit.

[0023] According to an eighth aspect, an embodiment of this application provides a power system, including a first power supply, a DC-to-DC unit, a second power supply, a first-stage DC-to-AC unit, and a second-stage DC-to-AC unit. An output terminal of the first power supply is coupled to an input terminal of the DC-to-DC unit. The DC-to-DC unit is coupled in series to an
20 output terminal of the second power supply, and a coupling point is a first node. A negative input terminal of the first-stage DC-to-AC unit is coupled to a positive input terminal of the second-stage DC-to-AC unit, and a coupling point is a second node. A positive output terminal formed after the DC-to-DC unit is coupled in series to the output terminal of the second power supply is a first port, and the first port is coupled to a positive input terminal of the first-stage DC-to-AC unit.
25 A negative output terminal formed after the DC-to-DC unit is coupled in series to the output terminal of the second power supply is a second port, and the second port is coupled to a negative input terminal of the second-stage DC-to-AC unit. Outputs of output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are isolated.

[0024] In the power system according to the eighth aspect, the DC-to-DC unit and the second
30 power supply are cascaded to increase output voltages of the DC-to-DC unit and the second power supply, so as to reduce a current between the DC-to-DC unit or the second power supply and the

DC-to-AC unit (the first-stage DC-to-AC unit and the second-stage DC-to-AC unit), so that a cable with a low wire diameter specification may be used between the DC-to-DC unit or the second power supply and the DC-to-AC unit, to resolve a cost problem of the cable from the DC-to-DC unit or the second power supply to the DC-to-AC unit.

5 **[0025]** With reference to the eighth aspect, in a possible implementation, the first port is coupled to the positive input terminal of the first-stage DC-to-AC unit by using a first conducting wire. The second port is coupled to the negative input terminal of the second-stage DC-to-AC unit by using a second conducting wire. The first node is coupled to the second node by using a third conducting wire. A current value of the third conducting wire is less than or equal to a current
10 value of the first conducting wire or the second conducting wire. Because the current value of the third conducting wire is small, a cable specification of the third conducting wire may be reduced, and costs of the third conducting wire may be further reduced. In addition, when output powers/voltages of the DC-to-DC unit and the second power supply are asymmetric, or when input powers/voltages of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are
15 asymmetric, a current loop can be provided to achieve voltage equalization.

BRIEF DESCRIPTION OF DRAWINGS

[0026] FIG. 1 is a schematic diagram of Embodiment 1 of a power system according to an embodiment of this application;

20 **[0027]** FIG. 2 is a schematic diagram of a power supply according to an embodiment of this application;

[0028] FIG. 3a is a schematic diagram of a photovoltaic array according to an embodiment of this application;

[0029] FIG. 3b is a schematic diagram of another photovoltaic array according to an embodiment of this application;

25 **[0030]** FIG. 4 is a schematic diagram of a DC-to-AC unit according to an embodiment of this application;

[0031] FIG. 5a is a schematic diagram of a plurality of combinations of power supplies connected in parallel according to an embodiment of this application;

[0032] FIG. 5b is a schematic diagram of a plurality of combinations of DC-to-AC units

connected in parallel according to an embodiment of this application;

[0033] FIG. 5c is another schematic diagram of a plurality of combinations of DC-to-AC units connected in parallel according to an embodiment of this application;

[0034] FIG. 6 is a schematic diagram of Embodiment 2 of a power system according to an embodiment of this application;

[0035] FIG. 7 is a schematic diagram of an embodiment of a power system according to an embodiment of this application;

[0036] FIG. 8 is a schematic diagram of an embodiment of a power system according to an embodiment of this application;

[0037] FIG. 9a is a schematic diagram of a power system that includes a first equalization circuit unit;

[0038] FIG. 9b1 is a schematic diagram 1 of a power system that includes a second equalization circuit unit;

[0039] FIG. 9b2 is a schematic diagram 2 of a power system that includes a second equalization circuit unit;

[0040] FIG. 9c is a schematic diagram of a power system that includes a third equalization circuit unit;

[0041] FIG. 9d1 is a schematic diagram 1 of a power system that includes a fourth equalization circuit unit;

[0042] FIG. 9d2 is a schematic diagram 2 of a power system that includes a fourth equalization circuit unit;

[0043] FIG. 10a is a schematic diagram of a plurality of combinations of power supplies connected in parallel according to an embodiment of this application;

[0044] FIG. 10b is a schematic diagram of a plurality of combinations of DC-to-AC units connected in parallel according to an embodiment of this application;

[0045] FIG. 10c is another schematic diagram of a plurality of combinations of DC-to-AC units connected in parallel according to an embodiment of this application;

[0046] FIG. 11 is a schematic diagram of a power system with a leakage current sensor according to an embodiment of this application;

[0047] FIG. 12a is a schematic diagram 1 of a power system with a voltage source according to an embodiment of this application;

- [0048]** FIG. 12b is a schematic diagram 2 of a power system with a voltage source according to an embodiment of this application;
- [0049]** FIG. 12c is a schematic diagram 3 of a power system with a voltage source according to an embodiment of this application;
- 5 **[0050]** FIG. 13 is a schematic diagram of a power system with an isolation unit according to an embodiment of this application;
- [0051]** FIG. 14a is a schematic diagram 1 of a power system having a combiner unit according to an embodiment of this application;
- [0052]** FIG. 14b is a schematic diagram 2 of a power system having a combiner unit according to an embodiment of this application;
- 10 **[0053]** FIG. 15a is a schematic diagram 1 of a power system that includes an energy storage unit according to an embodiment of this application;
- [0054]** FIG. 15b is a schematic diagram 2 of a power system that includes an energy storage unit according to an embodiment of this application;
- 15 **[0055]** FIG. 15c is a schematic diagram 3 of a power system that includes an energy storage unit according to an embodiment of this application;
- [0056]** FIG. 15d is a schematic diagram 4 of a power system that includes an energy storage unit according to an embodiment of this application;
- [0057]** FIG. 16 is a schematic diagram of Embodiment 3 of a power system according to an embodiment of this application;
- 20 **[0058]** FIG. 17 is a schematic diagram of a DC-to-DC unit according to an embodiment of this application;
- [0059]** FIG. 18 is a schematic diagram of Embodiment 4 of a power system according to an embodiment of this application;
- 25 **[0060]** FIG. 19 is a schematic diagram of an embodiment of a power system according to an embodiment of this application;
- [0061]** FIG. 20 is a schematic diagram of another embodiment of a power system according to an embodiment of this application;
- [0062]** FIG. 21 is a schematic diagram of a power system that includes a first equalization circuit unit according to an embodiment of this application;
- 30 **[0063]** FIG. 22a is a schematic diagram 1 of a power system that includes a second

equalization circuit unit according to an embodiment of this application;

[0064] FIG. 22b is a schematic diagram 2 of a power system that includes a second equalization circuit unit according to an embodiment of this application;

[0065] FIG. 23 is a schematic diagram of a power system that includes a third equalization circuit unit according to an embodiment of this application;

[0066] FIG. 24a is a schematic diagram 1 of a power system that includes a fourth equalization circuit unit according to an embodiment of this application;

[0067] FIG. 24b is a schematic diagram 2 of a power system that includes a fourth equalization circuit unit according to an embodiment of this application;

[0068] FIG. 25 is a schematic diagram of a plurality of combinations of DC-to-DC units connected in parallel according to an embodiment of this application;

[0069] FIG. 26 is a schematic diagram of a power system that is provided with an IMD according to an embodiment of this application;

[0070] FIG. 27 is a schematic diagram of a power system that is configured with a leakage current sensor according to an embodiment of this application;

[0071] FIG. 28 is a schematic diagram of a photovoltaic power generation system according to an embodiment of this application;

[0072] FIG. 29 is another schematic diagram of a photovoltaic power generation system according to an embodiment of this application;

[0073] FIG. 30 is another schematic diagram of a photovoltaic power generation system according to an embodiment of this application;

[0074] FIG. 31 is another schematic diagram of a photovoltaic power generation system according to an embodiment of this application;

[0075] FIG. 32a is another schematic diagram of a photovoltaic power generation system according to an embodiment of this application;

[0076] FIG. 32b is another schematic diagram of a photovoltaic power generation system according to an embodiment of this application;

[0077] FIG. 33 is another schematic diagram of a photovoltaic power generation system according to an embodiment of this application;

[0078] FIG. 34 is another schematic diagram of a photovoltaic power generation system according to an embodiment of this application;

[0079] FIG. 35 is another schematic diagram of a photovoltaic power generation system according to an embodiment of this application;

[0080] FIG. 36 is another schematic diagram of a photovoltaic power generation system according to an embodiment of this application;

5 **[0081]** FIG. 37 is another schematic diagram of a photovoltaic power generation system according to an embodiment of this application;

[0082] FIG. 38 is a schematic diagram of Embodiment 5 of a power system according to an embodiment of this application;

[0083] FIG. 39 is a schematic diagram of Embodiment 6 of a power system according to an
10 embodiment of this application;

[0084] FIG. 40 is a schematic diagram of an embodiment of a power system according to an embodiment of this application;

[0085] FIG. 41 is a schematic diagram of an embodiment of a power system according to an embodiment of this application;

15 **[0086]** FIG. 42 is a schematic diagram of a power system that includes a first equalization circuit unit according to an embodiment of this application;

[0087] FIG. 43 is a schematic diagram of a power system that includes a second equalization circuit unit according to an embodiment of this application;

[0088] FIG. 44 is a schematic diagram of a power system that includes a third equalization
20 circuit unit according to an embodiment of this application;

[0089] FIG. 45 is a schematic diagram of a power system that includes a fourth equalization circuit unit according to an embodiment of this application;

[0090] FIG. 46 is a schematic diagram of another embodiment of a photovoltaic power generation system according to an embodiment of this application;

25 **[0091]** FIG. 47 is a schematic diagram of another embodiment of a photovoltaic power generation system according to an embodiment of this application;

[0092] FIG. 48a is a schematic diagram 1 of another embodiment of a photovoltaic power generation system according to an embodiment of this application;

[0093] FIG. 48b is a schematic diagram 2 of another embodiment of a photovoltaic power
30 generation system according to an embodiment of this application;

[0094] FIG. 48c is a schematic diagram 3 of another embodiment of a photovoltaic power

generation system according to an embodiment of this application;

[0095] FIG. 49 is a schematic diagram of another embodiment of a photovoltaic power generation system according to an embodiment of this application;

[0096] FIG. 50 is a schematic diagram of an embodiment of a power system according to an
5 embodiment of this application;

[0097] FIG. 51a is a schematic diagram 1 of a power system according to an embodiment of this application;

[0098] FIG. 51b is a schematic diagram 2 of a power system according to an embodiment of this application;

10 **[0099]** FIG. 52 is a schematic diagram of an embodiment of a power system according to an embodiment of this application;

[00100] FIG. 53 is a schematic diagram of a power system that includes a first equalization circuit unit according to an embodiment of this application;

[00101] FIG. 54 is a schematic diagram of a power system that includes a second equalization
15 circuit unit according to an embodiment of this application;

[00102] FIG. 55 is a schematic diagram of a power system that includes a third equalization circuit unit according to an embodiment of this application;

[00103] FIG. 56 is a schematic diagram of a power system that includes a fourth equalization circuit unit according to an embodiment of this application;

20 **[00104]** FIG. 57 is a schematic diagram of a photovoltaic power generation system according to an embodiment of this application;

[00105] FIG. 58 is a schematic diagram of an embodiment of a photovoltaic power generation system according to an embodiment of this application;

[00106] FIG. 59 is a schematic diagram of an embodiment of a photovoltaic power generation
25 system according to an embodiment of this application; and

[00107] FIG. 60 is a schematic diagram of another embodiment of a photovoltaic power generation system according to an embodiment of this application.

DESCRIPTION OF EMBODIMENTS

[00108] The following describes in detail technical solutions in embodiments of this application

with reference to the accompanying drawings in embodiments of this application.

[00109] To resolve a problem of high cost and loss of a photovoltaic power generation system, an embodiment of this application provides a power system. An output terminal of a power supply or a direct current (DC)-to-DC unit is cascaded to increase an output voltage, to reduce a current
5 between the power supply or the DC-to-DC unit and a DC-to-alternating current (AC) unit, and resolve cost and loss problems of a cable from the power supply or the DC-to-DC unit to the DC-to-AC unit. In addition, according to the power system provided in embodiments of this application, a quantity of cables from the power supply or the DC-to-DC unit to the DC-to-AC unit may be further reduced by cascading the output terminal of the power supply or the DC-to-DC unit and
10 cascading an input of the DC-to-AC unit, to reduce system costs. In addition, in the power system provided in embodiments of this application, the cascaded input and isolated output of the DC-to-AC unit can reduce a specification of a power conversion device. Therefore, problems of insufficient specifications and high costs of power conversion devices in the current industry are resolved. In addition, a 1500 V circuit breaker may be used to reduce costs. In some embodiments,
15 when an output of the DC-to-DC unit is cascaded, in this embodiment of this application, a problem of potential induced degradation (PID) caused by a negative voltage of a photovoltaic cell panel to ground during operation of the system may be resolved by designing a system at a DC-to-DC unit level.

[00110] The following describes in detail the foregoing solutions by using embodiments. The
20 following embodiments are described by using a photovoltaic array as an example. Another similar power system has a same principle as the photovoltaic array. For implementation of the another similar power system, refer to the following embodiments of the photovoltaic array. Details are not described in this embodiment of this application.

Embodiment 1

25 [00111] FIG. 1 is a schematic diagram of Embodiment 1 of a power system according to an embodiment of this application. The power system includes N power supplies and M DC-to-AC units. N is an integer greater than 1. M is an integer greater than 1. It may be understood that N has no value relationship with M, that is, N may be equal to M, N may be greater than M, or N may be less than M. This is not limited in this embodiment of this application.

30 [00112] Among the N power supplies, each power supply is configured with a positive output

terminal and a negative output terminal, as shown in FIG. 2. FIG. 2 is a schematic diagram of a power supply according to an embodiment of this application. In this embodiment of this application, for ease of description, unless otherwise specified or marked, an output terminal in the upper right part of the power supply is generally referred to as a positive output terminal, and an output terminal in the lower right part of the power supply is generally referred to as a negative output terminal. The power supply in this embodiment of this application may be a photovoltaic array, an energy storage power supply, or a wind power generation direct current source. In actual application, the power supply may alternatively be another type of power supply. This is not limited in this embodiment of this application. In this embodiment of this application, the N power supplies may be of a same type, for example, all of the N power supplies are photovoltaic arrays. Alternatively, the N power supplies may not be of a same type, for example, a power supply 1 is a photovoltaic array, a power supply 2 is an energy storage power supply, and so on. This is not limited in this embodiment of this application.

[00113] The photovoltaic (PV) array may be formed by connecting photovoltaic cell panels in series or in parallel combinations, as shown in FIG. 3a. FIG. 3a is a schematic diagram of a photovoltaic array according to an embodiment of this application. Photovoltaic PV cell panels may be first connected in series and then connected in parallel to form the photovoltaic array, may be first connected in parallel and then connected in series to form the photovoltaic array, may be directly connected in series to form the photovoltaic array, or may be directly connected in parallel to form the photovoltaic array. This is not limited in this embodiment of this application. Alternatively, the photovoltaic array may be formed by connecting an output of the photovoltaic cell panel to an optimizer or a shutdown device, and then connecting in series or in parallel combinations, as shown in FIG. 3b. FIG. 3b is a schematic diagram of another photovoltaic array according to an embodiment of this application. An output of each photovoltaic cell panel may be connected to an optimizer or a shutdown device, and then an output of the optimizer or the shutdown device is combined in series/parallel to form the photovoltaic array. In a possible case, some photovoltaic cell panels are connected to the optimizer or the shutdown device, and some other photovoltaic cell panels are not connected to the optimizer or the shutdown device, and then these photovoltaic cell panels are combined in series/parallel to form the photovoltaic array. The optimizer or the shutdown device is a device that can implement a fast shutdown function. After receiving a shutdown instruction, the optimizer or the shutdown device can cut off a corresponding

line to disconnect the line. In actual application, the optimizer or the shutdown device may alternatively be replaced by another apparatus having a similar function. This is not limited in this embodiment of this application.

[00114] Among the M DC-to-AC units, each DC-to-AC unit is configured with a positive input terminal, a negative input terminal, and an output terminal, as shown in FIG. 4. FIG. 4 is a schematic diagram of a DC-to-AC unit according to an embodiment of this application. In this embodiment of this application, for ease of description, unless otherwise specified or marked, an input terminal in the upper left part of the DC-to-AC unit is generally referred to as a positive input terminal, an input terminal in the lower left part of the DC-to-AC unit is generally referred to as a negative input terminal, and an output terminal is arranged at a right side of the DC-to-AC unit. The DC-to-AC unit in this embodiment of this application is an apparatus that can convert a direct current into an alternating current, for example, an inverter. This is not limited in this embodiment of this application. An output of the DC-to-AC unit in this embodiment of this application may be a three-phase voltage or a single-phase voltage. The following embodiments are described by using an example in which a three-phase voltage is at an output terminal. For implementation of another case, for example, a single-phase voltage, refer to this embodiment of this application. Details are not described in this application.

[00115] It may be understood that, in this embodiment of this application, the output terminal may include a positive output terminal and a negative output terminal. For example, an output terminal of a power supply 1 includes a positive output terminal and a negative output terminal of the power supply 1. The input terminal may also include a positive input terminal and a negative input terminal. For example, an input terminal of a DC-to-AC unit 1 includes a positive input terminal and a negative input terminal.

[00116] It can be seen from FIG. 1 that, in the power system, the positive output terminal of the power supply 1 is coupled to the positive input terminal of the DC-to-AC unit 1, and a negative output terminal of a power supply N is coupled to a negative input terminal of a DC-to-AC unit M. The negative output terminal of the power supply 1 is coupled to a positive output terminal of a power supply 2, a negative output terminal of the power supply 2 is coupled to a positive output terminal of a power supply 3, ..., and so on. In addition, in this embodiment of this application, nodes such as a coupling node between the negative output terminal of the power supply 1 and the positive output terminal of the power supply 2, and a coupling node between the negative output

terminal of the power supply 2 and the positive output terminal of the power supply 3 each may be referred to as a first node 101. The negative input terminal of the DC-to-AC unit 1 is coupled to a positive input terminal of a DC-to-AC unit 2, a negative input terminal of the DC-to-AC unit 2 is coupled to a positive output terminal of a DC-to-AC unit 3, ..., and so on. In addition, in this embodiment of this application, nodes such as a coupling node between the negative input terminal of the DC-to-AC unit 1 and the positive input terminal of the DC-to-AC unit 2, and a coupling node between the negative input terminal of the DC-to-AC unit 2 and the positive output terminal of the DC-to-AC unit 3 each may be referred to as a second node 102. In this embodiment of this application, outputs of the power supply 1 and the power supply 2 are cascaded, outputs of the power supply 2 and the power supply 3 are cascaded, and so on. In this embodiment of this application, output terminals of the power supplies are cascaded, to increase an output voltage, reduce a current between the power supply and the DC-to-AC unit, and resolve cost and loss problems of a cable from the power supply to the DC-to-AC unit. For example, a maximum output voltage of each power supply is X volts, and a maximum output voltage after the N power supplies are cascaded is NX volts. In a case of a same power, when a voltage increases, an output current decreases, a wire diameter specification of a used cable decreases, and costs decrease.

[00117] At least one first node 101 and at least one second node 102 are coupled. For example, in some embodiments, one first node 101 is coupled to one second node 102, and another first node 101 is not coupled to another second node 102. In some other embodiments, two first nodes 101 are respectively coupled to two second nodes 102, and another first node 101 is not coupled to another second node 102. In some other embodiments, a quantity of first nodes 101 is equal to a quantity of second nodes 102, and each first node 101 is coupled to a corresponding second node 102. In some other embodiments, a quantity of first nodes 101 is different from a quantity of second nodes 102, each first node 101 is coupled to a corresponding second node 102, and a remaining first node 101 or a remaining second node 102 is not coupled. In actual application, another coupling manner may alternatively be used. This is not limited in this embodiment of this application. In this embodiment of this application, a quantity of cables connected between the power supply and the DC-to-AC unit is reduced in a manner of the first node 101 and the second node 102, to reduce costs of the power system.

[00118] In this embodiment of this application, outputs of output terminals of the DC-to-AC units are isolated. For example, an output terminal of the DC-to-AC unit 1 is isolated from an

output terminal of the DC-to-AC unit 2, and an output terminal of the DC-to-AC unit 2 is isolated from an output terminal of the DC-to-AC unit 3. In actual application, the output terminal of each DC-to-AC unit is coupled to different windings, and each winding may output a three-phase voltage or a single-phase voltage. This is not limited in this embodiment of this application. In this embodiment of this application, the cascaded input and isolated output of the DC-to-AC unit reduce a specification of a power conversion device. Therefore, problems of insufficient specifications (generally up to 1700 V for an insulated gate bipolar transistor (IGBT)) and high costs of power conversion devices in the current industry are resolved. In addition, a circuit breaker with a low specification may be used to reduce costs.

[00119] It may be understood that, in this embodiment of this application, coupling may also be referred to as a coupling connection, and may include but is not limited to a connection implemented by using any combination of a switching device, a current-limiting device, a protection device, a direct cable connection, or the like.

[00120] In some embodiments, the power supply 1, the power supply 2, ..., and the power supply N in FIG. 1 may be considered as one combination of power supplies, and the DC-to-AC unit 1, the DC-to-AC unit 2, ..., and the DC-to-AC unit M may be considered as one combination of DC-to-AC units. When there are at least two combinations of power supplies and/or at least two combinations of DC-to-AC units, same-type output terminals of at least two combinations of power supplies are connected in parallel, and same-type input terminals of at least two combinations of DC-to-AC units are connected in parallel. There is at least one cable coupled between the parallel-connected same-type output terminals and the parallel-connected same-type input terminals. FIG. 5a is a schematic diagram of a plurality of combinations of power supplies connected in parallel according to an embodiment of this application. In FIG. 5a, each vertical row is one combination of power supplies, and each combination of power supplies includes a power supply 1, a power supply unit 2, ..., and a power supply N. In this case, a positive output terminal of a power supply 1 in a first combination of power supplies is coupled in parallel with a positive output terminal of a power supply 1 in a second combination of power supplies (that is, same-type output terminals are coupled in parallel), a negative output terminal of the power supply 1 in the first combination of power supplies is coupled in parallel to a negative output terminal of the power supply 1 in the second combination of power supplies, ..., and so on. It may be understood that output terminals of the power supply 1, the power supply 2, ..., and the power supply N may be

cascaded to form at least one first node. FIG. 5b is a schematic diagram of a plurality of combinations of DC-to-AC units connected in parallel according to an embodiment of this application. In FIG. 5b, each vertical row is one combination of DC-to-AC units, and each combination of DC-to-AC units includes a DC-to-AC unit 1, a DC-to-AC unit 2, ..., and a DC-to-AC unit M. A positive input terminal of a DC-to-AC unit 1 in a first combination of DC-to-AC units is coupled in parallel to a positive input terminal of a DC-to-AC unit 1 in a second combination of DC-to-AC units (that is, same-type input terminals are coupled in parallel), a negative input terminal of the DC-to-AC unit 1 in the first combination of DC-to-AC units is coupled in parallel to a negative input terminal of the DC-to-AC unit 1 in the second combination of DC-to-AC units, ..., and so on. It may be understood that input terminals of the DC-to-AC unit 1, the DC-to-AC unit 2, ..., and the DC-to-AC unit M may be cascaded to form at least one second node. The at least one first node is coupled to the at least one second node, in other words, there is at least one cable coupled between the parallel-connected same-type output terminals and the parallel-connected same-type input terminals.

[00121] FIG. 5c is another schematic diagram of the plurality of combinations of DC-to-AC units connected in parallel according to an embodiment of this application. In FIG. 5c, each vertical row is one combination of DC-to-AC units, and each combination of DC-to-AC units includes a DC-to-AC unit 1, a DC-to-AC unit 2, ..., and a DC-to-AC unit M. In a possible case, an output terminal of the DC-to-AC unit 1 in the first combination of DC-to-AC units may be coupled in parallel to an output terminal of the DC-to-AC unit 1 in the second combination of DC-to-AC units, and then a winding is connected to implement parallel output. In another possible case, an output of an output terminal of the DC-to-AC unit 1 in the first combination of DC-to-AC units is isolated from an output of an output terminal of the DC-to-AC unit 1 in the second combination of DC-to-AC units, that is, different windings are connected to implement isolated output. The same rule is applied to another DC-to-AC unit. Details are not described in this embodiment of this application.

[00122] In this embodiment of this application, same-type output terminals mean corresponding output terminals of corresponding apparatuses in different combinations. For example, the positive output terminal of the power supply 1 in the first combination of power supplies and the positive output terminal of the power supply 1 in the second combination of power supplies are same-type output terminals; the output terminal of the DC-to-AC unit 1 in the first combination of DC-to-AC

units and the output terminal of the DC-to-AC unit 1 in the second combination of DC-to-AC units are same-type output terminals; and the output terminal of the DC-to-DC unit 1 in the first combination of DC-to-DC units and the output terminal of the DC-to-DC unit 1 in the second combination of DC-to-DC units are same-type output terminals. Same-type input terminals mean
5 corresponding input terminals of corresponding apparatuses in different combinations. For example, the positive input terminal of the DC-to-AC unit 1 in the first combination of DC-to-AC units and the positive input terminal of the DC-to-AC unit 1 in the second combination of DC-to-AC units are same-type input terminals; the positive input terminal of the DC-to-DC unit 1 in the first combination of DC-to-DC units and the positive input terminal of the DC-to-DC unit 1 in the
10 second combination of DC-to-DC units are same-type input terminals; and so on.

[00123] In some embodiments, a communication signal is coupled to a direct current cable connected between the power supply and the DC-to-AC unit. It may be understood that the direct current cable connected between the power supply and the DC-to-AC unit may be a direct current cable for coupling the positive output terminal of the power supply 1 and the positive input
15 terminal of the DC-to-AC unit 1, may be a direct current cable for coupling the negative output terminal of the power supply N and the negative input terminal of the DC-to-AC unit M, may be a direct current cable for coupling the first node and the second node, may be a direct current cable for cascading outputs the power supply 1, the power supply 2, ..., and the power supply N, or may be a direct current cable for cascading inputs of the DC-to-AC unit 1, the DC-to-AC unit 2, ..., and
20 the DC-to-AC unit M. Preferably, the communication signal may be a power line communication (PLC) signal. This type of signal coupled to the cable loads a high frequency that carries information into a current, and then an adapter that transmits and receives the information by using the cable separates the high frequency from the current to implement information transfer. Therefore, if the power supply and the DC-to-AC unit are devices that can recognize a
25 communication signal, the power supply may communicate with the DC-to-AC unit by using a communication signal coupled to a direct current cable. In actual application, the communication signal may alternatively be a signal that can implement communication other than the PLC signal. This is not limited in this embodiment of this application. In actual application, the power system may use a power supply and a DC-to-AC unit that can recognize a communication signal, or may
30 modify a power supply and a DC-to-AC unit so that the power supply and the DC-to-AC unit can recognize a communication signal. This is not limited in this embodiment of this application.

[00124] In some embodiments, the power supply is the photovoltaic array formed by connecting the output of the photovoltaic cell panel to the optimizer or the shutdown device, and then connecting in series or in parallel combinations. When the communication signal is coupled to the direct current cable connected between the power supply and the DC-to-AC unit, the communication signal also passes through the optimizer or the shutdown device, and the power supply or the DC-to-AC unit may control, by using the communication signal, shutdown of the optimizer or the shutdown device, to implement fast shutdown. That is, the power supply or the DC-to-AC unit may send a communication signal that carries a shutdown instruction to the optimizer or the shutdown device. After receiving the communication signal that carries the shutdown instruction, the optimizer or the shutdown device executes the shutdown instruction, to implement fast shutdown. A situation of the communication signal is similar to the description of the communication signal in the foregoing embodiment, and details are not described herein again.

[00125] In some embodiments, the power system further includes at least one energy storage unit. The energy storage unit is coupled in parallel to at least two direct current cables connected between the power supply and the DC-to-AC unit. In this embodiment of this application, the direct current cable connected between the power supply and the DC-to-AC unit may be a direct current cable connected between the power supply and the DC-to-AC unit, may be a direct current cable for coupling the positive output terminal of the power supply 1 and the positive input terminal of the DC-to-AC unit 1, may be a direct current cable for coupling the negative output terminal of the power supply N and the negative input terminal of the DC-to-AC unit M, or may be a direct current cable for coupling the first node and the second node. For example, the energy storage unit is coupled in parallel between the direct current cable for coupling the positive output terminal of the power supply 1 and the positive input terminal of the DC-to-AC unit 1 and the direct current cable for coupling the negative output terminal of the power supply N and the negative input terminal of the DC-to-AC unit M. Alternatively, the energy storage unit is coupled in parallel among three direct current cables for coupling the first node and the second node. It may be understood that a quantity of energy storage units included in one power system is not limited, that is, a plurality of energy storage units may be coupled in parallel at the same time. This is not limited in this embodiment of this application. In this embodiment of this application, the energy storage unit may be an energy storage device, or may include a direct current conversion unit and the energy storage device, or may be another apparatus capable of storing energy. This is

not limited in this embodiment of this application. The energy storage device may include but is not limited to a supercapacitor, a battery, and the like. The direct current conversion unit may be a DC-to-DC unit or the like. This is not limited in this embodiment of this application.

[00126] In some embodiments, when the power system is configured with the energy storage unit, a communication signal is coupled to a direct current cable connected between the energy storage unit and the power supply, and the energy storage unit may communicate with the power supply. A situation of the communication signal and a principle for implementing communication are similar to the description of the communication signal in the foregoing embodiment, and details are not described herein again. In some other embodiments, when the power system is configured with the energy storage unit, a communication signal is coupled to a direct current cable connected between the energy storage unit and the DC-to-AC unit, and the energy storage unit may communicate with the DC-to-AC unit. A situation of communication is similar to the foregoing situation of communication implemented between the energy storage unit and the power supply. Details are not described herein again.

Embodiment 2

[00127] FIG. 6 is a schematic diagram of Embodiment 2 of a power system according to an embodiment of this application. The power system includes a power supply 1, a power supply 2, a first-stage DC-to-AC unit, and a second-stage DC-to-AC unit. The power supply 1 and the power supply 2 may be a photovoltaic array, energy storage power supplies, or wind power generation direct current sources, which are similar to those in Embodiment 1, and details are not described herein again. The first-stage DC-to-AC unit and the second-stage DC-to-AC unit may be apparatuses that can convert a direct current into an alternating current, for example, an inverter. This is not limited in this embodiment of this application.

[00128] In this embodiment of this application, a positive output terminal of the power supply 1 is coupled to a positive input terminal of the first-stage DC-to-AC unit, a negative output terminal of the power supply 2 is coupled to a negative input terminal of the second-stage DC-to-AC unit, a negative output terminal of the power supply 1 is coupled to a positive output terminal of the power supply 2, and a negative input terminal of the first-stage DC-to-AC unit is coupled to a positive input terminal of the second-stage DC-to-AC unit. Therefore, outputs of the power supply 1 and the power supply 2 are cascaded, and inputs of the first-stage DC-to-AC unit and the second-

stage DC-to-AC unit are cascaded. In this embodiment of this application, output terminals of power supplies are cascaded to increase an output voltage, reduce a current between the power supply and the DC-to-AC unit, and resolve cost and loss problems of a cable from the power supply to the DC-to-AC unit. For example, a maximum output voltage of each of the power supply 1 and the power supply 2 is 1500 V, and after the outputs of the power supply 1 and the power supply 2 are cascaded, a maximum output voltage is 3 kV. In a case of a same power, when a voltage increases, an output current decreases, a wire diameter specification of a used cable decreases, and costs decrease.

[00129] Outputs of output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are isolated, and are connected to different windings. This is similar to the case in which the output of the DC-to-AC unit is isolated in Embodiment 1, and details are not described herein again. In this embodiment of this application, the cascaded input and isolated output of the DC-to-AC unit reduce a specification of a power conversion device. Specifications of power conversion devices in the current industry are insufficient (generally up to 1700 V for an IGBT). However, a 1500 V circuit breaker may be used in the power system provided in this embodiment of this application to reduce costs. The technical problem of insufficient specifications of the power conversion devices in the current industry is resolved.

[00130] A node for coupling the negative output terminal of the power supply 1 and the positive output terminal of the power supply 2 is referred to as a first node. A node for coupling the negative input terminal of the first-stage DC-to-AC unit and the positive input terminal of the second-stage DC-to-AC unit is referred to as a second node.

[00131] FIG. 7 is a schematic diagram of an embodiment of the power system according to an embodiment of this application. As shown in FIG. 7, in some embodiments, the positive output terminal of the power supply 1 is coupled to the positive input terminal of the first-stage DC-to-AC unit by using a first conducting wire. The negative output terminal of the power supply 2 is coupled to the negative input terminal of the second-stage DC-to-AC unit by using a second conducting wire. The first node and the second node are coupled by using a third conducting wire. It may be understood that, in this embodiment of this application, the first conducting wire, the second conducting wire, and the third conducting wire are all direct current cables connected between the power supply (the power supply 1 and the power supply 2) and the DC-to-AC unit (the first-stage DC-to-AC unit and the second-stage DC-to-AC unit). A material and a wire

diameter specification of the cable may be configured based on an actual situation. This is not limited in this embodiment of this application. It may be understood that, in the conventional technology, the power supply 1 and the power supply 2 may have four output terminals in total, and therefore, four cables are connected. However, in this embodiment of this application, the power supply 1 and the power supply 2 are cascaded, and the first node and the second node are coupled by using one cable, so that the existing technical solution of using four cables is modified into a solution that requires only three cables. Therefore, this can reduce costs of one cable and construction costs.

[00132] In some embodiments, because the first node is a middle point of cascading the power supply 1 and the power supply 2, and the second node is a middle point of cascading the first-stage DC-to-AC unit and the second-stage DC-to-AC unit, a current value of the third conducting wire may be less than or equal to a current value of the first conducting wire. When the current value of the third conducting wire is less than or equal to the current value of the first conducting wire, a wire diameter specification of the third conducting wire may be reduced, to reduce costs of the third conducting wire. In some other embodiments, similarly, the current value of the third conducting wire is less than or equal to a current value of the second conducting wire. Therefore, when the current value of the third conducting wire is less than or equal to the current value of the second conducting wire, a wire diameter specification of the third conducting wire may be reduced, to reduce cable costs of the third conducting wire. Certainly, the current value of the third conducting wire may alternatively be less than the current value of the first conducting wire and less than the current value of the second conducting wire. This may also reduce the wire diameter specification of the third conducting wire, and reduce the cable costs of the third conducting wire.

[00133] In some embodiments, the first conducting wire, the second conducting wire, and the third conducting wire form a distributed double (DC) bus. The first conducting wire and the second conducting wire form a positive bus. The second conducting wire and the third conducting wire form a negative bus. The third conducting wire is a neutral wire (Middle Cable) of the distributed double bus. The first conducting wire, the second conducting wire, and the third conducting wire are direct current conducting wires. In a 3D technology (three direct-Cable), a direct current bus is constructed by using three cables, a positive bus is constructed by using the first conducting wire and the second conducting wire, and a negative bus is constructed by using the second conducting wire and the third conducting wire.

[00134] FIG. 8 is a schematic diagram of an embodiment of the power system according to an embodiment of this application. As shown in FIG. 8, in some embodiments, both the first node and the second node are coupled to ground. In this embodiment of this application, both the first node and the second node are coupled to ground, so that when output powers or output voltages of the power supply 1 and the power supply 2 are asymmetric, or input powers or input voltages of the first-stage DC-to-AC unit and the second DC-to-AC unit are asymmetric, a current loop is provided to achieve voltage equalization, thereby ensuring normal operation of the system. In addition, no cable connection is required between the first node and the second node, and therefore costs of one cable and construction costs can be reduced.

[00135] In some embodiments, when the first node and the second node are coupled, when an output voltage and/or an output current and/or an output power of one of the power supply 1 and the power supply 2 are/is less than a preset value, the corresponding power supply stops working. In this case, at least one of the DC-to-AC unit 1 and the DC-to-AC unit 2 works. In an example, when the output voltage of the power supply 1 is less than the preset value, the power supply 1 stops working, and when the output voltage of the power supply 2 is greater than the preset value, the power supply 2 continues to work. In another example, when the output voltage of the power supply 2 is less than the preset value, the power supply 2 stops working. In this embodiment of this application, the power supply whose output is less than the preset value may be stopped from working. This avoids unnecessary waste, and improves conversion efficiency and utilization. In addition, it is ensured that at least one DC-to-AC unit works, and therefore, normal operation of the system can be ensured in real time.

[00136] When the first node and the second node are not coupled, impact of power supply inconsistency is considered. For example, due to different illuminations, in a photovoltaic power generation system, the output voltage of the power supply 1 may be greater than the output voltage of the power supply 2, that is, voltages and/or powers output by the power supply 1 and the power supply 2 may be asymmetric, resulting in a cask effect in the output powers. Therefore, when the first node and the second node are not coupled, the power system may be provided with an equalization circuit to prevent asymmetry of the voltages and/or powers output by the power supply 1 and the power supply 2. The following provides four equalization circuits. In actual application, another equalization circuit may alternatively exist. This is not limited in this embodiment of this application.

[00137] In some embodiments, the power system further includes a first equalization circuit unit. FIG. 9a is a schematic diagram of the power system that includes the first equalization circuit unit. The first equalization circuit unit is configured with a first interface, a second interface, and a third interface. The first interface is coupled to the second node. The second interface is coupled to the positive input terminal of the first-stage DC-to-AC unit. The third interface is coupled to the negative input terminal of the second-stage DC-to-AC unit. The first equalization circuit unit may balance the input voltages and/or powers and/or currents of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit. A working principle of the first equalization circuit unit is as follows: The first equalization circuit unit obtains energy from an input terminal of the first-stage DC-to-AC unit through the first interface and the second interface, and compensates the energy to the second-stage DC-to-AC unit through the first interface and the third interface. Alternatively, the first equalization circuit unit obtains energy from an input terminal of the second-stage DC-to-AC unit through the first interface and the third interface, and compensates the energy to the first-stage DC-to-AC unit through the first interface and the second interface.

[00138] In some embodiments, the power system further includes a second equalization circuit unit. FIG. 9b1 is a schematic diagram 1 of the power system that includes the second equalization circuit unit. FIG. 9b2 is a schematic diagram 2 of the power system that includes the second equalization circuit unit. The second equalization circuit unit is configured with a fourth interface and a fifth interface. The fourth interface is coupled to the second node. The fifth interface is coupled to the positive input terminal of the first-stage DC-to-AC unit or coupled to the negative input terminal of the second-stage DC-to-AC unit. A working principle of the second equalization circuit unit is similar to the working principle of the first equalization circuit unit. Specifically, the second equalization circuit unit may compensate energy of the first-stage DC-to-AC unit to the second-stage DC-to-AC unit, or compensate energy of the second-stage DC-to-AC unit to the first-stage DC-to-AC unit. Therefore, the second equalization circuit unit may be configured to balance the input voltages and/or powers and/or currents of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit.

[00139] In some embodiments, the power system further includes a third equalization circuit unit. FIG. 9c is a schematic diagram of the power system that includes the third equalization circuit unit. The third equalization circuit unit is configured with a sixth interface, a seventh interface, and an eighth interface. The sixth interface is coupled to the first node. The seventh interface is

coupled to the positive output terminal of the power supply 1. The eighth interface is coupled to the negative output terminal of the power supply 2. A working principle of the third equalization circuit unit is similar to the working principle of the first equalization circuit unit. Specifically, the third equalization circuit unit may compensate energy output by the power supply 1 to the power supply 2, or compensate energy output by the power supply 2 to the power supply 1. Therefore, the third equalization circuit unit may be configured to balance the output voltages and/or powers and/or currents of the power supply 1 and the power supply 2.

[00140] In some embodiments, the power system further includes a fourth equalization circuit unit. FIG. 9d1 is a schematic diagram 1 of the power system that includes the fourth equalization circuit unit. FIG. 9d2 is a schematic diagram 2 of the power system that includes the fourth equalization circuit unit. The fourth equalization circuit unit is configured with a ninth interface and a tenth interface. The ninth interface is coupled to the first node. The tenth interface is coupled to the positive output terminal of the power supply 1 or to the negative output terminal of the power supply 2. A working principle of the fourth equalization circuit unit is similar to the working principle of the first equalization circuit unit. Specifically, the fourth equalization circuit unit may compensate the energy output by the power supply 1 to the power supply 2, or compensate the energy output by the power supply 2 to the power supply 1. Therefore, the fourth equalization circuit unit may be configured to balance the output voltages and/or powers and/or currents of the power supply 1 and the power supply 2.

[00141] In some embodiments, the output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different transformers. Alternatively, the output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different windings of a same transformer, to implement isolated output.

[00142] In some embodiments, the power supply 1 and the power supply 2 are considered as one combination of power supplies. The first-stage DC-to-AC unit and the second-stage DC-to-AC unit are considered as one combination of DC-to-AC units. FIG. 10a is a schematic diagram of a plurality of combinations of power supplies connected in parallel according to an embodiment of this application. As shown in FIG. 10a, when at least two combinations of power supplies are coupled, an output terminal corresponding to a power supply 1 in a first combination of power supplies is coupled in parallel to an output terminal corresponding to a power supply 1 in a second combination of power supplies. This is similar to the description of the combination of power

supplies in Embodiment 1, and details are not described herein again. FIG. 10b is a schematic diagram of a plurality of combinations of DC-to-AC units connected in parallel according to an embodiment of this application. When at least two combinations of DC-to-AC units are connected in parallel, an input terminal of a first-stage DC-to-AC unit in a first combination of DC-to-AC units is connected in parallel to an input terminal of a first-stage DC-to-AC unit in a second combination of DC-to-AC units. This is similar to the description of the situation of the input terminal of the combination of DC-to-AC units in Embodiment 1, and details are not described herein again. FIG. 10c is another schematic diagram of a plurality of combinations of DC-to-AC units connected in parallel according to an embodiment of this application. When at least two combinations of DC-to-AC units are connected in parallel, an output of an output terminal of a first-stage DC-to-AC unit in a first combination of DC-to-AC units and an output of an output terminal of a first-stage DC-to-AC unit in a second combination of DC-to-AC units may be connected in parallel, or may be isolated. This is similar to the situation of the output terminal of the combination of DC-to-AC units in Embodiment 1, and details are not described herein again.

[00143] In some embodiments, an insulation monitoring device (IMD) is coupled between the output terminal of the first-stage DC-to-AC unit and a ground point. In some other embodiments, an IMD is coupled between the output terminal of the second-stage DC-to-AC unit and a ground point. In some other embodiments, a first IMD is coupled between the output terminal of the first-stage DC-to-AC unit and a ground point, and a second IMD is coupled between the output terminal of the second-stage DC-to-AC unit and the ground point. The IMD can detect insulation impedance to ground of the power system. When the insulation impedance to ground is less than a preset value, preferably, in this embodiment of this application, a coupling connection between the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit and a transformer winding may be broken, so that the entire system stops working, thereby further ensuring safety of system operation.

[00144] In this embodiment of this application, a communication signal is coupled to a direct current cable connected between the power supply 1, the power supply 2, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit, to implement communication between the power supply 1, the power supply 2, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit. The communication signal is preferably a PLC signal, which is similar to the description of the communication signal in the foregoing embodiment, and details are not described herein again.

[00145] In this embodiment of this application, a communication signal is coupled to an

alternating current cable connected to the output terminal of the first-stage DC-to-AC unit, and the alternating current cable may be further coupled to another device. The first-stage DC-to-AC unit may communicate with another device on the alternating current cable by using the communication signal. When a plurality of combinations of DC-to-AC units are connected in parallel, and outputs of a plurality of first-stage DC-to-AC units are connected in parallel, the parallel-connected output terminals of the plurality of first-stage DC-to-AC units may communicate, by using a communication signal on a connected alternating current cable, with another device coupled to the alternating current cable. The another device described above may be an alternating current device that uses an alternating current. Similarly, a communication situation of the output terminal of the second-stage DC-to-AC unit is similar to that of the first-stage DC-to-AC unit, and details are not described herein again. The communication signal is preferably a PLC signal, which is similar to the description of the communication signal in the foregoing embodiment, and details are not described herein again.

[00146] FIG. 11 is a schematic diagram of the power system with a leakage current sensor according to an embodiment of this application. As shown in FIG. 11, in some embodiments, the positive output terminal and the negative output terminal of the power supply 1 may be coupled to a leakage current sensor to detect a leakage current value of the output terminal of the power supply 1. The leakage current sensor may be embedded inside the power supply 1, or may be exposed outside the power supply 1. This is not limited in this embodiment of this application. The positive output terminal and the negative output terminal of the power supply 2 may be coupled to a leakage current sensor to detect a leakage current value of the output terminal of the power supply 2. The leakage current sensor may be embedded inside the power supply 2, or may be exposed outside the power supply 2. This is not limited in this embodiment of this application. The positive input terminal and the negative input terminal of the first-stage DC-to-AC unit may be coupled to a leakage current sensor to detect a leakage current at the input terminal of the first-stage DC-to-AC unit. The leakage current sensor may be embedded inside the first-stage DC-to-AC unit, or may be exposed outside the first-stage DC-to-AC unit. This is not limited in this embodiment of this application. An internal output phase wire of the first-stage DC-to-AC unit may be coupled to a leakage current sensor to detect a leakage current of the output terminal of the first-stage DC-to-AC unit. The leakage current sensor is usually arranged inside the first-stage DC-to-AC unit. Similarly, the input terminal and the output terminal of the second-stage DC-to-AC unit may also

be provided with a leakage current sensor like the first-stage DC-to-AC unit. Details are not described herein again. When any leakage current sensor detects that a corresponding leakage current value is greater than a preset threshold, the leakage current sensor may send a signal to any one or more or all of the power supply 1, the power supply 2, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit. Then, any one or more or all of the power supply 1, the power supply 2, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit may report an alarm to a host computer connected thereto, or may send a signal to stop the power system, or may take other measures. This is not limited in this embodiment of this application.

[00147] In some embodiments, at least one switch is connected in series to an internal output phase wire connected to the output terminal of the first-stage DC-to-AC unit, to implement fast shutdown of the output of the first-stage DC-to-AC unit. The switch may be a relay, a circuit breaker, or a contactor, or may be another type of switch. This is not limited in this embodiment of this application. Similarly, a switch may also be connected in series to an internal output phase wire connected to the output terminal of the second-stage DC-to-AC unit. This is similar to the case in which a switch is connected in series to the output phase wire of the first-stage DC-to-AC unit. Details are not described herein again.

[00148] In this embodiment of this application, when the power supply 1 and the power supply 2 are a photovoltaic array, the power system may be referred to as a photovoltaic power generation system. For another type of power system, for example, a wind power generation system, an energy storage system, or a hybrid power generation system, refer to the photovoltaic power generation system for implementation. Details are not described for another type of power system in this embodiment of this application. The following describes the photovoltaic power generation system in detail.

[00149] In the photovoltaic power generation system, only one of the first node and the second node needs to be coupled to ground, that is, the first node is coupled to ground or the second node is coupled to ground. In some embodiments, both the first node and the second node may alternatively be coupled to ground. The first node and/or the second node and/is coupled to ground, so that when the output powers or output voltages of the power supply 1 and the power supply 2 are asymmetric, or the input powers or input voltages of the first-stage DC-to-AC unit and the second DC-to-AC unit are asymmetric, a current loop can be provided to achieve voltage equalization, thereby ensuring normal operation of the system, and reducing costs of one cable and

construction costs.

[00150] In the photovoltaic power generation system, a PID phenomenon may be eliminated by coupling a voltage source. FIG. 12a is a schematic diagram 1 of the power system with a voltage source according to an embodiment of this application. The voltage source is coupled between the ground point and a neutral point of a transformer winding corresponding to the output terminal of the second-stage DC-to-AC unit, to adjust a potential to ground of the neutral point. When the photovoltaic power generation system is normally connected to a grid for working, the voltage source is used to inject a voltage and a current between three-phase A/B/C and the ground, to ensure that voltages to ground at the negative output terminals of the power supply 1 and the power supply 2 are equal to 0, or voltages to ground at the positive output terminals of the power supply 1 and the power supply 2 are equal to 0. This prevents a cell panel in the photovoltaic array (the power supply 1 and the power supply 2) from generating a PID phenomenon. In addition, in this embodiment of this application, voltages may be adjusted so that the voltages to ground at the negative output terminals of the power supply 1 and the power supply 2 are greater than 0 (for a cell panel that generates a PID phenomenon when the voltage to ground of the negative output terminal PV- is less than 0), or the voltages to ground at the positive output terminals of the power supply 1 and the power supply 2 are less than 0 (for a cell panel that generates a PID phenomenon when the voltage to ground of the positive output terminal PV+ is greater than 0). This implements a PID repair function of the cell panel, and ensures that the voltages to ground at the positive output terminals and the negative output terminals of the power supply 1 and the power supply 2 do not exceed a maximum applied system voltage of the cell panel, to ensure system safety. The voltage may alternatively be adjusted by coupling the voltage source between the ground point and a neutral point of a transformer winding corresponding to the output terminal of the first-stage DC-to-AC unit. This is similar to the foregoing principle of coupling the voltage source between the ground point and the neutral point of the transformer winding corresponding to the output terminal of the second-stage DC-to-AC unit, and details are not described herein again.

[00151] FIG. 12b is a schematic diagram 2 of the power system with a voltage source according to an embodiment of this application. In this embodiment, the voltage source is coupled between the ground point and an external phase wire at an output terminal of the second-stage DC-to-AC unit, to adjust a potential to ground of the corresponding output phase wire. For example, when the external phase wires at the output side are ABC cables, the voltage source may be separately

connected to three cables, that is, ABC cables. When the photovoltaic power generation system is normally connected to a grid for working, the voltage source is used to inject a voltage and a current between three-phase A/B/C and the ground, to ensure that voltages to ground at the negative output terminals of the power supply 1 and the power supply 2 are equal to 0, or voltages to ground at the positive output terminals of the power supply 1 and the power supply 2 are equal to 0. This prevents a cell panel in the photovoltaic array (the power supply 1 and the power supply 2) from generating a PID phenomenon. This is similar to the foregoing principle of coupling the voltage source between the ground point and the neutral point of the transformer winding corresponding to the output terminal of the second-stage DC-to-AC unit, and details are not described herein again.

[00152] FIG. 12c is a schematic diagram 3 of the power system with a voltage source according to an embodiment of this application. In this embodiment, the voltage source is coupled between the ground point and an internal phase wire at the output terminal of the second-stage DC-to-AC unit, to adjust a potential to ground of the corresponding output phase wire. When the photovoltaic power generation system is normally connected to a grid for working, the voltage source is used to inject a voltage and a current between three-phase A/B/C and the ground, to ensure that voltages to ground at the negative output terminals of the power supply 1 and the power supply 2 are equal to 0, or voltages to ground at the positive output terminals of the power supply 1 and the power supply 2 are equal to 0. This prevents a cell panel in the photovoltaic array (the power supply 1 and the power supply 2) from generating a PID phenomenon. This is similar to the foregoing principle of coupling the voltage source between the ground point and the neutral point of the transformer winding corresponding to the output terminal of the second-stage DC-to-AC unit, and details are not described herein again. This is also similar to the principle of coupling the voltage source between the ground point and the internal phase wire at the output terminal of the first-stage DC-to-AC unit, and details are not described herein again.

[00153] In some possible embodiments, the voltage source may alternatively be replaced by a compensation power module, to implement a similar function. Details are not described herein again.

[00154] FIG. 13 is a schematic diagram of the power system with an isolation unit according to

an embodiment of this application. In the photovoltaic power generation system, the first-stage DC-to-AC unit may further internally include an AC-to-DC isolation unit. An input terminal of the isolation unit is coupled to an internal phase wire at the output terminal of the first-stage DC-to-AC unit. A first output terminal of the isolation unit is coupled to ground, and a second output terminal of the isolation unit is coupled to the positive input terminal and/or the negative input terminal of the first-stage DC-to-AC unit. The isolation unit may be configured to adjust an output voltage to ground of the first power supply and/or the second power supply. Similarly, the second-stage DC-to-AC unit may also internally include an AC-to-DC isolation unit. An input terminal of the isolation unit may be coupled to an internal phase wire at the output terminal of the second-stage DC-to-AC unit. A first output terminal of the isolation unit is coupled to ground, and a second output terminal of the isolation unit is coupled to the positive input terminal and/or the negative input terminal of the second-stage DC-to-AC unit, to adjust an output voltage to ground of the first power supply and/or the second power supply, so as to eliminate the PID phenomenon.

[00155] In some cases, an isolation unit is arranged inside the first-stage DC-to-AC unit, and no isolation unit is arranged inside the second-stage DC-to-AC unit. In some other cases, no isolation unit is arranged inside the first-stage DC-to-AC unit, and an isolation unit is arranged inside the second-stage DC-to-AC unit. In some other cases, an isolation unit is arranged inside each of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit. The isolation unit inside the first-stage DC-to-AC unit may be referred to as a first AC-to-DC isolation unit, and the isolation unit inside the second-stage DC-to-AC unit may be referred to as a second AC-to-DC isolation unit. This is not limited in this embodiment of this application.

[00156] In some embodiments, in the photovoltaic power generation system, the first power supply and the second power supply are a photovoltaic array, and may be a photovoltaic array formed by serially or parallelly connecting an output terminal of a photovoltaic cell panel to an optimizer or a shutdown device and then connecting in series or in parallel combinations, as shown in FIG. 3b. In this photovoltaic system, a communication signal may be coupled to a direct current cable connected to an output terminal of the optimizer or the shutdown device, and the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit may communicate with the optimizer or the shutdown device by using the communication signal, and control the optimizer or the shutdown device to implement fast shutdown of the optimizer or the shutdown device.

[00157] In some embodiments, the photovoltaic power generation system may further include

a combiner unit. FIG. 14a is a schematic diagram 1 of the power system having a combiner unit according to an embodiment of this application. The photovoltaic power generation system includes two combiner units, where one combiner unit is a first combiner unit, and the other combiner unit is a second combiner unit. An input terminal of the first combiner unit is coupled to an output terminal of the power supply 1. A positive output terminal of the first combiner unit is coupled to the positive input terminal of the first-stage DC-to-AC unit. A negative output terminal of the first combiner unit is coupled to a positive output terminal of the second combiner unit and then coupled to the second node. A negative output terminal of the second combiner unit is coupled to the negative input terminal of the second-stage DC-to-AC unit. In actual application, a direct current cable connected to the positive output terminal of the first combiner unit may be referred to as a positive bus, and a direct current cable connected to the negative output terminal of the first combiner unit may be referred to as a negative bus. The same rule is applied to the second combiner unit, and details are not described herein again. The photovoltaic power generation system using the combiner unit may be connected to more power supplies 1 and power supplies 2, thereby improving photovoltaic power generation efficiency.

[00158] FIG. 14b is a schematic diagram 2 of the power system having a combiner unit according to an embodiment of this application. In some embodiments, the photovoltaic power generation system may include a combiner unit. An input terminal of the combiner unit may be coupled to an output terminal of the power supply 1, or may be coupled to an output terminal of the power supply 2. The combiner unit has three output terminals. A first output terminal is coupled to the positive input terminal of the first-stage DC-to-AC unit, a second output terminal is coupled to the second node, and a third output terminal is coupled to the negative input terminal of the second-stage DC-to-AC unit. It may be understood that, the first output terminal, the second output terminal, and the third output terminal are only names in a relatively broad sense. In actual application, the output terminal may alternatively have another proper name. This is not limited in this embodiment of this application. In addition, in actual application, a direct current cable connected to the first output terminal of the combiner unit may be referred to as a positive bus, and a direct current cable connected to the third output terminal of the combiner unit may be referred to as a negative bus. The photovoltaic power generation system using the combiner unit may be connected to more power supplies 1 and power supplies 2, thereby improving photovoltaic power generation efficiency.

[00159] In some embodiments, the photovoltaic power generation system may further include at least one energy storage unit. At least two direct current cables connected to the power supply 1, the power supply 2, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit are coupled in parallel to the energy storage unit. FIG. 15a is a schematic diagram 1 of the power system that includes an energy storage unit according to an embodiment of this application. In this embodiment of this application, the positive output terminal of the power supply 1 is coupled to the positive input terminal of the first-stage DC-to-AC unit by using a first direct current cable. The first node is coupled to the second node by using a second direct current cable. The negative output terminal of the power supply 2 is coupled to the negative input terminal of the second-stage DC-to-AC unit by using a third direct current cable. The energy storage unit is coupled in parallel to the first direct current cable and the second direct current cable. FIG. 15b is a schematic diagram 2 of the power system that includes an energy storage unit according to an embodiment of this application. The energy storage unit is coupled in parallel to the first direct current cable and the third direct current cable. FIG. 15c is a schematic diagram 3 of the power system that includes an energy storage unit according to an embodiment of this application. The energy storage unit is coupled in parallel to the second direct current cable and the third direct current cable. FIG. 15d is a schematic diagram 4 of the power system that includes an energy storage unit according to an embodiment of this application. The energy storage unit is coupled in parallel to three direct current cables. In the photovoltaic system provided in this embodiment of this application, the energy storage unit can collect energy and provide the energy to an apparatus connected to the energy storage unit.

[00160] In this embodiment with the energy storage unit, the energy storage unit may be an energy storage device, or may include a direct current conversion unit and the energy storage device. This is similar to the description of the energy storage unit in Embodiment 1, and details are not described herein again.

[00161] In this embodiment with the energy storage unit, the energy storage unit may communicate with the power supply 1, the power supply 2, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit by using a communication signal coupled to the direct current cable. This is similar to the description of the energy storage unit in Embodiment 1, and details are not described herein again.

Embodiment 3

[00162] FIG. 16 is a schematic diagram of Embodiment 3 of a power system according to an embodiment of this application. The power system includes N power supplies, N DC-to-DC units, and M DC-to-AC units. The N power supplies include a power supply 1, a power supply 2, ..., and a power supply N. These power supplies may be a photovoltaic array, energy storage power supplies, wind power generation direct current sources, or the like, and are similar to those in Embodiment 1, and details are not described herein again. The M DC-to-AC units include a DC-to-AC unit 1, a DC-to-AC unit 2, ..., and a DC-to-AC unit M. These DC-to-AC units may be apparatuses that can convert a direct current into an alternating current, for example, an inverter, and are similar to those in Embodiment 1, and details are not described herein again.

[00163] FIG. 17 is a schematic diagram of a DC-to-DC unit according to an embodiment of this application. In this embodiment of this application, the N DC-to-DC units include a DC-to-DC unit 1, a DC-to-DC unit 2, ..., and a DC-to-DC unit N. As shown in FIG. 17, each DC-to-DC unit may be configured with a positive input terminal, a negative input terminal, a positive output terminal, and a negative output terminal. For ease of description, in this embodiment of this application, unless otherwise specified or marked, an input terminal in the upper left part of the DC-to-DC unit is generally referred to as a positive input terminal, an input terminal in the lower left part is generally referred to as a negative input terminal, an output terminal in the upper right part is referred to as a positive output terminal, and an output terminal in the lower right part is referred to as a negative output terminal. It may be understood that, in this embodiment of this application, the DC-to-DC unit may be an apparatus that can convert a direct current into a direct current, for example, a DC/DC converter. This is not limited in this embodiment of this application.

[00164] As shown in FIG. 16, an output terminal of the power supply 1 is coupled to an input terminal of the DC-to-DC unit 1. Specifically, a positive output terminal of the power supply 1 is coupled to a positive output terminal of the DC-to-DC unit 1, and a negative output terminal of the power supply 1 is coupled to a negative output terminal of the DC-to-DC unit 1. Coupling between another power supply and another DC-to-DC unit is similar to the coupling described herein. For example, an output terminal of the power supply 2 is coupled to an input terminal of the DC-to-DC unit 2. Details are not described herein again.

[00165] It may be understood that, a power supply number, a DC-to-DC unit number, and a

DC-to-AC unit number in this embodiment of this application are used for ease of description, so that sequence numbers from 1 to N or M are used, and do not represent an actual sequence. In actual application, each power supply, each DC-to-DC unit, and each DC-to-AC unit may be numbered based on an actual situation. This is not limited in this embodiment of this application.

5 **[00166]** As shown in FIG. 16, the positive output terminal of the DC-to-DC unit 1 is coupled to a positive input terminal of the DC-to-AC unit 1, and a negative output terminal of the DC-to-DC unit N is coupled to a negative input terminal of the DC-to-AC unit M. The negative output terminal of the DC-to-DC unit 1 is coupled to a positive output terminal of the DC-to-DC unit 2, and a coupling node is referred to as a first node; a negative output terminal of the DC-to-DC unit 10 2 is coupled to a positive output terminal of the DC-to-DC unit 3, and a coupling node is referred to as a first node, ..., and so on, so as to form a plurality of first nodes. A negative input terminal of the DC-to-AC unit 1 is coupled to a positive input terminal of the DC-to-AC unit 2, and a coupling node is referred to as a second node; a negative input terminal of the DC-to-AC unit 2 is coupled to a positive input terminal of the DC-to-AC unit 3, and a coupling node is referred to as a second node, ..., and so on, so as to form a plurality of second nodes. In this embodiment of this application, output terminals of the DC-to-DC units are cascaded, and input terminals of the DC-to-AC units are cascaded. The output terminals of the DC-to-DC units are cascaded to increase an output voltage, to reduce a current between the DC-to-DC unit and the DC-to-AC unit, and resolve cost and loss problems of a cable from the DC-to-DC unit to the DC-to-AC unit. For example, a 20 maximum output voltage of each DC-to-DC unit is X volts, and after the N DC-to-DC units are cascaded, a maximum output voltage is NX volts. In a case of a same power, when a voltage increases, an output current decreases, a wire diameter specification of a used cable decreases, and costs decrease.

25 **[00167]** In this embodiment of this application, at least one first node and at least one second node are coupled. For example, in some embodiments, one first node is coupled to one second node, and another first node is not coupled to another second node. In some other embodiments, two first nodes are respectively coupled to two second nodes, and another first node is not coupled to another second node. In some other embodiments, a quantity of first nodes is equal to a quantity of second nodes, and each first node is coupled to a corresponding second node. In some other 30 embodiments, a quantity of first nodes is different from a quantity of second nodes, each first node is coupled to a corresponding second node, and a remaining first node or a remaining second node

is not coupled. In actual application, another coupling manner may alternatively be used. This is not limited in this embodiment of this application. In this embodiment of this application, a quantity of cables connected between the DC-to-DC unit and the DC-to-AC unit is reduced in a manner of the first node and the second node, to reduce costs of the power system.

5 **[00168]** In this embodiment of this application, outputs of output terminals of DC-to-AC units are isolated. For example, an output terminal of the DC-to-AC unit 1 is isolated from an output terminal of the DC-to-AC unit 2, and an output terminal of the DC-to-AC unit 2 is isolated from an output terminal of the DC-to-AC unit 3. In actual application, an output terminal of each DC-to-AC unit is coupled to different windings, and each winding may output a three-phase voltage
10 or a single-phase voltage. This is not limited in this embodiment of this application. In this embodiment of this application, the cascaded input and isolated output of the DC-to-AC unit reduce a specification of a power conversion device. Therefore, problems of insufficient specifications (generally up to 1700 V for an insulated gate bipolar transistor (IGBT)) and high costs of power conversion devices in the current industry are resolved. In addition, a circuit breaker
15 with a low specification may be used to reduce costs.

[00169] In some embodiments, the power supply 1, the power supply 2, ..., and the power supply N in FIG. 16 may be considered as one combination of power supplies. The DC-to-DC unit 1, the DC-to-DC unit 2, ..., and the DC-to-DC unit N may be considered as one combination of DC-to-DC units. The DC-to-AC unit 1, the DC-to-AC unit 2, ..., and the DC-to-AC unit M may
20 be considered as one combination of DC-to-AC units. Therefore, one power system includes at least one combination of power supplies, one combination of DC-to-DC units, and one combination of DC-to-AC units. When there are a plurality of combinations of DC-to-DC units and/or a plurality of combinations of DC-to-AC units, same-type output terminals of at least two combinations of DC-to-DC units are connected in parallel, and same-type input terminals of at
25 least two combinations of DC-to-AC units are connected in parallel. There is at least one cable coupled between the parallel-connected same-type output terminals and the parallel-connected same-type input terminals. Meanings of the same-type output terminals and same-type input terminals are similar to those described in Embodiment 1, and details are not described herein again. It may be understood that output terminals of the DC-to-DC unit 1, the DC-to-DC unit 2, ...,
30 and the DC-to-DC unit N may be cascaded to form at least one first node. Input terminals of the DC-to-AC unit 1, the DC-to-AC unit 2, ..., and the DC-to-AC unit M may be cascaded to form at

least one second node. The at least one first node is coupled to the at least one second node, in other words, there is at least one cable coupled between the parallel-connected same-type output terminals and the parallel-connected same-type input terminals. In this embodiment of this application, if there are a plurality of combinations of power supplies, the plurality of combinations of power supplies may be connected in series/parallel, and then be connected to a combination of DC-to-DC units. A specific coupling connection manner of these power supplies is not limited in this embodiment of this application.

[00170] In this embodiment of this application, same-type output terminals of the plurality of combinations of DC-to-AC units may be coupled in parallel, or outputs of the same-type output terminals may be isolated. This is similar to the description corresponding to FIG. 5c in the foregoing embodiment, and details are not described herein again.

[00171] In some embodiments, a communication signal is coupled to a direct current cable connected between the power supply and the DC-to-DC unit. A communication signal is also coupled to a direct current cable connected between the DC-to-DC unit and the DC-to-AC unit.

Preferably, the communication signal may be a PLC signal. This is similar to the description of the communication signal in Embodiment 1, and details are not described herein again. In actual application, the power system may use a power supply, a DC-to-DC unit, and a DC-to-AC unit that can recognize a communication signal, or may modify a power supply, a DC-to-DC unit, and a DC-to-AC unit so that the power supply, the DC-to-DC unit, and the DC-to-AC unit can recognize a communication signal. This is not limited in this embodiment of this application.

[00172] In some embodiments, the power supply is a photovoltaic array formed by connecting an output of a photovoltaic cell panel to an optimizer or a shutdown device, and then connecting in series or in parallel combinations. When a communication signal is coupled to a direct current cable connected between the power supply, the DC-to-DC unit, and the DC-to-AC unit, the communication signal also passes through the optimizer or the shutdown device, and the power supply, the DC-to-DC unit, or the DC-to-AC unit may control, by using the communication signal, shutdown of the optimizer or the shutdown device, to implement fast shutdown. That is, the power supply, the DC-to-DC unit, or the DC-to-AC unit may send a communication signal that carries a shutdown instruction to the optimizer or the shutdown device. After receiving the communication signal that carries the shutdown instruction, the optimizer or the shutdown device executes the shutdown instruction, to implement fast shutdown. A situation of the communication signal is

similar to the description of the communication signal in Embodiment 1, and details are not described herein again.

[00173] In some embodiments, the power system further includes at least one energy storage unit. The energy storage unit is coupled in parallel to at least two direct current cables connected between the DC-to-DC unit and the DC-to-AC unit. In this embodiment of this application, the direct current cable connected between the DC-to-DC unit and the DC-to-AC unit may be a direct current cable for coupling the positive output terminal of the DC-to-DC unit 1 and the positive input terminal of the DC-to-AC unit 1, may be a direct current cable for coupling the negative output terminal of the DC-to-DC unit N and the negative input terminal of the DC-to-AC unit M, or may be a direct current cable for coupling the first node and the second node. For example, the energy storage unit is coupled in parallel between the direct current cable for coupling the positive output terminal of the DC-to-DC unit 1 and the positive input terminal of the DC-to-AC unit 1 and the direct current cable for coupling the negative output terminal of the DC-to-DC unit N and the negative input terminal of the DC-to-AC unit N. Alternatively, the energy storage unit is coupled in parallel among three direct current cables for coupling the first node and the second node. It may be understood that a quantity of energy storage units included in one power system is not limited, that is, a plurality of energy storage units may be coupled in parallel at the same time. This is not limited in this embodiment of this application.

[00174] In the embodiment that includes the energy storage unit, the energy storage unit may be an energy storage device, or may include a direct current conversion unit and the energy storage device, or may be another apparatus capable of storing energy. This is similar to the description of the energy storage unit in Embodiment 1, and details are not described herein again. A communication signal is coupled to a direct current cable connected between the energy storage unit and the DC-to-DC unit, and the energy storage unit may communicate with the DC-to-DC unit. A communication signal is coupled to a direct current cable connected between the energy storage unit and the DC-to-AC unit, and the energy storage unit may communicate with the DC-to-AC unit. A situation of the communication signal and a principle for implementing communication are similar to the description of the communication signal in Embodiment 1, and details are not described herein again.

Embodiment 4

[00175] FIG. 18 is a schematic diagram of Embodiment 4 of a power system according to an embodiment of this application. The power system includes a power supply 1, a power supply 2, a first-stage DC-to-DC unit, a second-stage DC-to-DC unit, a first-stage DC-to-AC unit, and a second-stage DC-to-AC unit. The power supply 1 and the power supply 2 may be a photovoltaic array, energy storage power supplies, or wind power generation direct current sources, which are similar to the power supplies in Embodiment 1, and details are not described herein again. The first-stage DC-to-DC unit and the second-stage DC-to-DC unit are similar to the DC-to-DC units in Embodiment 3, and details are not described herein again. The first-stage DC-to-AC unit and the second-stage DC-to-AC unit may be apparatuses that can convert a direct current into an alternating current, for example, an inverter. The first-stage DC-to-AC unit and the second-stage DC-to-AC unit are similar to the DC-to-AC units in Embodiment 1, and details are not described herein again.

[00176] In this embodiment of this application, an output terminal of the power supply 1 is coupled to an input terminal of the first-stage DC-to-DC unit. For example, a positive output terminal of the power supply 1 is coupled to a positive input terminal of the first-stage DC-to-DC unit, and a negative output terminal of the power supply 1 is coupled to a negative input terminal of the first-stage DC-to-DC unit. Similarly, an output terminal of the power supply 2 is coupled to an input terminal of the second-stage DC-to-DC unit. As shown in FIG. 18, marks "+" and marks "-" are added to corresponding positions of input terminals and output terminals of the power supply 1, the power supply 2, the first-stage DC-to-DC unit, and the second-stage DC-to-DC unit. The mark "+" indicates a positive output terminal or a positive input terminal. The mark "-" indicates a negative output terminal or a negative input terminal. Meanings of the mark "+" and the mark "-" in other drawings provided in this embodiment of this application are similar. Details are not described again.

[00177] In this embodiment of this application, a positive output terminal of the first-stage DC-to-DC unit is coupled to a positive input terminal of the first-stage DC-to-AC unit. A negative output terminal of the second-stage DC-to-DC unit is coupled to a negative input terminal of the second-stage DC-to-AC unit. A negative output terminal of the first-stage DC-to-DC unit is coupled to a positive output terminal of the second-stage DC-to-DC unit. A negative input terminal

of the first-stage DC-to-AC unit is coupled to a positive input terminal of the second-stage DC-to-AC unit. Therefore, outputs of the first-stage DC-to-DC unit and the second-stage DC-to-DC unit are cascaded, and inputs of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are cascaded. In this embodiment of this application, the output terminals of the DC-to-DC units are cascaded to increase an output voltage, to reduce a current between the DC-to-DC unit and the DC-to-AC unit, and resolve cost and loss problems of a cable from the DC-to-DC unit to the DC-to-AC unit. For example, a maximum output voltage of each of the first-stage DC-to-DC unit and the second-stage DC-to-DC unit is 1500 V, and after outputs of the first-stage DC-to-DC unit and the second-stage DC-to-DC unit are cascaded, the maximum output voltage is 3 kV. In a case of a same power, when a voltage increases, an output current decreases, a wire diameter specification of a used cable decreases, and costs decrease.

[00178] In this embodiment of this application, outputs of output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are isolated, and are connected to different windings. This is similar to the case in which the output of the DC-to-AC unit is isolated in Embodiment 1, and details are not described herein again. In this embodiment of this application, the cascaded input and isolated output of the DC-to-AC unit reduce a specification of a power conversion device. Specifications of power conversion devices in the current industry are insufficient (generally up to 1700 V for an IGBT). However, a 1500 V circuit breaker may be used in the power system provided in this embodiment of this application to reduce costs. The technical problem of insufficient specifications of the power conversion devices in the current industry is resolved.

[00179] A node for coupling the negative output terminal of the first-stage DC-to-DC unit and the positive output terminal of the second-stage DC-to-DC unit is referred to as a first node. A node for coupling the negative input terminal of the first-stage DC-to-AC unit and the positive input terminal of the second-stage DC-to-AC unit is referred to as a second node.

[00180] In some embodiments, the first node is coupled to the second node. When an input voltage and/or an input current and/or an input power of one of the first-stage DC-to-DC unit and the second-stage DC-to-DC unit are/is less than a preset value, the corresponding DC-to-DC unit stops working. For example, when the input voltage of the first-stage DC-to-DC unit is less than the preset value, the first-stage DC-to-DC unit stops working. In another example, when the input power of the second-stage DC-to-DC unit is less than the preset value, the second-stage DC-to-

DC unit stops working. At least one of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit works. In this embodiment of this application, when the input voltage and/or the input current and/or the input power of the first-stage DC-to-DC unit or the second-stage DC-to-DC unit are/is excessively low, the unit with a low voltage and/or current and/or power is stopped, and an appropriate unit is selected to work. This can avoid unnecessary waste and improve conversion efficiency and utilization of the entire system.

[00181] FIG. 19 is a schematic diagram of an embodiment of the power system according to an embodiment of this application. As shown in FIG. 19, in some embodiments, the positive output terminal of the first-stage DC-to-DC unit is coupled to the positive input terminal of the first-stage DC-to-AC unit by using a first conducting wire. The negative output terminal of the second-stage DC-to-DC unit is coupled to the negative input terminal of the second-stage DC-to-AC unit by using a second conducting wire. The first node and the second node are coupled by using a third conducting wire. It may be understood that, in this embodiment of this application, the first conducting wire, the second conducting wire, and the third conducting wire are all direct current cables connected between the DC-to-DC unit (the first-stage DC-to-DC unit and the second-stage DC-to-DC unit) and the DC-to-AC unit (the first-stage DC-to-AC unit and the second-stage DC-to-AC unit). A material and a wire diameter specification of the cable may be configured based on an actual situation. This is not limited in this embodiment of this application. It may be understood that, in the conventional technology, the first-stage DC-to-DC unit and the second-stage DC-to-DC unit may have four output terminals in total, and therefore, four cables are connected. However, in this embodiment of this application, the first-stage DC-to-DC unit and the second-stage DC-to-DC unit are cascaded, and the first node and the second node are coupled by using one cable, so that the existing technical solution of four cables is modified into a solution that requires only three cables. Therefore, this can reduce costs of one cable and construction costs.

[00182] In some embodiments, the first conducting wire, the second conducting wire, and the third conducting wire form a distributed double (DC) bus. The first conducting wire and the second conducting wire form a positive bus. The second conducting wire and the third conducting wire form a negative bus. The third conducting wire is a neutral wire (Middle Cable) of the distributed double bus. The first conducting wire, the second conducting wire, and the third conducting wire are direct current conducting wires. In a 3D technology (three direct-Cable), a direct current bus is constructed by using three cables, a positive bus is constructed by using the first conducting

wire and the second conducting wire, and a negative bus is constructed by using the second conducting wire and the third conducting wire.

[00183] In addition, because the first node is a middle point of cascading the first-stage DC-to-DC unit and the second-stage DC-to-DC unit, and the second node is a middle point of cascading the first-stage DC-to-AC unit and the second-stage DC-to-AC unit, a current value of the third conducting wire may be less than or equal to a current value of the first conducting wire. When the current value of the third conducting wire is less than or equal to the current value of the first conducting wire, a wire diameter specification of the third conducting wire may be reduced, to reduce costs of the third conducting wire. In another possible case, similarly, a current value of the third conducting wire is less than or equal to a current value of the second conducting wire. Therefore, when the current value of the third conducting wire is less than or equal to the current value of the second conducting wire, a wire diameter specification of the third conducting wire may be reduced, to reduce cable costs of the third conducting wire. Certainly, the current value of the third conducting wire may alternatively be less than the current value of the first conducting wire and less than the current value of the second conducting wire. This may also reduce the wire diameter specification of the third conducting wire, and reduce the cable costs of the third conducting wire.

[00184] FIG. 20 is a schematic diagram of another embodiment of the power system according to an embodiment of this application. As shown in FIG. 20, in some embodiments, both the first node and the second node are coupled to ground. In this embodiment of this application, both the first node and the second node are coupled to ground, so that when output powers or output voltages of the first-stage DC-to-DC unit and the second-stage DC-to-DC unit are asymmetric, or input powers or input voltages of the first-stage DC-to-AC unit and the second DC-to-AC unit are asymmetric, a current loop is provided to achieve voltage equalization, thereby ensuring normal operation of the system. In addition, no cable connection is required between the first node and the second node, and therefore costs of one cable and construction costs can be reduced.

[00185] When the first node and the second node are not coupled, impact of power supply inconsistency is considered. For example, due to different illuminations, in a photovoltaic power generation system, an output voltage of the power supply 1 may be greater than an output voltage of the power supply 2, and output voltages of the first-stage DC-to-DC unit and the second-stage DC-to-DC unit are also different. That is, voltages and/or powers output by the first-stage DC-to-

DC unit and the second-stage DC-to-DC unit may be asymmetric, resulting in a cask effect in the output powers. Therefore, when the first node and the second node are not coupled, the power system may be provided with an equalization circuit to prevent asymmetry of the voltages and/or powers output by the first-stage DC-to-DC unit and the second-stage DC-to-DC unit. The following provides a plurality of equalization circuits. In actual application, another equalization circuit may alternatively exist. This is not limited in this embodiment of this application.

[00186] FIG. 21 is a schematic diagram of the power system that includes a first equalization circuit unit according to an embodiment of this application. In some embodiments, the power system further includes the first equalization circuit unit. The first equalization circuit unit is configured with a first interface, a second interface, and a third interface. The first interface is coupled to the second node. The second interface is coupled to the positive input terminal of the first-stage DC-to-AC unit. The third interface is coupled to the negative input terminal of the second-stage DC-to-AC unit. The first equalization circuit unit may balance the input voltages and/or powers and/or currents of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit. A working principle of the first equalization circuit unit is as follows: The first equalization circuit unit obtains energy from an input terminal of the first-stage DC-to-AC unit through the first interface and the second interface, and compensates the energy to the second-stage DC-to-AC unit through the first interface and the third interface. Alternatively, the first equalization circuit unit obtains energy from an input terminal of the second-stage DC-to-AC unit through the first interface and the third interface, and compensates the energy to the first-stage DC-to-AC unit through the first interface and the second interface.

[00187] In a possible embodiment, the first equalization circuit unit may include four interfaces, that is, the first equalization circuit unit is further configured with a fourth interface. The fourth interface is coupled to the first node. As shown in FIG. 21, a dashed line indicates that in a possible embodiment, the fourth interface is coupled to the first node. When energy compensation is performed by using the first equalization circuit that includes four interfaces, the first equalization circuit may further compensate energy of the first-stage DC-to-DC unit and the second-stage DC-to-DC unit, that is, balance and adjust corresponding voltages and/or powers and/or currents.

[00188] FIG. 22a is a schematic diagram 1 of the power system that includes a second equalization circuit unit according to an embodiment of this application. In a case, the second equalization circuit unit is configured with a fifth interface and a sixth interface. The fifth interface

is coupled to the second node. The sixth interface is coupled to the positive input terminal of the first-stage DC-to-AC unit. A working principle of the second equalization circuit unit is similar to the working principle of the first equalization circuit unit. Specifically, the second equalization circuit unit may compensate energy of the first-stage DC-to-AC unit to the second-stage DC-to-AC unit, or compensate energy of the second-stage DC-to-AC unit to the first-stage DC-to-AC unit. Therefore, the second equalization circuit unit may be configured to balance the input voltages and/or powers and/or currents of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit. FIG. 22b is a schematic diagram 2 of the power system that includes a second equalization circuit unit according to an embodiment of this application. In another case, the second equalization circuit unit is configured with a fifth interface and a sixth interface. The fifth interface is coupled to the second node. The sixth interface is coupled to the negative input terminal of the second-stage DC-to-AC unit. The second equalization circuit unit may be configured to balance the input voltages and/or powers and/or currents of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit. This is similar to the second equalization circuit unit corresponding to FIG. 22a, and details are not described herein again.

[00189] FIG. 23 is a schematic diagram of the power system that includes a third equalization circuit unit according to an embodiment of this application. The third equalization circuit unit is configured with a seventh interface, an eighth interface, and a ninth interface. The seventh interface is coupled to the first node. The eighth interface is coupled to the positive output terminal of the first-stage DC-to-DC unit. The ninth interface is coupled to the negative output terminal of the second-stage DC-to-DC unit. A working principle of the third equalization circuit unit is similar to the working principle of the first equalization circuit unit. Specifically, the third equalization circuit unit may compensate energy output by the first-stage DC-to-DC unit to the second-stage DC-to-DC unit, or compensate energy output by the second-stage DC-to-DC unit to the first-stage DC-to-DC unit. Therefore, the third equalization circuit unit may be configured to balance the output voltages and/or powers and/or currents of the first-stage DC-to-DC unit and the second-stage DC-to-DC unit.

[00190] In a possible embodiment, the third equalization circuit unit may include four interfaces, that is, the third equalization circuit unit is further configured with a tenth interface. The tenth interface is coupled to the second node. As shown in FIG. 21, a dashed line indicates that in a possible embodiment, the tenth interface is coupled to the second node. When energy

compensation is performed by using the third equalization circuit that includes four interfaces, the third equalization circuit unit may further compensate energy of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit, that is, balance and adjust corresponding voltages and/or powers and/or currents.

5 **[00191]** FIG. 24a is a schematic diagram 1 of a power system that includes a fourth equalization circuit unit according to an embodiment of this application. In a case, the fourth equalization circuit unit is configured with an eleventh interface and a twelfth interface. The eleventh interface is coupled to the first node. The twelfth interface is coupled to the positive input terminal of the first-stage DC-to-DC unit. A working principle of the fourth equalization circuit unit is similar to the
10 working principle of the second equalization circuit unit. Specifically, the fourth equalization circuit unit may compensate energy of the first-stage DC-to-DC unit to the second-stage DC-to-DC unit, or compensate energy of the second-stage DC-to-DC unit to the first-stage DC-to-DC unit. Therefore, the fourth equalization circuit unit may be configured to balance the input voltages and/or powers and/or currents of the first-stage DC-to-DC unit and the second-stage DC-to-DC
15 unit. FIG. 24b is a schematic diagram 2 of the power system that includes a fourth equalization circuit unit according to an embodiment of this application. In another case, the fourth equalization circuit unit is configured with an eleventh interface and a twelfth interface. The eleventh interface is coupled to the first node. The twelfth interface is coupled to the negative input terminal of the second-stage DC-to-DC unit. The second equalization circuit unit may be configured to balance
20 the input voltages and/or powers and/or currents of the first-stage DC-to-DC unit and the second-stage DC-to-DC unit. This is similar to the fourth equalization circuit unit corresponding to FIG. 24a, and details are not described herein again.

[00192] In some embodiments, the output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different transformers. Alternatively, the
25 output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different windings of a same transformer, to implement isolated output.

[00193] In some embodiments, the first-stage DC-to-DC unit and the second-stage DC-to-DC unit are considered as one combination of DC-to-DC units. FIG. 25 is a schematic diagram of a plurality of combinations of DC-to-DC units connected in parallel according to an embodiment of
30 this application. As shown in FIG. 25, when a plurality of combinations of DC-to-DC units are connected in parallel, same-type output terminals corresponding to different combinations of DC-

to-DC units are connected in parallel. For example, a positive output terminal of a first-stage DC-to-DC unit in a first combination of DC-to-DC units is coupled to a positive output terminal of a first-stage DC-to-DC unit in a second combination of DC-to-DC units. Meanings of the same-type output terminals are similar to those described in Embodiment 2, and details are not described herein again. Parallel connection of a plurality of combinations of DC-to-AC units is similar to the description in Embodiment 2, and details are not described herein again. It may be understood that, outputs of same-type output terminals of the plurality of combinations of DC-to-AC units may be coupled in parallel, or may be isolated. This is similar to the description in Embodiment 2, and details are not described herein again.

[00194] In some embodiments, an insulation monitoring device (IMD) is coupled between an output terminal of the first-stage DC-to-AC unit and a ground point. FIG. 26 is a schematic diagram of the power system that is provided with an IMD according to an embodiment of this application. In some other embodiments, an IMD is coupled between an output terminal of the second-stage DC-to-AC unit and a ground point. In some other embodiments, a first IMD is coupled between an output terminal of the first-stage DC-to-AC unit and a ground point, and a second IMD is coupled between an output terminal of the second-stage DC-to-AC unit and a ground point. The IMD can detect insulation impedance to ground of the power system. When the insulation impedance to ground is less than a preset value, preferably, in this embodiment of this application, a coupling connection between the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit and a transformer winding may be broken, so that the entire system stops working, thereby further ensuring safety of system operation.

[00195] In this embodiment of this application, a communication signal is coupled to a direct current cable connected between the power supply 1, the power supply 2, the first-stage DC-to-DC unit, the second-stage DC-to-DC unit, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit, to implement communication between the power supply 1, the power supply 2, the first-stage DC-to-DC unit, the second-stage DC-to-DC unit, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit. The communication signal is preferably a PLC signal, which is similar to the description of the communication signal in the foregoing embodiment, and details are not described herein again.

[00196] In this embodiment of this application, a communication signal is coupled to an alternating current cable connected to the output terminal of the first-stage DC-to-AC unit, and the

alternating current cable may be further coupled to another device. The first-stage DC-to-AC unit may communicate with the another device on the alternating current cable by using the communication signal. When a plurality of combinations of DC-to-AC units are connected in parallel, and outputs of a plurality of first-stage DC-to-AC units are connected in parallel, the parallel-connected output terminals of the plurality of first-stage DC-to-AC units may communicate, by using a communication signal on a connected alternating current cable, with another device coupled to the alternating current cable. The another device described above may be an alternating current device that uses an alternating current. Similarly, a communication situation of the output terminal of the second-stage DC-to-AC unit is similar to that of the first-stage DC-to-AC unit, and details are not described herein again. The communication signal is preferably a PLC signal, which is similar to the description of the communication signal in the foregoing embodiment, and details are not described herein again.

[00197] In some embodiments, the power system provided in this embodiment of this application may be further configured with a leakage current sensor. The leakage current sensor may be arranged at the output terminal of the power supply 1, the output terminal of the power supply 2, the input terminal and the output terminal of the first-stage DC-to-DC unit, the input terminal and the output terminal of the second-stage DC-to-DC unit, the input terminal and the output terminal of the first-stage DC-to-AC unit, and the input terminal and the output terminal of the second-stage DC-to-AC unit. A case in which the leakage current sensor is arranged at the output terminal of the power supply 1, the output terminal of the power supply 2, the input terminal and the output terminal of the first-stage DC-to-AC unit, and the input terminal and the output terminal of the second-stage DC-to-AC unit is similar to the embodiment corresponding to FIG. 11, and details are not described herein again. A case in which the leakage current sensor is arranged at the input terminal and the output terminal of the first-stage DC-to-DC unit and the input terminal and the output terminal of the second-stage DC-to-DC unit is shown in FIG. 27. FIG. 27 is a schematic diagram of the power system that is configured with the leakage current sensor according to an embodiment of this application. It can be learned that the leakage current sensor may be arranged at the input terminal and the output terminal of the first-stage DC-to-DC unit and the input terminal and the output terminal of the second-stage DC-to-DC unit. It should be noted that, when the leakage current sensor is configured at the output terminal of the first-stage DC-to-DC unit and the output terminal of the second-stage DC-to-DC unit, the leakage current

sensor may be coupled to a direct current cable corresponding to the first node. When the first node and the second node are coupled to ground, the leakage current sensor may be connected to a ground cable, to implement a leakage current detection function. In actual application, three leakage current sensors may be configured, as shown in FIG. 27, or one or more of the leakage current sensors may be selected for configuration. This is not limited in this embodiment of this application. When any leakage current sensor detects that a corresponding leakage current value is greater than a preset threshold, the leakage current sensor may send a signal to any one or more or all of the power supply 1, the power supply 2, the first-stage DC-to-DC unit, the second-stage DC-to-DC unit, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit. Then, any one or more or all of the power supply 1, the power supply 2, the first-stage DC-to-DC unit, the second-stage DC-to-DC unit, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit may report an alarm to a host computer connected thereto, or may send a signal to stop the power system, or may take other measures. This is not limited in this embodiment of this application.

[00198] In some embodiments, at least one switch is connected in series to an internal output phase wire connected to the output terminal of the first-stage DC-to-AC unit, to implement fast shutdown of an output of the first-stage DC-to-AC unit. The switch may be a relay, a circuit breaker, or a contactor, or may be another type of switch. This is not limited in this embodiment of this application. Similarly, a switch may also be connected in series to an internal output phase wire connected to the output terminal of the second-stage DC-to-AC unit. This is similar to the case in which a switch is connected in series to the output phase wire of the first-stage DC-to-AC unit. Details are not described herein again.

[00199] In this embodiment of this application, when the power supply 1 and the power supply 2 are a photovoltaic array, the power system may be referred to as a photovoltaic power generation system. In this embodiment of this application, the power supply 1 may be referred to as a first photovoltaic array, and the power supply 2 may be referred to as a second photovoltaic array. In actual application, another name may be used. This is not limited in this embodiment of this application. For another type of power system, for example, a wind power generation system, an energy storage system, or a hybrid power generation system, refer to the photovoltaic power generation system for implementation. Details are not described for another type of power system in this embodiment of this application. The following describes the photovoltaic power generation system in detail.

[00200] In the photovoltaic power generation system, only one of the first node and the second node needs to be coupled to ground, that is, the first node is coupled to ground or the second node is coupled to ground. In some embodiments, both the first node and the second node may alternatively be coupled to ground. The first node and/or the second node and/is coupled to ground, so that when the output powers or output voltages of the first-stage DC-to-DC unit and the second DC-to-DC unit are asymmetric, or the input powers or input voltages of the first-stage DC-to-AC unit and the second DC-to-AC unit are asymmetric, a current loop can be provided to achieve voltage equalization, thereby ensuring normal operation of the system, and reducing costs of one cable and construction costs.

[00201] In the photovoltaic power generation system, as shown in FIG. 18, preferably, the negative input terminal and the negative output terminal of the first-stage DC-to-DC unit are directly coupled, or connected with only a small voltage drop. The connection with only a small voltage drop means that a voltage drop at two connected terminals is small. The voltage drop may be caused by coupling of a fuse, or may be caused by another case. This is not limited in this embodiment of this application. Similarly, the negative input terminal and the positive output terminal of the second-stage DC-to-DC unit are directly coupled, or connected with only a small voltage drop. In the embodiment corresponding to FIG. 18, negative output electrodes of the first photovoltaic array (the power supply 1) and the second photovoltaic array (the power supply 2) are equipotential. Normally, impedance to ground of the entire system is symmetrically distributed. When the system is normally connected to a grid for working, the first node, the second node, and the ground are equipotential. In this case, voltages to ground at PV- of cell panels of the first photovoltaic array and the second photovoltaic array are near 0 V. This eliminates a negative bias voltage to ground at PV- of the cell panel, and avoids a PID phenomenon of the cell panel (for a cell panel that has a negative voltage to ground at PV- and generates a PID phenomenon).

[00202] FIG. 28 is a schematic diagram of the photovoltaic power generation system according to an embodiment of this application. Preferably, the positive input terminal and the negative output terminal of the first-stage DC-to-DC unit are directly coupled, or connected with only a small voltage drop. The positive input terminal and the positive output terminal of the second-stage DC-to-DC unit are directly coupled, or connected with only a small voltage drop. The connection with only a small voltage drop means that a voltage drop at two connected terminals is small. This is similar to the description of the embodiment corresponding to FIG. 18, and details

are not described herein again. In this embodiment of this application, different manners of direct connection or connection with only a small voltage drop may be used to ensure that a positive output electrode of the second photovoltaic array and a positive output electrode of the first photovoltaic array are equipotential. Normally, impedance to ground of the entire system is symmetrically distributed. When the system is normally connected to a grid for working, the first node, the second node, and the ground are equipotential. In this case, output voltages to ground at PV+ of cell panels of the first photovoltaic array and the second photovoltaic array are near 0 V. This eliminates a positive bias voltage to ground at PV+ of the cell panel, and avoids a PID phenomenon of the cell panel (for a cell panel that has a positive voltage to ground at PV+ and generates a PID phenomenon). Similarly, when outputs of the first photovoltaic array and the second photovoltaic array share a negative terminal, a same effect can also be achieved.

[00203] In this embodiment of this application, in the photovoltaic power generation system, the PID phenomenon may alternatively be eliminated by coupling a voltage source. In some embodiments, a voltage source is coupled between the ground point and a neutral point of a transformer winding corresponding to the output terminal of the second-stage DC-to-AC unit, to adjust a potential to ground of the neutral point. When the photovoltaic power generation system is normally connected to the grid for working, the voltage source is used to inject a voltage and a current between three-phase A/B/C and the ground, to ensure that voltages to ground at negative output terminals of the first photovoltaic array and the second photovoltaic array are equal to 0, or voltages to ground at positive output terminals of the first photovoltaic array and the second photovoltaic array are equal to 0. This prevents the cell panel in the photovoltaic array (the first photovoltaic array and the second photovoltaic array) from generating a PID phenomenon. In addition, in this embodiment of this application, voltages may be adjusted so that voltages to ground at the negative output terminals of the first photovoltaic array and the second photovoltaic array are greater than 0 (for a cell panel that has a negative voltage to ground at the negative output terminal PV- and generates a PID phenomenon), or voltages to ground at the positive output terminals of the first photovoltaic array and the second photovoltaic array are less than 0 (for a cell panel that has a positive voltage to ground at the positive output terminal PV+ and generates a PID phenomenon). This implements a PID repair function of the cell panel, and ensures that the voltages to ground at the positive output terminals and the negative output terminals of the first photovoltaic array and the second photovoltaic array do not exceed a maximum applied system

voltage of the cell panel, to ensure system safety. The voltage may alternatively be adjusted by coupling a voltage source between the ground point and a neutral point of a transformer winding corresponding to the output terminal of the first-stage DC-to-AC unit. This is similar to the foregoing principle of coupling the voltage source between the ground point and the neutral point of the transformer winding corresponding to the output terminal of the second-stage DC-to-AC unit, and details are not described herein again.

[00204] In some embodiments, in the photovoltaic power generation system, a voltage source may be coupled between the ground point and an external phase wire at an output side of the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit, to adjust a potential to ground of the corresponding output phase wire and eliminate a PID phenomenon. This is similar to the principle in the embodiment corresponding to FIG. 12b, and details are not described herein again.

[00205] In some embodiments, in the photovoltaic power generation system, a voltage source may be coupled between the ground point and an internal phase wire at the output terminal of the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit, to adjust a potential to ground of the corresponding output phase wire and eliminate a PID phenomenon. This is similar to the principle in the embodiment corresponding to FIG. 12c, and details are not described herein again.

[00206] FIG. 29 is another schematic diagram of the photovoltaic power generation system according to an embodiment of this application. In some embodiments, in the photovoltaic power generation system, a neutral point of a transformer winding corresponding to the output terminal of the first-stage DC-to-AC unit or the second-stage DC-to-AC unit is coupled to ground, or coupled to ground by using a current-limiting device, so that a voltage to ground of the neutral point is close to or equal to 0 V, to eliminate a PID phenomenon. As shown in FIG. 29, the transformer winding corresponding to the output terminal of the second-stage DC-to-AC unit is a second winding, and the second winding is a three-phase four-wire (ABCN) double-split transformer. Generally, an N wire is connected to a neutral point of a transformer, and grounded. The N wire of the second winding is coupled to ground, or coupled to ground by using the current-limiting device. When the system is connected to the grid and normally works, a potential of a positive input electrode (the second node) of the second-stage DC-to-AC unit is higher than a ground potential, so that voltages to ground of the negative output electrode of the second photovoltaic array and the negative output terminal of the first photovoltaic array are greater than or equal to 0 V. A PID suppression and repair function of the cell panel is implemented. Similarly,

in an application in which the positive output terminals of the first photovoltaic array and the second photovoltaic array are coupled together in FIG. 28, an N wire of the transformer winding (the first winding) corresponding to the output terminal of the first-stage DC-to-AC unit is coupled to ground, or coupled to ground by using a current-limiting device, so that a potential of the negative input terminal of the first-stage DC-to-AC unit is lower than the ground potential. In this case, potentials of the positive output terminals of the first photovoltaic array and the second photovoltaic array are equal to a potential of the second node, and less than the ground potential, that is, ≤ 0 V. This eliminates a positive bias voltage to ground at PV+ of the cell panel, and avoids the PID phenomenon of the cell panel (for a cell panel that has a positive voltage to ground at PV+ and generates a PID phenomenon). In another aspect, in this embodiment of this application, an input voltage of the photovoltaic array may be controlled by using a maximum power point tracking (MPPT) function of the DC-to-DC unit, so that a sum of the input voltage and a voltage to ground of the negative electrode of the photovoltaic array does not exceed a maximum applied system voltage of the cell panel, to ensure safety of system operation.

[00207] FIG. 30 is another schematic diagram of the photovoltaic power generation system according to an embodiment of this application. In some embodiments, when the output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different windings of a same transformer, a neutral point of a winding corresponding to the output terminal of the first-stage DC-to-AC unit and a neutral point of a winding corresponding to the output terminal of the second-stage DC-to-AC unit are coupled by using two series resistors or current-limiting devices, and a middle point between the two series resistors or the two current-limiting devices is coupled to ground. As shown in FIG. 30, N wires of the first winding and the second winding are coupled by using the two series resistors or current-limiting devices, and the middle point between the two series resistors or the two current-limiting devices is coupled to ground. When the system is normally connected to the grid for working, the first node, the second node, and the ground are equipotential. For the embodiment corresponding to FIG. 28, the positive output electrode of the second photovoltaic array, the positive output electrode of the first photovoltaic array, and the ground may be equipotential, thereby preventing the photovoltaic array from generating a PID phenomenon. For the example in FIG. 29, the negative output electrode of the second photovoltaic array, the negative output electrode of the first photovoltaic array, and the ground may be equipotential, thereby preventing the photovoltaic array from generating a PID

phenomenon.

[00208] In some embodiments, in the photovoltaic power generation system, the photovoltaic power generation system further includes an isolation unit. The isolation unit is also referred to as an AC-to-DC isolation unit, and may be arranged inside the first-stage DC-to-AC unit. An input terminal of the isolation unit is coupled to the internal phase wire at the output terminal of the first-stage DC-to-AC unit to obtain energy. A first output terminal of the isolation unit is coupled to ground, and a second output terminal of the isolation unit is coupled to the positive input terminal and/or negative input terminal of the first-stage DC-to-AC unit. The isolation unit may be configured to adjust an output voltage to ground of the first power supply and/or the second power supply, to eliminate a PID phenomenon. The isolation unit may alternatively be arranged inside the second-stage DC-to-AC unit. An input terminal of the isolation unit may be coupled to an internal phase wire at the output terminal of the second-stage DC-to-AC unit, a first output terminal of the isolation unit is coupled to ground, and a second output terminal of the isolation unit is coupled to the positive input terminal and/or negative input terminal of the second-stage DC-to-AC unit, to adjust an output voltage to ground of the first power supply and/or the second power supply, to eliminate a PID phenomenon. This is specifically similar to the embodiment corresponding to FIG. 13, and details are not described herein again.

[00209] In some embodiments, in the photovoltaic power generation system, the first photovoltaic array and the second photovoltaic array each may be a photovoltaic array formed by serially connecting an output terminal of a photovoltaic cell panel to an optimizer or a shutdown device, and then connecting in series or in parallel combinations, and a communication signal is coupled to a direct current cable connected to an output terminal of the optimizer or the shutdown device. The first-stage DC-to-DC unit and/or the second-stage DC-to-DC unit and/or the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit may communicate with the optimizer or the shutdown device by using the communication signal, and control the optimizer or the shutdown device to implement fast shutdown of the optimizer or the shutdown device.

[00210] In some embodiments, a communication signal is coupled to a direct current cable between the first-stage DC-to-AC unit, the second-stage DC-to-AC unit, the first-stage DC-to-DC unit, and the second-stage DC-to-DC unit. The first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit control/controls the first-stage DC-to-DC unit and/or the second-stage DC-to-DC unit by using the communication signal, to implement fast shutdown of the input terminal of the

first-stage DC-to-DC unit and/or the input terminal of the second-stage DC-to-DC unit.

[00211] In some embodiments, the photovoltaic power generation system further includes at least one energy storage unit. At least two direct current cables connected to the first-stage DC-to-DC unit, the second-stage DC-to-DC unit, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit are coupled in parallel to the energy storage unit. This is specifically similar to the energy storage unit in Embodiment 3, and details are not described herein again.

[00212] In the embodiment that includes the energy storage unit, the energy storage unit may be an energy storage device, or may include a direct current conversion unit and the energy storage device, or may be another apparatus capable of storing energy. This is similar to the description of the energy storage unit in Embodiment 1, and details are not described herein again. A communication signal is coupled to a direct current cable connected between the energy storage unit and the DC-to-DC unit, and the energy storage unit may communicate with the DC-to-DC unit. A communication signal is coupled to a direct current cable connected between the energy storage unit and the DC-to-AC unit, and the energy storage unit may communicate with the DC-to-AC unit. A situation of the communication signal and a principle for implementing communication are similar to the description of the communication signal in Embodiment 1, and details are not described herein again.

[00213] FIG. 31 is another schematic diagram of the photovoltaic power generation system according to an embodiment of this application. In some embodiments, a negative output terminal of the first photovoltaic array and a negative output terminal of the second photovoltaic array are coupled as a first coupling point. The negative input terminal of the first-stage DC-to-DC unit and the negative input terminal of the second-stage DC-to-DC unit are coupled as a second coupling point. The first coupling point and the second coupling point are connected by using one cable. In this implementation, one cable may be connected to the first coupling point and the second coupling point, to reduce cables and reduce costs. In some other embodiments, the first coupling point and the second coupling point may be separately grounded, to implement power flow. This can further reduce a quantity of cables and reduce system costs. Similarly, in the photovoltaic power generation system shown in FIG. 28, the positive output terminals of the first photovoltaic array and the second photovoltaic array are coupled, the positive input terminals of the first DC-to-DC unit and the second DC-to-DC unit are coupled, and then the two coupling points are grounded by using one cable, or both terminals are grounded, to implement power flow.

[00214] FIG. 32a is another schematic diagram of the photovoltaic power generation system according to an embodiment of this application. In some embodiments, the photovoltaic power generation system further includes a combiner unit. The combiner unit includes at least three input terminals, which are respectively connected to the positive output terminal of the first-stage DC-to-DC unit, the first node, and the negative output terminal of the second-stage DC-to-DC unit. In actual application, the combiner unit may further include more input terminals to connect more first-stage DC-to-DC units and more second-stage DC-to-DC units. It may be understood that the first-stage DC-to-DC unit is coupled to the first photovoltaic array, and the second-stage DC-to-DC unit is coupled to the second photovoltaic array. An output terminal of the combiner unit is connected to the positive input terminal of the first-stage DC-to-AC unit, the second node, and the negative input terminal of the second-stage DC-to-AC unit. In this embodiment of this application, the combiner unit is coupled between the DC-to-DC unit and the DC-to-AC unit, so that the photovoltaic power generation system can be coupled to more first photovoltaic arrays and more second photovoltaic arrays, thereby facilitating expansion of a scale of the photovoltaic power generation system. In another possible embodiment, the combiner unit may be provided with three busbars, including a first busbar, a second busbar, and a third busbar. The first busbar is coupled to the positive output terminal of the first-stage DC-to-DC unit, the second busbar is coupled to the first node, and the third busbar is coupled to the negative output terminal of the second-stage DC-to-DC unit. In another aspect, the first busbar is coupled to the positive input terminal of the first-stage DC-to-AC unit, the second busbar is coupled to the second node, and the third busbar is coupled to the negative input terminal of the second-stage DC-to-AC unit. FIG. 32b is another schematic diagram of the photovoltaic power generation system according to an embodiment of this application. As shown in FIG. 32b, when the photovoltaic power generation system includes a plurality of first-stage DC-to-AC units and second-stage DC-to-AC units, the photovoltaic power generation system may alternatively couple the plurality of first-stage DC-to-AC units and second-stage DC-to-AC units to the foregoing three busbars. Combination is performed by using the combiner unit. This is not limited in this embodiment of this application.

[00215] FIG. 33 is another schematic diagram of the photovoltaic power generation system according to an embodiment of this application. In some embodiments, the second-stage DC-to-DC unit may be replaced by a combiner unit. The output of the second photovoltaic array is implemented by using the combiner unit. In addition, when the first node and the second node are

not connected, and when the system is normally connected to the grid for working, the input voltages of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are determined based on the output voltages and powers of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit. In this case, the first-stage DC-to-DC unit controls its output voltage and current, that is, a voltage and a current output by the second photovoltaic array may be adjusted, to implement MPPT tracking of the second photovoltaic array.

[00216] FIG. 34 is another schematic diagram of the photovoltaic power generation system according to an embodiment of this application. In some embodiments, the second-stage DC-to-DC unit may be replaced by a combiner unit, and the first node and the second node are separately coupled to ground. The output of the second photovoltaic array is combined by using the combiner unit, and then is coupled in series to the output terminal of the first-stage DC-to-DC unit after the combination. The coupling node is the first node, and the first node and the second node are grounded and coupled to implement power connection.

[00217] FIG. 35 is another schematic diagram of the photovoltaic power generation system according to an embodiment of this application. In some embodiments, similarly, the first-stage DC-to-DC unit may also be replaced by a combiner unit. A principle is similar to that of replacing the second-stage DC-to-DC unit with the combiner unit. Details are not described herein again. In this embodiment of this application, the first node and the second node may be coupled and then grounded. In some embodiments, the combiner unit and the second-stage DC-to-DC unit may be used as a same whole. This is not limited in this embodiment of this application.

[00218] FIG. 36 is another schematic diagram of the photovoltaic power generation system according to an embodiment of this application. In this embodiment, the second-stage DC-to-DC unit may be replaced by a combiner unit. In addition, the photovoltaic power generation system is provided with an equalization circuit. When output powers and/or output voltages of the first photovoltaic array and the second photovoltaic array are asymmetric, the equalization circuit is configured to balance the output powers and/or voltages of the first photovoltaic array and the second photovoltaic array, to maximize application of the output powers of the first photovoltaic array and the second photovoltaic array. The equalization circuit includes a first interface, a second interface, and a third interface. The first interface is coupled to the first node (a coupling point between the negative output terminal of the combiner unit and the positive output terminal of the first-stage DC-to-DC unit). The second interface is coupled to the positive output terminal of the

combiner unit. The third interface is coupled to the negative output terminal of the first-stage DC-to-DC unit. A working principle of the equalization circuit is as follows: The equalization circuit unit obtains energy through the second interface and the third interface, and compensates the energy to the first photovoltaic array or the first-stage DC-to-DC unit with a low output power and/or voltage. Alternatively, the equalization circuit obtains energy from the second photovoltaic array through the first interface and the second interface, and compensates the energy to the first-stage DC-to-DC unit through the first interface and the third interface. Alternatively, the equalization circuit unit obtains energy from the first-stage DC-to-DC unit through the first interface and the third interface, and compensates the energy to the second photovoltaic array through the first interface and the second interface. In some embodiments, the equalization circuit unit may further include a fourth interface. The fourth interface is coupled to the second node. This is specifically similar to the third equalization circuit unit in the embodiment corresponding to FIG. 23, and details are not described herein again.

[00219] FIG. 37 is another schematic diagram of the photovoltaic power generation system according to an embodiment of this application. In some embodiments, the first-stage DC-to-DC unit is specifically a BOOST DC/DC unit, the second-stage DC-to-DC unit is specifically a BUCK-BOOST DC/DC unit, and the BOOST DC/DC unit and the BUCK-BOOST DC/DC unit form an MPPT combiner box. In this embodiment of this application, a negative input electrode and a negative output electrode of the BOOST DC/DC unit are directly connected. A positive input electrode of the BOOST DC/DC unit is connected to the positive output electrode of the first photovoltaic array, and the negative input electrode of the BOOST DC/DC unit is connected to the negative output electrode of the first photovoltaic array. A negative input electrode and a positive output electrode of the BUCK-BOOST DC/DC unit are directly connected. A positive input electrode of the BUCK-BOOST DC/DC unit is connected to the positive output electrode of the second photovoltaic array, and the negative input electrode of the BUCK-BOOST DC/DC unit is connected to the negative output electrode of the second photovoltaic array. In some embodiments, the photovoltaic power generation system includes a plurality of first-stage DC-to-DC units and a plurality of second-stage DC-to-DC units. Negative output terminals of all first-stage DC-to-DC units are connected to positive output terminals of all second-stage DC-to-DC units to form a third output terminal of the MPPT combiner box. Positive output electrodes of all first-stage DC-to-DC units form a first output terminal of the MPPT combiner box. Negative output electrodes of all

second-stage DC-to-DC units form a second output terminal of the MPPT combiner box.

[00220] In FIG. 37, the first-stage DC-to-AC unit and the second-stage DC-to-AC unit form an inverter. When the photovoltaic power generation system includes a plurality of inverters, negative input electrodes of all first-stage DC-to-AC units are connected to positive input electrodes of all second-stage DC-to-AC units to form a third input terminal of the inverter, positive input electrodes of all first-stage DC-to-AC units form a first input terminal of the inverter, negative input electrodes of all second-stage DC-to-AC units are connected to form a third input terminal of the inverter, output terminals of all first-stage DC-to-AC units form a first output terminal of the inverter, and output terminals of all second-stage DC-to-AC units form a second output terminal of the inverter.

[00221] In FIG. 37, the first output terminal of the MPPT combiner box is coupled to the first input terminal of the inverter. The second output terminal of the MPPT combiner box is coupled to the second input terminal of the inverter. The third output terminal of the MPPT combiner box is coupled to the third input terminal of the inverter. The first output terminal and the second output terminal of the inverter are respectively connected to the first winding and the second winding of the double-split transformer. To suppress generation of a PID phenomenon of the photovoltaic cell panel, a same implementation as the foregoing implementation example may be used, for example, arranging an isolation unit and a voltage source. For the coupling manner of the output terminal of the DC-to-DC unit, the coupling manner of the input terminal of the DC-to-AC unit, and the coupling manner of the output terminal of the DC-to-DC unit and the input terminal of the DC-to-AC unit, a same implementation as the foregoing implementation example may be used, and details are not described herein again.

Embodiment 5

[00222] FIG. 38 is a schematic diagram of Embodiment 5 of a power system according to an embodiment of this application. The power system includes a power supply, a DC-to-DC unit, and N DC-to-AC units. An output terminal of the power supply is coupled to an input terminal of the DC-to-DC unit, and the power supply may be photovoltaic arrays, an energy storage power supply, a wind power generation direct current source, or the like. This is similar to the power supply in Embodiment 3, and details are not described herein again. An output terminal of the DC-to-DC unit includes a positive output terminal, a negative output terminal, and a third output terminal.

The positive output terminal of the DC-to-DC unit is coupled to a positive input terminal of a first DC-to-AC unit. The negative output terminal of the DC-to-DC unit is coupled to a negative input terminal of an N^{th} DC-to-AC unit. The third output terminal of at least one DC-to-DC unit is coupled to at least one first node. The first node is formed by serially coupling a negative input terminal of an n^{th} DC-to-AC unit and a positive input terminal of an $(n+1)^{\text{th}}$ DC-to-AC unit, where n is an integer greater than 0 and less than N . That is, a negative input terminal of a DC-to-AC unit 1 is coupled in series to a positive input terminal of a DC-to-AC unit 2 to form a first node, a negative input terminal of the DC-to-AC unit 2 is coupled in series to a positive input terminal of a DC-to-AC unit 3 to form a first node, ..., and so on. This is similar to the DC-to-AC unit in Embodiment 3, and details are not described herein again.

[00223] In this embodiment of this application, the DC-to-DC unit may be an apparatus that can convert a direct current into a direct current, for example, a DC/DC converter. The input terminal of the DC-to-DC unit may be connected to one power supply, or may be connected to a plurality of power supplies. This is not limited in this embodiment of this application. A manner of coupling the input terminal of the DC-to-DC unit and the power supply is generally that a positive output terminal of the power supply is coupled to a positive input terminal of the DC-to-DC unit, and a negative output terminal of the power supply is coupled to a negative input terminal of the DC-to-DC unit. Details are not described again in this embodiment of this application.

[00224] In this embodiment of this application, input terminals of the DC-to-AC units are cascaded, to reduce a current between the DC-to-DC unit and the DC-to-AC unit, and resolve cost and loss problems of a cable from the DC-to-DC unit to the DC-to-AC unit. When the DC-to-DC unit is connected to a plurality of power supplies, an output voltage may be increased, to reduce the current between the DC-to-DC unit and the DC-to-AC unit, and resolve cost and loss problems of the cable from the DC-to-DC unit to the DC-to-AC unit.

[00225] In this embodiment of this application, the third output terminal of the at least one DC-to-DC unit is coupled to the at least one first node. For example, in some embodiments, one third output terminal is coupled to one first node, and another third output terminal is not coupled to another first node. In some other embodiments, two third output terminals are respectively coupled to two first nodes, and another third output terminal is not coupled to another first node. In some other embodiments, a quantity of third output terminals is equal to a quantity of first nodes, and each third output terminal is coupled to a corresponding first node. In some other embodiments, a

quantity of third output terminals is different from a quantity of first nodes, each third output terminal is coupled to a corresponding first node, and a remaining third output terminal or a remaining first node is not coupled. In actual application, another coupling manner may alternatively be used. This is not limited in this embodiment of this application. In this embodiment of this application, a quantity of cables connected between the DC-to-DC unit and the DC-to-AC unit is reduced in a manner of the third output terminal and the first node, to reduce costs of the power system.

[00226] In this embodiment of this application, outputs of output terminals of DC-to-AC units are isolated. For example, an output terminal of the DC-to-AC unit 1 is isolated from an output terminal of the DC-to-AC unit 2, and an output terminal of the DC-to-AC unit 2 is isolated from an output terminal of the DC-to-AC unit 3. In actual application, an output terminal of each DC-to-AC unit is coupled to different windings, and each winding may output a three-phase voltage or a single-phase voltage. This is not limited in this embodiment of this application. In this embodiment of this application, the cascaded input and isolated output of the DC-to-AC unit reduce a specification of a power conversion device. Therefore, problems of insufficient specifications (generally up to 1700 V for an insulated gate bipolar transistor, IGBT) and high costs of power conversion devices in the current industry are resolved. In addition, a circuit breaker with a low specification may be used to reduce costs.

[00227] In some embodiments, the DC-to-AC unit 1, the DC-to-AC unit 2, ..., and the DC-to-AC unit M may be considered as one combination of DC-to-AC units. Therefore, one power system includes at least one power supply, one DC-to-DC unit, and one combination of DC-to-AC units. When there are a plurality of power supplies and/or a plurality of DC-to-DC units and/or a plurality of combinations of DC-to-AC units, output terminals of the plurality of power supplies that are connected in series and in parallel are connected to an input terminal of one DC-to-DC unit, or are respectively connected to input terminals of a plurality of different DC-to-DC units. Same-type output terminals of a plurality of DC-to-DC units are coupled in parallel, and same-type input terminals of at least two combinations of DC-to-AC units are connected in parallel. At least one parallel-connected third output terminal is coupled to at least one parallel-connected first node. In this embodiment of this application, same-type output terminals of a plurality of combinations of DC-to-AC units may be coupled in parallel, or outputs of the same-type output terminals may be isolated. This is similar to the description corresponding to FIG. 5c in the

foregoing embodiment, and details are not described herein again.

[00228] In some embodiments, a communication signal is coupled to a direct current cable connected between the power supply and the DC-to-DC unit. A communication signal is also coupled to a direct current cable connected between the DC-to-DC unit and the DC-to-AC unit.

5 Preferably, the communication signal may be a PLC signal. This is similar to the description of the communication signal in Embodiment 1, and details are not described herein again. In actual application, the power system may use a power supply, a DC-to-DC unit, and a DC-to-AC unit that can recognize a communication signal, or may modify a power supply, a DC-to-DC unit, and a DC-to-AC unit so that the power supply, the DC-to-DC unit, and the DC-to-AC unit can
10 recognize a communication signal. This is not limited in this embodiment of this application.

[00229] In some embodiments, the power supply is a photovoltaic array formed by connecting an output of a photovoltaic cell panel to an optimizer or a shutdown device, and then connecting in series or in parallel combinations. When a communication signal is coupled to a direct current cable connected between the power supply, the DC-to-DC unit, and the DC-to-AC unit, the
15 communication signal also passes through the optimizer or the shutdown device, and the power supply, the DC-to-DC unit, or the DC-to-AC unit may control, by using the communication signal, shutdown of the optimizer or the shutdown device, to implement fast shutdown. That is, the power supply, the DC-to-DC unit, or the DC-to-AC unit may send a communication signal that carries a shutdown instruction to the optimizer or the shutdown device. After receiving the communication
20 signal that carries the shutdown instruction, the optimizer or the shutdown device executes the shutdown instruction, to implement fast shutdown. A situation of the communication signal is similar to the description of the communication signal in Embodiment 1, and details are not described herein again.

[00230] In some embodiments, the power system further includes at least one energy storage
25 unit. The energy storage unit is coupled in parallel to at least two direct current cables connected between the DC-to-DC unit and the DC-to-AC unit. In this embodiment of this application, the direct current cable connected between the DC-to-DC unit and the DC-to-AC unit may be a direct current cable for coupling the positive output terminal of the DC-to-DC unit and a positive input terminal of the DC-to-AC unit 1, may be a direct current cable for coupling the negative output
30 terminal of the DC-to-DC unit and a negative input terminal of the DC-to-AC unit N, or may be a direct current cable for coupling the third output terminal and the first node. For example, the

energy storage unit is coupled in parallel between the direct current cable for coupling the positive output terminal of the DC-to-DC unit and the positive input terminal of the DC-to-AC unit 1 and the direct current cable for coupling the negative output terminal of the DC-to-DC unit and the negative input terminal of the DC-to-AC unit N. Alternatively, the energy storage unit is coupled
5 in parallel among three direct current cables for coupling the third output terminal and the first node. It may be understood that a quantity of energy storage units included in one power system is not limited, that is, a plurality of energy storage units may be coupled in parallel at the same time. This is not limited in this embodiment of this application.

[00231] In the embodiment that includes the energy storage unit, the energy storage unit may
10 be an energy storage device, or may include a direct current conversion unit and an energy storage device, or may be another apparatus capable of storing energy. This is similar to the description of the energy storage unit in Embodiment 1, and details are not described herein again. A communication signal is coupled to a direct current cable connected between the energy storage unit and the DC-to-DC unit, and the energy storage unit may communicate with the DC-to-DC
15 unit. A communication signal is coupled to a direct current cable connected between the energy storage unit and the DC-to-AC unit, and the energy storage unit may communicate with the DC-to-AC unit. A situation of the communication signal and a principle for implementing communication are similar to the description of the communication signal in Embodiment 1, and details are not described herein again.

Embodiment 6

[00232] FIG. 39 is a schematic diagram of Embodiment 6 of a power system according to an embodiment of this application. The power system includes a power supply, a DC-to-DC unit, a first-stage DC-to-AC unit, and a second-stage DC-to-AC unit. An output terminal of the power supply is coupled to an input terminal of the DC-to-DC unit. The power supply may be
25 photovoltaic arrays, an energy storage power supply, a wind power generation direct current source, or the like. The DC-to-DC unit may be an apparatus that can convert a direct current into an alternating current, for example, an inverter. This is similar to the description in Embodiment 5, and details are not described herein again. A positive output terminal of the DC-to-DC unit is coupled to a positive input terminal of the first-stage DC-to-AC unit. A negative output terminal
30 of the DC-to-DC unit is coupled to a negative input terminal of the second-stage DC-to-AC unit.

A negative input terminal of the first-stage DC-to-AC unit is coupled to a positive input terminal of the second-stage DC-to-AC unit.

[00233] In this embodiment of this application, input terminals of the DC-to-AC units are cascaded, to reduce a current between the DC-to-DC unit and the DC-to-AC unit, and resolve cost and loss problems of a cable from the DC-to-DC unit to the DC-to-AC unit. When the DC-to-DC unit is connected to a plurality of power supplies, an output voltage may be increased, to reduce the current between the DC-to-DC unit and the DC-to-AC unit, and resolve cost and loss problems of the cable from the DC-to-DC unit to the DC-to-AC unit.

[00234] In this embodiment of this application, outputs of output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are isolated, and are connected to different windings. This is similar to the case in which the output of the DC-to-AC unit is isolated in Embodiment 1, and details are not described herein again. In this embodiment of this application, the cascaded input and isolated output of the DC-to-AC unit reduce a specification of a power conversion device. Specifications of power conversion devices in the current industry are insufficient (generally up to 1700 V for an IGBT). However, a 1500 V circuit breaker may be used in the power system provided in this embodiment of this application to reduce costs. The technical problem of insufficient specifications of the power conversion devices in the current industry is resolved.

[00235] A third output terminal of the DC-to-DC unit may also be referred to as a middle point of an output terminal potential or referred to as a first node. The negative input terminal of the first-stage DC-to-AC unit is coupled to the positive input terminal of the second-stage DC-to-AC unit, and a coupling node after coupling is a second node.

[00236] FIG. 40 is a schematic diagram of an embodiment of the power system according to an embodiment of this application. As shown in FIG. 40, in some embodiments, the positive output terminal of the DC-to-DC unit is coupled to the positive input terminal of the first-stage DC-to-AC unit by using a first conducting wire. The negative output terminal of the DC-to-DC unit is coupled to the negative input terminal of the second-stage DC-to-AC unit by using a second conducting wire. The first node and the second node are coupled by using a third conducting wire. It may be understood that, in this embodiment of this application, the first conducting wire, the second conducting wire, and the third conducting wire are all direct current cables connected between the DC-to-DC unit and the DC-to-AC unit (the first-stage DC-to-AC unit and the second-

stage DC-to-AC unit). A material and a wire diameter specification of the cable may be configured based on an actual situation. This is not limited in this embodiment of this application.

[00237] In some embodiments, the first conducting wire, the second conducting wire, and the third conducting wire form a distributed double (DC) bus. The first conducting wire and the second conducting wire form a positive bus. The second conducting wire and the third conducting wire form a negative bus. The third conducting wire is a neutral wire (Middle Cable) of the distributed double bus. The first conducting wire, the second conducting wire, and the third conducting wire are direct current conducting wires. In a 3D technology (three direct-Cable), a direct current bus is constructed by using three cables, a positive bus is constructed by using the first conducting wire and the second conducting wire, and a negative bus is constructed by using the second conducting wire and the third conducting wire.

[00238] In addition, because the first node is the middle point of the output terminal potential of the DC-to-DC unit, and the second node is a middle point of cascading the first-stage DC-to-AC unit and the second-stage DC-to-AC unit, a current value of the third conducting wire may be less than or equal to a current value of the first conducting wire. When the current value of the third conducting wire is less than or equal to the current value of the first conducting wire, a wire diameter specification of the third conducting wire may be reduced, to reduce costs of the third conducting wire. In another possible case, similarly, a current value of the third conducting wire is less than or equal to a current value of the second conducting wire. Therefore, when the current value of the third conducting wire is less than or equal to the current value of the second conducting wire, a wire diameter specification of the third conducting wire may be reduced, to reduce cable costs of the third conducting wire. Certainly, the current value of the third conducting wire may alternatively be less than the current value of the first conducting wire and less than the current value of the second conducting wire. This may also reduce the wire diameter specification of the third conducting wire, and reduce the cable costs of the third conducting wire.

[00239] FIG. 41 is a schematic diagram of an embodiment of the power system according to an embodiment of this application. As shown in FIG. 41, in some embodiments, both the first node and the second node are coupled to ground. In this embodiment of this application, both the first node and the second node are coupled to ground, so that when output powers or output voltages of the DC-to-DC units are asymmetric, or input powers or input voltages of the first-stage DC-to-AC unit and the second DC-to-AC unit are asymmetric, a current loop is provided to achieve

voltage equalization, thereby ensuring normal operation of the system. In addition, no cable connection is required between the first node and the second node, and therefore costs of one cable and construction costs can be reduced.

[00240] FIG. 42 is a schematic diagram of the power system that includes a first equalization circuit unit according to an embodiment of this application. In some embodiments, the power system further includes a first equalization circuit unit. The first equalization circuit unit is configured with a first interface, a second interface, and a third interface. The first interface is coupled to the second node. The second interface is coupled to the positive input terminal of the first-stage DC-to-AC unit. The third interface is coupled to the negative input terminal of the second-stage DC-to-AC unit. The first equalization circuit unit may balance input voltages and/or powers and/or currents of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit. A working principle of the first equalization circuit unit is as follows: The first equalization circuit unit obtains energy from an input terminal of the first-stage DC-to-AC unit through the first interface and the second interface, and compensates the energy to the second-stage DC-to-AC unit through the first interface and the third interface. Alternatively, the first equalization circuit unit obtains energy from an input terminal of the second-stage DC-to-AC unit through the first interface and the third interface, and compensates the energy to the first-stage DC-to-AC unit through the first interface and the second interface.

[00241] In a possible embodiment, the first equalization circuit unit may include four interfaces, that is, the first equalization circuit unit is further configured with a fourth interface. The fourth interface is coupled to the first node. This is similar to the embodiment corresponding to FIG. 21, and details are not described herein again.

[00242] FIG. 43 is a schematic diagram of the power system that includes a second equalization circuit unit according to an embodiment of this application. The second equalization circuit unit is configured with a fifth interface and a sixth interface. The fifth interface is coupled to the second node. In some embodiments, the sixth interface is coupled to the positive input terminal of the first-stage DC-to-AC unit. This is similar to the embodiment corresponding to FIG. 22a, and details are not described herein again. In some embodiments, the sixth interface is coupled to the negative input terminal of the second-stage DC-to-AC unit. This is similar to the embodiment corresponding to FIG. 22b, and details are not described herein again.

[00243] FIG. 44 is a schematic diagram of the power system that includes a third equalization

circuit unit according to an embodiment of this application. The third equalization circuit unit is configured with a seventh interface, an eighth interface, and a ninth interface. The seventh interface is coupled to the first node. The eighth interface is coupled to the positive output terminal of the DC-to-DC unit. The ninth interface is coupled to the negative output terminal of the DC-to-DC unit. In some embodiments, the third equalization circuit unit is further configured with a tenth interface. The tenth interface is coupled to the second node. A principle of the third equalization circuit unit is similar to that in the embodiment corresponding to FIG. 23, and details are not described herein again.

[00244] FIG. 45 is a schematic diagram of the power system that includes a fourth equalization circuit unit according to an embodiment of this application. The fourth equalization circuit unit is configured with an eleventh interface and a twelfth interface. The eleventh interface is coupled to the first node. In some embodiments, the twelfth interface is coupled to a positive input terminal of the DC-to-DC unit. A principle of the fourth equalization circuit unit is similar to that in the embodiment corresponding to FIG. 24a, and details are not described herein again. In some embodiments, the twelfth interface is coupled to a negative input terminal of the DC-to-DC unit. A principle of the fourth equalization circuit unit is similar to that in the embodiment corresponding to FIG. 24b, and details are not described herein again.

[00245] In some embodiments, the output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different transformers. Alternatively, the output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different windings of a same transformer, to implement isolated output.

[00246] In some embodiments, there are a plurality of power supplies and/or a plurality of DC-to-DC units and/or a plurality of DC-to-AC units. The power system specifically includes at least one power supply, at least one DC-to-DC unit, and at least one pair of DC-to-AC conversion units. A pair of DC-to-AC conversion units includes a first-stage DC-to-AC unit and a second-stage DC-to-AC unit. When at least one power supply, at least one DC-to-DC unit, and at least one pair of DC-to-AC conversion units are coupled, each DC-to-DC unit is coupled to at least one power supply. Alternatively, same-type input terminals of each DC-to-DC unit are coupled in parallel and then coupled to each power supply. Each pair of DC-to-AC conversion units is coupled to at least one pair of DC-to-DC units. Alternatively, same-type input terminals of each pair of DC-to-AC conversion units are coupled in parallel and then coupled to each DC-to-DC unit. This is similar

to the description of parallel connection of a plurality of units in Embodiment 5, and details are not described herein again.

[00247] In some embodiments, an insulation monitoring device is coupled between the output terminal of the first-stage DC-to-AC unit and a ground point. In some other embodiments, an IMD is coupled between the output terminal of the second-stage DC-to-AC unit and a ground point. In some other embodiments, a first IMD is coupled between the output terminal of the first-stage DC-to-AC unit and a ground point, and a second IMD is coupled between the output terminal of the second-stage DC-to-AC unit and a ground point. The IMD can detect insulation impedance to ground of the power system. When the insulation impedance to ground is less than a preset value, preferably, in this embodiment of this application, a coupling connection between the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit and a transformer winding may be broken, so that the entire system stops working, thereby further ensuring safety of system operation. This is similar to the embodiment corresponding to FIG. 26, and details are not described herein again.

[00248] In this embodiment of this application, a communication signal is coupled to a direct current cable connected between the power supply, the DC-to-DC unit, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit, to implement communication between the power supply, the DC-to-DC unit, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit. The communication signal is preferably a PLC signal, which is similar to the description of the communication signal in the foregoing embodiment, and details are not described herein again.

[00249] In this embodiment of this application, a communication signal is coupled to an alternating current cable connected to the output terminal of the first-stage DC-to-AC unit, and the alternating current cable may be further coupled to another device. The first-stage DC-to-AC unit may communicate with the another device on the alternating current cable by using the communication signal. When a plurality of combinations of DC-to-AC units are connected in parallel, and outputs of a plurality of first-stage DC-to-AC units are connected in parallel, parallel-connected output terminals of the plurality of first-stage DC-to-AC units may communicate, by using a communication signal on a connected alternating current cable, with another device coupled to the alternating current cable. The another device described above may be an alternating current device that uses an alternating current. Similarly, a communication situation of the output terminal of the second-stage DC-to-AC unit is similar to that of the first-stage DC-to-AC unit, and details are not described herein again. The communication signal is preferably a PLC signal, which

is similar to the description of the communication signal in the foregoing embodiment, and details are not described herein again.

[00250] In some embodiments, the power system provided in this embodiment of this application may be further configured with a leakage current sensor. The output terminal of the power supply is coupled to a leakage current sensor; and/or the input terminal of the DC-to-DC unit is coupled to a leakage current sensor; and/or the positive input terminal of the first-stage DC-to-AC unit and the negative input terminal of the first-stage DC-to-AC unit are coupled to a leakage current sensor; and/or the positive input terminal of the second-stage DC-to-AC unit and the negative input terminal of the second-stage DC-to-AC unit are coupled to a leakage current sensor; and/or an internal output phase wire of the first-stage DC-to-AC unit is coupled to a leakage current sensor; and/or an internal output phase wire of the second-stage DC-to-AC unit is coupled to a leakage current sensor. When the leakage current sensor detects that a leakage current value is greater than a preset threshold, the power supply and/or the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit and/or the DC-to-DC unit and/or the leakage current sensor report/reports an alarm and/or the power system stops working. This is similar to the embodiment corresponding to FIG. 27, and details are not described herein again.

[00251] In some embodiments, at least one switch is connected in series to an internal output phase wire connected to the output terminal of the first-stage DC-to-AC unit, to implement fast shutdown of an output of the first-stage DC-to-AC unit. The switch may be a relay, a circuit breaker, or a contactor, or may be another type of switch. This is not limited in this embodiment of this application. Similarly, a switch may also be connected in series to an internal output phase wire connected to the output terminal of the second-stage DC-to-AC unit. This is similar to the case in which a switch is connected in series to the output phase wire of the first-stage DC-to-AC unit. Details are not described herein again.

[00252] In this embodiment of this application, when the power supply is a photovoltaic array, the power system may be referred to as a photovoltaic power generation system. For another type of power system, for example, a wind power generation system, an energy storage system, or a hybrid power generation system, refer to the photovoltaic power generation system for implementation. Details are not described for another type of power system in this embodiment of this application. The following describes the photovoltaic power generation system in detail.

[00253] In the photovoltaic power generation system, only one of the first node and the second

node needs to be coupled to ground, that is, the first node is coupled to ground or the second node is coupled to ground. In some embodiments, both the first node and the second node may alternatively be coupled to ground. The first node and/or the second node are/is coupled to ground, so that when the output powers or output voltages of the first-stage DC-to-DC unit and the second DC-to-DC unit are asymmetric, or the input powers or input voltages of the first-stage DC-to-AC unit and the second DC-to-AC unit are asymmetric, a current loop can be provided to achieve voltage equalization, thereby ensuring normal operation of the system, and reducing costs of one cable and construction costs.

[00254] In this embodiment of this application, in the photovoltaic power generation system, a PID phenomenon may be eliminated by coupling a voltage source. In some embodiments, a voltage source is coupled between a ground point and a neutral point of a transformer winding corresponding to the output terminal of the second-stage DC-to-AC unit, to adjust a potential to ground of the neutral point. Alternatively, a voltage source may be coupled between a ground point and a neutral point of a transformer winding corresponding to the output terminal of the first-stage DC-to-AC unit, to adjust a voltage. This is similar to the description in Embodiment 4, and details are not described herein again.

[00255] In some embodiments, in the photovoltaic power generation system, a voltage source may be coupled between a ground point and an external phase wire at the output side of the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit, to adjust a potential to ground of the corresponding output phase wire and eliminate a PID phenomenon. This is similar to the principle in the embodiment corresponding to FIG. 12b, and details are not described herein again.

[00256] In some embodiments, in the photovoltaic power generation system, a voltage source may be coupled between a ground point and an internal phase wire at the output terminal of the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit, to adjust a potential to ground of the corresponding output phase wire and eliminate a PID phenomenon. This is similar to the principle in the embodiment corresponding to FIG. 12c, and details are not described herein again.

[00257] In some embodiments, in the photovoltaic power generation system, the photovoltaic power generation system further includes an isolation unit. The isolation unit is also referred to as an AC-to-DC isolation unit, and may be arranged inside the first-stage DC-to-AC unit. An input terminal of the isolation unit is coupled to the internal phase wire at the output terminal of the first-stage DC-to-AC unit. A first output terminal of the isolation unit is coupled to ground, and a second

output terminal of the isolation unit is coupled to the positive input terminal and/or the negative input terminal of the first-stage DC-to-AC unit. The isolation unit may alternatively be arranged inside the second-stage DC-to-AC unit. This is specifically similar to the embodiment corresponding to FIG. 13, and details are not described herein again.

5 **[00258]** In some embodiments, in the photovoltaic power generation system, the photovoltaic array may be a photovoltaic array formed by serially connecting an output terminal of the photovoltaic cell panel to an optimizer or a shutdown device and then connecting in series or in parallel combinations, and a communication signal is coupled to a direct current cable connected to an output terminal of the optimizer or the shutdown device. The DC-to-DC unit and/or the first-
10 stage DC-to-AC unit and/or the second-stage DC-to-AC unit may communicate with the optimizer or the shutdown device by using the communication signal, and control the optimizer or the shutdown device to implement fast shutdown of the optimizer or the shutdown device.

[00259] In some embodiments, a communication signal is coupled to a direct current cable between the first-stage DC-to-AC unit, the second-stage DC-to-AC unit, and the DC-to-DC unit.
15 The first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit control/controls the DC-to-DC unit by using the communication signal, to implement fast shutdown of the input terminal of the DC-to-DC unit.

[00260] In some embodiments, the photovoltaic power generation system further includes at least one energy storage unit. At least two direct current cables connected to the DC-to-DC unit,
20 the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit are coupled in parallel to the energy storage unit. This is specifically similar to the energy storage unit in Embodiment 5, and details are not described herein again.

[00261] In the embodiment that includes the energy storage unit, the energy storage unit may be an energy storage device, or may include a direct current conversion unit and an energy storage
25 device, or may be another apparatus capable of storing energy. This is similar to the description of the energy storage unit in Embodiment 1, and details are not described herein again. A communication signal is coupled to a direct current cable connected between the energy storage unit and the DC-to-DC unit, and the energy storage unit may communicate with the DC-to-DC unit. A communication signal is coupled to a direct current cable connected between the energy
30 storage unit and the DC-to-AC unit, and the energy storage unit may communicate with the DC-to-AC unit. A situation of the communication signal and a principle for implementing

communication are similar to the description of the communication signal in Embodiment 1, and details are not described herein again.

[00262] FIG. 46 is a schematic diagram of another embodiment of the photovoltaic power generation system according to an embodiment of this application. The power supply is specifically formed by series-parallel connection of photovoltaic cell panels. The DC-to-DC unit is specifically a common positive DC/DC converter. When the system is connected to a grid for working, a potential of BUS 0 is equal to a potential of the ground. In this case, a potential of PV+ to ground is consistent with a potential of BUS+ to a middle point (a potential of a positive terminal BUS+ of a bus to the middle point BUS 0 of the bus). As long as a voltage of the positive terminal BUS+ of the bus to the middle point BUS 0 of the bus is greater than or equal to a voltage of PV+ to PV−, a voltage to ground of the photovoltaic cell panel is greater than or equal to 0 V, and a PID phenomenon is eliminated. Alternatively, to further stabilize the potential of BUS 0, BUS 0 may be coupled to ground to ensure that the potential of BUS 0 is consistent with the potential of the ground when the system normally works. The DC-to-DC converter is a boost converter. A boost function can implement that the voltage of BUS+ to BUS 0 is greater than or equal to the voltage of PV+ to PV−, and the voltage to ground of the photovoltaic cell panel is greater than or equal to 0 V. In addition, if a BUS 0 point is grounded, sampling of voltages of V0+ and V0− to ground is implemented in the DC-to-DC converter; and if the used voltage exceeds a preset value, the DC-to-DC converter stops working. Alternatively, if the BUS 0 point is coupled to the DC-to-DC converter, sampling of voltages of V0+ and V0− to the BUS 0 point is implemented; and if the used voltage exceeds a preset value, the DC-to-DC converter stops working.

[00263] Similarly, to meet the requirement that the voltage to ground of the photovoltaic cell panel needs to be less than 0 V to eliminate a PID phenomenon, the DC-to-DC unit to be used may be a common negative DC-to-DC converter, as shown in FIG. 47. FIG. 47 is a schematic diagram of another embodiment of the photovoltaic power generation system according to an embodiment of this application. When the system is connected to a grid for working, a potential of BUS 0 is equal to a potential of the ground. In this case, a potential to ground of PV− is consistent with a potential of BUS− to a middle point (a potential of a negative terminal BUS− of a bus to the middle point BUS 0 of the bus). As long as an absolute value of a voltage of BUS− to the middle point BUS 0 of the bus is greater than or equal to a voltage of PV+ to PV−, a voltage to ground of the photovoltaic cell panel is less than or equal to 0 V, and a PID phenomenon is eliminated.

Alternatively, to further stabilize the potential of BUS 0, BUS 0 may be coupled to ground to ensure that the potential of BUS 0 is consistent with the potential of the ground when the system normally works. The DC-to-DC converter is a boost converter. A boost function can implement that the absolute value of the voltage of BUS- to the middle point BUS 0 of the bus is greater than or equal to the voltage of PV+ to PV-, and the voltage to ground of the photovoltaic cell panel is less than or equal to 0 V. A PID phenomenon is eliminated.

[00264] FIG. 48a is a schematic diagram 1 of another embodiment of the photovoltaic power generation system according to an embodiment of this application. The DC-to-DC unit may include a first-stage DC-to-DC converter and a second-stage DC-to-DC converter. The first-stage DC-to-DC converter may implement a boost/buck/buck-boost function. The second-stage DC-to-DC converter transfers a part of energy on C1 to C2 by controlling a DC/DC module inside the second-stage DC-to-DC converter, so that an average voltage of C1 is equal to an average voltage of C2. When the system is connected to a grid for working, a potential of BUS 0 is equal to potentials of the ground and the second node. In this case, a potential of a string PV- is higher than or equal to the potential of the second node, and a voltage to ground of the string PV- is greater than or equal to 0 V. This eliminates a PID phenomenon. Alternatively, to further stabilize the potential of the second node, BUS 0 may be coupled to the second node, or BUS 0 and/or the second node may be coupled to ground, to ensure that the potential of the second node and the potential of the ground are consistent when the system normally works.

[00265] As shown in FIG. 48b and FIG. 48c, if the node 2 and BUS 0 (the second node) are coupled, when an input voltage and/or an input current and/or an input power of the first-stage DC-to-DC unit exceed/exceeds a first preset value, the first-stage DC-to-DC unit works in a bypass mode; and/or when a voltage and/or a power output by the first-stage DC-to-DC unit exceed/exceeds a second preset value, a second-stage DC-to-DC unit stops working (an output of the first-stage DC-to-DC unit directly reaches the DC-to-AC unit); and/or at least one of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit works. In this embodiment of this application, when the input voltage and/or the input power and/or the output voltage and/or the output power of the first-stage DC-to-DC unit are/is excessively high, a proper unit and/or a proper working mode are/is selected. This can ensure normal working of the system in real time or avoid unnecessary waste, and improve conversion efficiency of the entire system.

[00266] The foregoing first-stage DC-to-DC unit works in the bypass mode, including two

cases, as shown in FIG. 48b and FIG. 48c. FIG. 48b is a schematic diagram 2 of another embodiment of the photovoltaic power generation system according to an embodiment of this application. As shown in FIG. 48b, the first-stage DC-to-DC unit works in the bypass mode, and the bypass mode is that a bypass unit is coupled in parallel between the positive input terminal and the positive output terminal of the first-stage DC-to-DC unit. In this case, a power flows into an input side of the second-stage DC-to-DC unit through the bypass unit, and the first-stage DC-to-DC unit stops working. The bypass unit may be a diode, a switch, a relay, a semiconductor switch tube, or the like. When the bypass unit is the diode, an anode of the diode is coupled to the positive input terminal, and a cathode of the diode is coupled to the positive output terminal. FIG. 48c is a schematic diagram 3 of another embodiment of the photovoltaic power generation system according to an embodiment of this application. As shown in FIG. 48c, the bypass mode is that a bypass unit is coupled in parallel between a negative input terminal and a negative output terminal of the first-stage DC-to-DC unit. In this case, a power flows into an input side of the second-stage DC-to-DC unit through the bypass unit, and the first-stage DC-to-DC unit stops working. The bypass unit may be a diode, a switch, a relay, a semiconductor switch tube, or the like. When the bypass unit is the diode, an anode of the diode is coupled to the negative output terminal, and a cathode of the diode is coupled to the negative input terminal.

[00267] In some embodiments, in the examples shown in FIG. 48a, FIG. 48b, and FIG. 48c, there are a plurality of first-stage DC-to-DC units, and output terminals of the plurality of first-stage DC-to-DC units are coupled in parallel, and then coupled to the second-stage DC-to-DC unit.

[00268] Similarly, to meet a requirement that a PID phenomenon can be eliminated only when the voltage to ground of the photovoltaic cell panel is less than 0 V, the DC-to-DC unit shown in FIG. 49 may be used. FIG. 49 is a schematic diagram of another embodiment of the photovoltaic power generation system according to an embodiment of this application. A principle of the photovoltaic power generation system is similar to that in FIG. 48a, FIG. 48b, and FIG. 48c, and details are not described herein again.

Embodiment 7

[00269] FIG. 50 is a schematic diagram of an embodiment of a power system according to an embodiment of this application. The power system includes N first power supplies, M second power supplies, N DC-to-DC units, and S DC-to-AC units. An output terminal of the first power

supply is coupled to an input terminal of the DC-to-DC unit. A positive terminal formed by serially connecting output terminals of the N DC-to-DC units and output terminals of the M second power supplies is coupled to a positive terminal formed by serially connecting input terminals of the S DC-to-AC units. A negative terminal formed by serially connecting output terminals of the N DC-to-DC units and output terminals of the M second power supplies is coupled to a negative terminal formed by serially connecting input terminals of the S DC-to-AC units. The output terminals of the N DC-to-DC units and the output terminals of the M second power supplies are coupled in series, and series coupling points form a first node. The input terminals of the S DC-to-AC units are coupled in series, and series coupling points form a second node. At least one first node and at least one second node are coupled by using at least one cable. An output terminal of the DC-to-AC unit is isolated.

[00270] In this embodiment of this application, the positive terminal formed by serially connecting the output terminals of the N DC-to-DC units and the output terminals of the M second power supplies is a port that does not participate in series connection, and may be a positive terminal of the DC-to-DC unit or a positive terminal of the second power supply. The negative terminal formed by serially connecting the output terminals of the N DC-to-DC units and the output terminals of the M second power supplies is another port that does not participate in series connection, and may be a negative terminal of the DC-to-DC unit or a negative terminal of the second power supply. The first node formed by serially connecting the output terminals of the N DC-to-DC units and the output terminals of the M second power supplies is a coupling node formed through series coupling, and may be a coupling node formed by serially connecting the DC-to-DC units, a coupling node formed by serially connecting the second power supplies, or a coupling node formed by serially connecting the DC-to-DC units and the second power supplies.

[00271] In this embodiment of this application, the positive terminal formed by serially connecting the input terminals of the S DC-to-AC units may be an input port that does not participate in series connection. For example, FIG. 50 shows a positive input terminal of a DC-to-AC unit 1. The negative terminal formed by serially connecting the input terminals of the S DC-to-AC units may be an input port that does not participate in series connection. For example, FIG. 50 shows a negative input terminal of a DC-to-AC unit S. The second node formed by serially connecting the input terminals of the S DC-to-AC units is a coupling node formed through series connection. In FIG. 50, a node formed by coupling input terminals of the DC-to-AC unit 1 and the

DC-to-AC unit 2 is a second node, a node formed by coupling input terminals of a DC-to-AC unit 3 and a DC-to-AC unit 4 is also a second node, and in addition, there are other second nodes, which are not enumerated herein.

[00272] In this embodiment of this application, the first power supply and the second power supply may be a photovoltaic array, energy storage power supplies, wind power generation direct current sources, or the like, which are similar to the power supplies in Embodiment 3. Details are not described herein again. The DC-to-DC unit may be an apparatus that can convert a direct current into a direct current, for example, a DC/DC converter. The DC-to-DC unit is similar to the DC-to-DC unit in Embodiment 3, and details are not described herein again. The DC-to-AC unit may be an apparatus that can convert a direct current into an alternating current, for example, an inverter. The DC-to-AC unit is similar to the DC-to-AC unit in Embodiment 3, and details are not described herein again.

[00273] In this embodiment of this application, the output terminal of the second power supply is cascaded, the output terminal of the DC-to-DC unit is cascaded, and the input terminal of the DC-to-AC unit is cascaded, to increase an output voltage, reduce a current between the DC-to-DC unit and the DC-to-AC unit, and resolve cost and loss problems of a cable from the DC-to-DC unit to the DC-to-AC unit. When the DC-to-DC unit is connected to a plurality of power supplies, the output voltage may be increased, to reduce the current between the DC-to-DC unit and the DC-to-AC unit, and resolve cost and loss problems of the cable from the DC-to-DC unit to the DC-to-AC unit.

[00274] In this embodiment of this application, at least one first node and at least one second node are coupled. For example, in some embodiments, one first node is coupled to one second node, and another first node is not coupled to another second node. In some other embodiments, two first nodes are respectively coupled to two second nodes, and another first node is not coupled to another second node. In some other embodiments, a quantity of first nodes is equal to a quantity of second nodes, and each first node is coupled to a corresponding second node. In some other embodiments, a quantity of first nodes is different from a quantity of second nodes, each first node is coupled to a corresponding second node, and a remaining first node or a remaining second node is not coupled. In actual application, another coupling manner may alternatively be used. This is not limited in this embodiment of this application. In this embodiment of this application, a quantity of cables connected between the second power supply, the DC-to-DC unit, and the DC-

to-AC unit is reduced in a manner of the first node and the second node, to reduce costs of the power system.

[00275] In this embodiment of this application, outputs of output terminals of DC-to-AC units are isolated. This is similar to the descriptions in Embodiments 1, 3, and 5, and details are not described herein again.

[00276] In some embodiments, at least two groups of corresponding first nodes are connected in parallel, and at least two groups of corresponding second nodes are connected in parallel. At least one parallel-connected first node is coupled to at least one parallel-connected second node. At least one parallel-connected third node is connected in parallel to at least one parallel-connected second node. It may be understood that when there are a plurality of groups of first power supplies, a plurality of groups of second power supplies, a plurality of groups of DC-to-DC units, and a plurality of groups of DC-to-AC units, the foregoing connection manner may be used.

[00277] In some embodiments, outputs of same-type output terminals of a plurality of groups of DC-to-AC units are connected in parallel, or isolated. This is similar to the description in Embodiment 3, and details are not described herein again.

[00278] In some embodiments, a communication signal is coupled to a direct current cable connected between any two of the first power supply, the second power supply, the DC-to-DC unit, and the DC-to-AC unit, so that any two of the first power supply, the second power supply, the DC-to-DC unit, and the DC-to-AC unit may communicate by using the communication signal. Preferably, the communication signal may be a PLC signal. This is similar to the description in Embodiment 3, and details are not described herein again.

[00279] In some embodiments, the power supply is a photovoltaic array formed by connecting an output of a photovoltaic cell panel to an optimizer or a shutdown device, and then connecting in series or in parallel combinations. When a communication signal is coupled to the direct current cable connected between the power supply, the DC-to-DC unit, and the DC-to-AC unit, the communication signal also passes through the optimizer or the shutdown device, and the power supply, the DC-to-DC unit, or the DC-to-AC unit may control, by using the communication signal, shutdown of the optimizer or the shutdown device, to implement fast shutdown. That is, the power supply, the DC-to-DC unit, or the DC-to-AC unit may send a communication signal that carries a shutdown instruction to the optimizer or the shutdown device. After receiving the communication signal that carries the shutdown instruction, the optimizer or the shutdown device executes the

shutdown instruction, to implement fast shutdown. A situation of the communication signal is similar to the description of the communication signal in Embodiment 1, and details are not described herein again.

[00280] In some embodiments, a communication signal is coupled to a direct current cable connected between the DC-to-DC unit and the DC-to-AC unit, and the DC-to-AC unit may control the DC-to-DC unit by using the communication signal, to implement fast shutdown of an input of the DC-to-DC unit. For example, the DC-to-AC unit sends a communication signal that carries a shutdown instruction, and the communication signal reaches the DC-to-DC unit through the corresponding direct current cable, so that the DC-to-DC unit executes the shutdown instruction after receiving the communication signal, thereby implementing fast shutdown of the input of the DC-to-DC unit.

[00281] In some embodiments, the power system further includes at least one energy storage unit. The energy storage unit is coupled in parallel to at least two direct current cables connected between the second power supply, the DC-to-DC unit, and the DC-to-AC unit. The direct current cables may be direct current cables for coupling the first node and the second node. For example, the energy storage unit is coupled in parallel between a direct current cable for coupling a positive output terminal of a DC-to-DC unit 1 and the positive input terminal of the DC-to-AC unit 1 and a direct current cable for coupling a negative output terminal of a DC-to-DC unit 2 and a negative input terminal of the DC-to-AC unit 2. Alternatively, the energy storage unit is coupled in parallel among three direct current cables for coupling the first node and the second node. It may be understood that a quantity of energy storage units included in one power system is not limited, that is, a plurality of energy storage units may be coupled in parallel at the same time. This is not limited in this embodiment of this application.

[00282] In the embodiment that includes the energy storage unit, the energy storage unit may be an energy storage device, or may include a direct current conversion unit and an energy storage device, or may be another apparatus capable of storing energy. This is similar to the description of the energy storage unit in Embodiment 1, and details are not described herein again. A communication signal is coupled to a direct current cable connected between the energy storage unit and the DC-to-DC unit, and the energy storage unit may communicate with the DC-to-DC unit. A communication signal is coupled to a direct current cable connected between the energy storage unit and the DC-to-AC unit, and the energy storage unit may communicate with the DC-

to-AC unit. A situation of the communication signal and a principle for implementing communication are similar to the description of the communication signal in Embodiment 1, and details are not described herein again.

Embodiment 8

5 **[00283]** FIG. 51a is a schematic diagram 1 of a power system according to an embodiment of this application. FIG. 51b is a schematic diagram 2 of a power system according to an embodiment of this application. The power system includes a power supply 1, a power supply 2, a DC-to-DC unit, a first-stage DC-to-AC unit, and a second-stage DC-to-AC unit. An output terminal of the power supply 1 is coupled to an input terminal of the DC-to-DC unit. The DC-to-DC unit is
10 coupled in series to an output terminal of the second power supply, and a coupling point is a first node. A negative input terminal of the first-stage DC-to-AC unit is coupled to a positive input terminal of the second-stage DC-to-AC unit, and a coupling point is a second node. A positive output terminal formed after the DC-to-DC unit is coupled in series to the output terminal of the second power supply is a first port (for example, a positive output terminal of the DC-to-DC unit
15 in FIG. 51a or a positive output terminal of the power supply 2 in FIG. 51b), and the first port is coupled to a positive input terminal of the first-stage DC-to-AC unit. A negative output terminal formed after the DC-to-DC unit is coupled in series to the output terminal of the second power supply is a second port (for example, a negative output terminal of the power supply 2 in FIG. 51a or a negative output terminal of the DC-to-DC unit in FIG. 51b), and the second port is coupled to
20 a negative input terminal of the second-stage DC-to-AC unit. Outputs of output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are isolated.

[00284] Specifically, in a possible case, as shown in FIG. 51a, the positive output terminal of the DC-to-DC unit is coupled to the positive input terminal of the first-stage DC-to-AC unit, the negative output terminal of the DC-to-DC unit is coupled to the positive output terminal of the
25 power supply 2 to form the first node, the negative output terminal of the power supply 2 is coupled to the negative input terminal of the second-stage DC-to-AC unit, and the negative input terminal of the first-stage DC-to-AC unit is coupled to the positive input terminal of the second-stage DC-to-AC unit to form the second node. In another possible case, as shown in FIG. 51b, the output terminal of the power supply 1 is coupled to the input terminal of the DC-to-DC unit, the negative
30 output terminal of the DC-to-DC unit is coupled to the negative input terminal of the second-stage

DC-to-AC unit, the positive output terminal of the DC-to-DC unit is coupled to the negative output terminal of the power supply 2, the positive output terminal of the power supply 2 is coupled to the negative input terminal of the first-stage DC-to-AC unit, and the negative input terminal of the first-stage DC-to-AC unit is coupled to the positive input terminal of the second-stage DC-to-AC unit. The following embodiment describes the case in FIG. 51a. The same rule is applied to the case in FIG. 51b, and details are not described again.

[00285] In this embodiment of this application, a cascading manner is used to increase an output voltage, to reduce a current between the power supply 2, the DC-to-DC unit, and the DC-to-AC unit, and resolve cost and loss problems of a cable from the DC-to-DC unit to the DC-to-AC unit.

[00286] FIG. 52 is a schematic diagram of an embodiment of the power system according to an embodiment of this application. In some embodiments, the first node is coupled to the second node, and four output ports of the DC-to-DC unit and the power supply 2 may be cascaded to the DC-to-AC unit by using three cables, thereby reducing a quantity of cables and reducing costs. In addition, if a current value of a cable between the first node and the second node is less than current values of the other two cables, a cable with a low wire diameter specification may be used between the first node and the second node, thereby further reducing cable costs. This is similar to the description of FIG. 19 in Embodiment 4, and details are not described herein again.

[00287] In some embodiments, the first port is coupled to the positive input terminal of the first-stage DC-to-AC unit by using a first conducting wire. The second port is coupled to the negative input terminal of the second-stage DC-to-AC unit by using a second conducting wire. The first node and the second node are coupled by using a third conducting wire. The first conducting wire, the second conducting wire, and the third conducting wire form a distributed double (DC) bus. The first conducting wire and the second conducting wire form a positive bus. The second conducting wire and the third conducting wire form a negative bus. The third conducting wire is a neutral wire (Middle Cable) of the distributed double bus. The first conducting wire, the second conducting wire, and the third conducting wire are direct current conducting wires. In a 3D technology (three direct-Cable), a direct current bus is constructed by using three cables, a positive bus is constructed by using the first conducting wire and the second conducting wire, and a negative bus is constructed by using the second conducting wire and the third conducting wire.

[00288] In some embodiments, both the first node and the second node are coupled to ground. In this embodiment of this application, both the first node and the second node are coupled to

ground, so that when output powers or output voltages of the DC-to-DC unit and the power supply
2 are asymmetric, or input powers or input voltages of the first-stage DC-to-AC unit and the second
DC-to-AC unit are asymmetric, a current loop is provided to achieve voltage equalization, thereby
ensuring normal operation of the system. In addition, no cable connection is required between the
5 first node and the second node, and therefore costs of one cable and construction costs can be
reduced.

[00289] In some embodiments, the first node is coupled to the second node. When an input
voltage and/or an input current and/or an input power of the DC-to-DC unit are/is less than a preset
value, or an output voltage and/or an output current and/or an output power of the second power
10 supply are/is less than a preset value, the corresponding DC-to-DC unit or the second power supply
stops working. For example, when the input voltage of the DC-to-DC unit is less than the preset
value, the DC-to-DC unit stops working. In another example, when the output voltage of the
second power supply is less than the preset value, the second power supply stops working. At least
one of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit works. In this
15 embodiment of this application, when the input voltage and/or the input current and/or the input
power of the DC-to-DC unit are/is excessively low, or the output voltage and/or the output current
and/or the output power of the second power supply are/is excessively low, the corresponding DC-
to-DC unit or the second power supply stops working, and an appropriate unit is selected to work.
This can avoid unnecessary waste and improve conversion efficiency and utilization of the entire
20 system.

[00290] When the first node and the second node are not coupled, the voltage may be adjusted
by using an equalization circuit unit.

[00291] FIG. 53 is a schematic diagram of the power system that includes a first equalization
circuit unit according to an embodiment of this application. In some embodiments, the power
25 system further includes the first equalization circuit unit. The first equalization circuit unit is
configured with a first interface, a second interface, and a third interface. The first interface is
coupled to the second node. The second interface is coupled to the positive input terminal of the
first-stage DC-to-AC unit. The third interface is coupled to the negative input terminal of the
second-stage DC-to-AC unit. In some embodiments, the first equalization circuit unit is further
30 configured with a fourth interface. The fourth interface is coupled to the first node. This is similar
to the embodiment corresponding to FIG. 21, and details are not described herein again.

[00292] FIG. 54 is a schematic diagram of the power system that includes a second equalization circuit unit according to an embodiment of this application. In some embodiments, the power system includes the second equalization circuit unit. The second equalization circuit unit is configured with a fifth interface and a sixth interface. The fifth interface is coupled to the second node. The sixth interface is coupled to the positive input terminal of the first-stage DC-to-AC unit or the negative input terminal of the second-stage DC-to-AC unit. This is similar to the embodiments corresponding to FIG. 22a and FIG. 22b, and details are not described herein again.

[00293] FIG. 55 is a schematic diagram of the power system that includes a third equalization circuit unit according to an embodiment of this application. In some embodiments, the power system includes the third equalization circuit unit. The third equalization circuit unit is configured with a seventh interface, an eighth interface, and a ninth interface. The seventh interface is coupled to the first node. The eighth interface is coupled to the positive output terminal of the DC-to-DC unit. The ninth interface is coupled to the negative output terminal of the power supply 2. In some embodiments, the third equalization circuit unit is further configured with a tenth interface. The tenth interface is coupled to the second node. This is similar to the embodiment corresponding to FIG. 23, and details are not described herein again.

[00294] FIG. 56 is a schematic diagram of the power system that includes a fourth equalization circuit unit according to an embodiment of this application. In some embodiments, the power system includes the fourth equalization circuit unit. The fourth equalization circuit unit is configured with an eleventh interface and a twelfth interface. The eleventh interface is coupled to the first node. The twelfth interface is coupled to the positive output terminal of the DC-to-DC unit or the negative output terminal of the power supply 2. This is similar to the embodiments corresponding to FIG. 24a and FIG. 24b, and details are not described herein again.

[00295] In some embodiments, the output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different transformers. Alternatively, the output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different windings of a same transformer, to implement isolated output.

[00296] In some embodiments, the power system specifically includes at least one pair of power supplies, at least one DC-to-DC unit, and at least one pair of DC-to-AC conversion units. One pair of power supplies includes a power supply 1 and a power supply 2. A pair of DC-to-AC conversion units includes a first-stage DC-to-AC unit and a second-stage DC-to-AC unit. When at least one

pair of power supplies, at least one DC-to-DC unit, and at least one pair of DC-to-AC conversion units are coupled, each DC-to-DC unit is coupled to at least one power supply 1. Each pair of DC-to-AC conversion units is coupled to at least one DC-to-DC unit or coupled to the power supply 2. Alternatively, same-type input terminals of each pair of DC-to-AC conversion units are coupled in parallel, and then are coupled to one DC-to-DC unit or one power supply 2. It may be understood that, outputs of same-type output terminals of a plurality of combinations of DC-to-AC units may be coupled in parallel, or may be isolated. This is similar to the description in Embodiment 2, and details are not described herein again.

[00297] In some embodiments, an IMD is coupled between an output terminal of the first-stage DC-to-AC unit and a ground point. In some other embodiments, an IMD is coupled between an output terminal of the second-stage DC-to-AC unit and a ground point. In some other embodiments, a first IMD is coupled between an output terminal of the first-stage DC-to-AC unit and a ground point, and a second IMD is coupled between an output terminal of the second-stage DC-to-AC unit and a ground point. The IMD can detect insulation impedance to ground of the power system. When the insulation impedance to ground is less than a preset value, preferably, in this embodiment of this application, a coupling connection between the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit and a transformer winding may be broken, so that the entire system stops working, thereby further ensuring safety of system operation.

[00298] In this embodiment of this application, a communication signal is coupled to a direct current cable connected between the power supply 1, the power supply 2, the DC-to-DC unit, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit, to implement communication between the power supply 1, the power supply 2, the DC-to-DC unit, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit. The communication signal is preferably a PLC signal, which is similar to the description of the communication signal in the foregoing embodiment, and details are not described herein again.

[00299] In this embodiment of this application, a communication signal is coupled to an alternating current cable connected to an output terminal of the first-stage DC-to-AC unit, and the alternating current cable may be further coupled to another device. The first-stage DC-to-AC unit may communicate with another device on the alternating current cable by using the communication signal. When a plurality of combinations of DC-to-AC units are connected in parallel, and outputs of a plurality of first-stage DC-to-AC units are connected in parallel, the

parallel-connected output terminals of the plurality of first-stage DC-to-AC units may communicate, by using a communication signal on a connected alternating current cable, with another device coupled to the alternating current cable. The another device described above may be an alternating current device that uses an alternating current. Similarly, a communication situation of the output terminal of the second-stage DC-to-AC unit is similar to that of the first-stage DC-to-AC unit, and details are not described herein again. The communication signal is preferably a PLC signal, which is similar to the description of the communication signal in the foregoing embodiment, and details are not described herein again.

[00300] In some embodiments, the power system provided in this embodiment of this application may be further configured with a leakage current sensor. The leakage current sensor may be arranged at an output terminal of the power supply 1, an output terminal of the power supply 2, an input terminal and an output terminal of the DC-to-DC unit, an input terminal and an output terminal of the first-stage DC-to-AC unit, and an input terminal and an output terminal of the second-stage DC-to-AC unit. This is similar to the embodiments corresponding to FIG. 11 and FIG. 27, and details are not described herein again.

[00301] In some embodiments, at least one switch is connected in series to an internal output phase wire connected to the output terminal of the first-stage DC-to-AC unit, to implement fast shutdown of an output of the first-stage DC-to-AC unit. The switch may be a relay, a circuit breaker, or a contactor, or may be another type of switch. This is not limited in this embodiment of this application. Similarly, a switch may also be connected in series to an internal output phase wire connected to the output terminal of the second-stage DC-to-AC unit. This is similar to the case in which a switch is connected in series to the output phase wire of the first-stage DC-to-AC unit. Details are not described herein again.

[00302] In this embodiment of this application, when the power supply 1 and the power supply 2 are a photovoltaic array, the power system may be referred to as a photovoltaic power generation system. In this embodiment of this application, the power supply 1 may be referred to as a first photovoltaic array, and the power supply 2 may be referred to as a second photovoltaic array. In actual application, another name may be used. This is not limited in this embodiment of this application. For another type of power system, for example, a wind power generation system, an energy storage system, or a hybrid power generation system, refer to the photovoltaic power generation system for implementation. Details are not described for another type of power system

in this embodiment of this application. The following describes the photovoltaic power generation system in detail.

[00303] In the photovoltaic power generation system, only one of the first node and the second node needs to be coupled to ground, that is, the first node is coupled to ground or the second node is coupled to ground. In some embodiments, both the first node and the second node may alternatively be coupled to ground. The first node and/or the second node are/is coupled to ground, so that when the output powers or output voltages of the first-stage DC-to-DC unit and the second DC-to-DC unit are asymmetric, or the input powers or input voltages of the first-stage DC-to-AC unit and the second DC-to-AC unit are asymmetric, a current loop can be provided to achieve voltage equalization, thereby ensuring normal operation of the system, and reducing costs of one cable and construction costs.

[00304] FIG. 57 is a schematic diagram of the photovoltaic power generation system according to an embodiment of this application. In some embodiments, in the photovoltaic power generation system, the positive input terminal and the negative output terminal of the DC-to-DC unit are directly coupled, or connected with only a small voltage drop. This can implement that a positive output electrode of the second photovoltaic array and a positive output electrode of the first photovoltaic array are equipotential. Normally, impedance to ground of the entire system is symmetrically distributed. When the system is normally connected to a grid for working, the first node, the second node, and the ground are equipotential. In this case, output voltages to ground at PV+ of cell panels of the first photovoltaic array and the second photovoltaic array are near 0 V. This eliminates a positive bias voltage to ground at PV+ of the cell panel, and avoids a PID phenomenon of the cell panel (for a cell panel that has a positive voltage to ground at PV+ and generates a PID phenomenon). Similarly, in some other embodiments, the negative input terminal and the positive output terminal of the DC-to-DC unit are directly coupled, or connected with only a small voltage drop. This is similar to the principle in the embodiment corresponding to FIG. 27, and details are not described herein again.

[00305] In this embodiment of this application, in the photovoltaic power generation system, a PID phenomenon may alternatively be eliminated by coupling a voltage source. In some embodiments, a voltage source is coupled between a ground point and a neutral point of a transformer winding corresponding to the output terminal of the second-stage DC-to-AC unit, to adjust a potential to ground of the neutral point. In some other embodiments, a voltage source may

be coupled between a ground point and a neutral point of a transformer winding corresponding to the output terminal of the first-stage DC-to-AC unit, to adjust a voltage. In some other embodiments, a voltage source may be coupled between a ground point and an external phase wire at an output side of the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit, to adjust a potential to ground of the corresponding output phase wire and eliminate a PID phenomenon. In some other embodiments, a voltage source may be coupled between a ground point and an internal phase wire at the output terminal of the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit, to adjust a potential to ground of the corresponding output phase wire and eliminate a PID phenomenon. This is similar to the principles in the embodiments in FIG. 12a, FIG. 12b, and FIG. 12c, and details are not described herein again.

[00306] In some embodiments, in the photovoltaic power generation system, a neutral point of a transformer winding corresponding to the output terminal of the first-stage DC-to-AC unit or the second-stage DC-to-AC unit is coupled to ground, or coupled to ground by using a current-limiting device, so that a voltage to ground of the neutral point is close to or equal to 0 V, to eliminate a PID phenomenon. In some embodiments, when the output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different windings of a same transformer, a neutral point of the winding corresponding to the output terminal of the first-stage DC-to-AC unit and a neutral point of the winding corresponding to the output terminal of the second-stage DC-to-AC unit are coupled by using two series resistors or current-limiting devices, and a middle point between the two series resistors or the two current-limiting devices is coupled to ground, to eliminate a PID phenomenon. The principle is similar to the principles in the embodiments corresponding to FIG. 29 and FIG. 30, and details are not described herein again.

[00307] In some embodiments, in the photovoltaic power generation system, the photovoltaic power generation system further includes an isolation unit. The isolation unit may be arranged inside the first-stage DC-to-AC unit or inside the second-stage DC-to-AC unit. This is similar to the embodiment corresponding to FIG. 13, and details are not described herein again.

[00308] In some embodiments, in the photovoltaic power generation system, the first photovoltaic array and the second photovoltaic array each may be a photovoltaic array formed by serially connecting an output terminal of the photovoltaic cell panel to an optimizer or a shutdown device and then connecting in series or in parallel combinations, and a communication signal is coupled to a direct current cable connected to an output terminal of the optimizer or the shutdown

device. The DC-to-DC unit and/or the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit may communicate with the optimizer or the shutdown device by using the communication signal, and control the optimizer or the shutdown device to implement fast shutdown of the optimizer or the shutdown device.

5 **[00309]** In some embodiments, a communication signal is coupled to a direct current cable between the DC-to-AC unit, the first-stage DC-to-DC unit, and the second-stage DC-to-DC unit. The first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit control/controls the DC-to-DC unit by using the communication signal, to implement fast shutdown of the input terminal of the DC-to-DC unit.

10 **[00310]** In some embodiments, the photovoltaic power generation system further includes at least one energy storage unit. At least two direct current cables connected to the second photovoltaic array, the DC-to-DC unit, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit are coupled in parallel to the energy storage unit. This is specifically similar to the energy storage unit in Embodiment 3, and details are not described herein again.

15 **[00311]** In the embodiment that includes the energy storage unit, the energy storage unit may be an energy storage device, or may include a direct current conversion unit and an energy storage device, or may be another apparatus capable of storing energy. This is similar to the description of the energy storage unit in Embodiment 1, and details are not described herein again. A communication signal is coupled to a direct current cable connected between the energy storage
20 unit and the DC-to-DC unit, and the energy storage unit may communicate with the DC-to-DC unit. A communication signal is coupled to a direct current cable connected between the energy storage unit and the DC-to-AC unit, and the energy storage unit may communicate with the DC-to-AC unit. A situation of the communication signal and a principle for implementing communication are similar to the description of the communication signal in Embodiment 1, and
25 details are not described herein again.

[00312] FIG. 58 is a schematic diagram of an embodiment of the photovoltaic power generation system according to an embodiment of this application. In some embodiments, as shown in FIG. 58, an output terminal of the second photovoltaic array is coupled to a combiner box. An input terminal of the combiner box is coupled to output terminals of a plurality of second photovoltaic
30 arrays. A positive output terminal of the combiner box is coupled in series to the negative output terminal of the DC-to-DC unit. A negative output terminal of the combiner box is coupled to the

negative input terminal of the second-stage DC-to-AC unit. The input terminal of the combiner box is coupled to the output terminals of the plurality of second photovoltaic arrays. The positive output terminal of the combiner box is coupled in series to the negative output terminal of the DC-to-DC unit. The negative output terminal of the combiner box is coupled to the negative input terminal of the second-stage DC-to-AC unit. The positive output terminal of the DC-to-DC unit is coupled to the positive input terminal of the first-stage DC-to-AC unit. This is similar to the embodiment corresponding to FIG. 34, and details are not described herein again.

[00313] FIG. 59 is a schematic diagram of an embodiment of the photovoltaic power generation system according to an embodiment of this application. In some embodiments, as shown in FIG.

59, an output terminal of the second photovoltaic array is coupled to a combiner box. An input terminal of the combiner box is coupled to output terminals of a plurality of second photovoltaic arrays. A negative output terminal of the combiner box is coupled in series to the positive output terminal of the DC-to-DC unit. A positive output terminal of the combiner box is coupled to the positive input terminal of the first-stage DC-to-AC unit. The negative output terminal of the DC-to-DC unit is coupled to the negative input terminal of the second-stage DC-to-AC unit. This is similar to the embodiment corresponding to FIG. 35, and details are not described herein again. In the foregoing embodiments, the first photovoltaic array and the second photovoltaic array are usually connected in a co-PV+ or co-PV- manner. For example, FIG. 28 shows a co-PV+ connection manner of the first photovoltaic array and the second photovoltaic array. For example, the embodiment corresponding to FIG. 29 is a co-PV- connection manner of the first photovoltaic array and the second photovoltaic array. In actual application, the foregoing connection manner may not be used. For example, FIG. 60 is a schematic diagram of another embodiment of the photovoltaic power generation system according to an embodiment of this application. As shown in FIG. 60, a negative output terminal of the first photovoltaic array is coupled to the negative input terminal of the first-stage DC-to-DC unit. A positive output terminal of the second photovoltaic array is coupled to the positive input terminal of the second-stage DC-to-DC unit. In addition, the negative output terminal of the first-stage DC-to-DC unit is coupled to the positive output terminal of the second-stage DC-to-DC unit, and a coupling point is the first node. Therefore, in this embodiment of this application, the negative output terminal of the first photovoltaic array and the positive output terminal of the second photovoltaic array have a same potential, and are not connected in a co-PV+ or co-PV- connection manner, and should also be

understood as one of the connection manners provided in this embodiment of this application. The compensation power module in FIG. 60 is similar to the voltage source in the embodiment corresponding to FIG. 12b, and details are not described herein again.

CLAIMS

What is claimed is:

1. A power system, comprising N power modules, N DC-to-DC units, and M DC-to-AC units, wherein

5 an output terminal of the power module is coupled to an input terminal of the DC-to-DC unit;
a positive output terminal of a first DC-to-DC unit is coupled to a positive input terminal of a first DC-to-AC unit;

a negative output terminal of an n^{th} DC-to-DC unit is coupled in series to a positive output terminal of an $(n+1)^{\text{th}}$ DC-to-DC unit to form a first node, wherein n is an integer greater than 0
10 and less than N;

a negative output terminal of an N^{th} DC-to-DC unit is coupled to a negative input terminal of an M^{th} DC-to-AC unit;

a negative input terminal of an m^{th} DC-to-AC unit is coupled in series to a positive input terminal of an $(m+1)^{\text{th}}$ DC-to-AC unit to form a second node, wherein m is an integer greater than
15 0 and less than M;

at least one first node and at least one second node are coupled; and

an output of an output terminal of the DC-to-AC unit is isolated.

2. The power system according to claim 1, wherein the power module is a photovoltaic array and/or an energy storage power supply and/or a wind power generation direct current source; and
20 the photovoltaic array is formed by connecting photovoltaic cell panels in series or in parallel combinations, or is formed by connecting an output of the photovoltaic cell panel to an optimizer or a shutdown device, and then connecting in series or in parallel combinations.

3. The power system according to claim 1, wherein same-type output terminals of at least two groups of DC-to-DC units are first connected in parallel and then connected in series to form the
25 first node;

same-type input terminals of at least two groups of DC-to-AC units are first connected in parallel and then connected in series to form the second node; and

outputs of same-type output terminals of the at least two groups of DC-to-AC units are connected in parallel, or isolated.

30 4. The power system according to claim 1, wherein a communication signal is coupled to a

direct current cable connected to any two of the power supply, the DC-to-DC unit, and the DC-to-AC unit, and is used to implement communication between the power supply, the DC-to-DC unit, and the DC-to-AC unit.

5 5. The power system according to claim 2, wherein the power module is the photovoltaic array, and the photovoltaic array is formed by connecting the output of the photovoltaic cell panel to the optimizer or the shutdown device, and then connecting in series or in parallel combinations; a communication signal is coupled to a direct current cable connected to the power module, the DC-to-DC unit, and the DC-to-AC unit; and

10 the DC-to-DC unit and/or the DC-to-AC unit control/controls the optimizer or the shutdown device by using the communication signal, to implement fast shutdown; or

 the DC-to-AC unit controls the DC-to-DC unit by using the communication signal, to implement fast shutdown of an input of the DC-to-DC unit.

 6. The power system according to claim 1, further comprising at least one energy storage unit, wherein

15 the energy storage unit is coupled in parallel to at least two direct current cables connected between the DC-to-DC unit and the DC-to-AC unit.

 7. The power system according to claim 6, wherein the energy storage unit is an energy storage device, or the energy storage unit comprises a direct current conversion unit and the energy storage device; and the energy storage device comprises a supercapacitor or a battery.

20 8. The power system according to claim 6, wherein a communication signal is coupled to a direct current cable connected between the energy storage unit and the DC-to-DC unit, and is used to implement communication between the energy storage unit and the power module; or a communication signal is coupled to a direct current cable connected between the energy storage unit and the DC-to-AC unit, and is used to implement communication between the energy storage unit and the DC-to-AC unit.

 9. A power system, comprising a first power supply, a second power supply, a first-stage DC-to-DC unit, a second-stage DC-to-DC unit, a first-stage DC-to-AC unit, and a second-stage DC-to-AC unit, wherein

30 an output terminal of the first power supply is coupled to an input terminal of the first-stage DC-to-DC unit;

 an output terminal of the second power supply is coupled to an input terminal of the second-

stage DC-to-DC unit;

a positive output terminal of the first-stage DC-to-DC unit is coupled to a positive input terminal of the first-stage DC-to-AC unit;

a negative output terminal of the first-stage DC-to-DC unit is coupled to a positive output
5 terminal of the second-stage DC-to-DC unit to form a first node;

a negative output terminal of the second-stage DC-to-DC unit is coupled to a negative output terminal of the second-stage DC-to-AC unit;

a negative input terminal of the first-stage DC-to-AC unit is coupled to a positive input terminal of the second-stage DC-to-AC unit to form a second node; and

10 outputs of output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are isolated.

10. The power system according to claim 9, wherein the positive output terminal of the first-stage DC-to-DC unit is coupled to the positive input terminal of the first-stage DC-to-AC unit by using a first conducting wire, the negative output terminal of the second-stage DC-to-DC unit is
15 coupled to the negative output terminal of the second-stage DC-to-AC unit by using a second conducting wire, and the first node is coupled to the second node by using a third conducting wire; and

a current value of the third conducting wire is less than or equal to a current value of the first conducting wire; or

20 a current value of the third conducting wire is less than or equal to a current value of the second conducting wire.

11. The power system according to claim 10, wherein

the first conducting wire, the second conducting wire, and the third conducting wire are direct current conducting wires;

25 the first conducting wire, the second conducting wire, and the third conducting wire form a distributed double bus, the first conducting wire and the second conducting wire form a positive bus, and the second conducting wire and the third conducting wire form a negative bus; and

the third conducting wire is a neutral wire of the distributed double bus.

12. The power system according to claim 9, wherein the first node is coupled to the second
30 node; when an input voltage and/or an input current and/or an input power of one of the first-stage DC-to-DC unit and the second-stage DC-to-DC unit are/is less than a preset value, the

corresponding DC-to-DC unit stops working; and

at least one of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit works.

13. The power system according to claim 9, wherein both the first node and the second node are coupled to ground.

5 14. The power system according to claim 9, further comprising a first equalization circuit unit, wherein the first equalization circuit unit is configured with a first interface, a second interface, and a third interface;

the first interface is coupled to the first node, the second interface is coupled to the positive output terminal of the first-stage DC-to-DC unit, and the third interface is coupled to the negative
10 output terminal of the second-stage DC-to-DC unit, to balance output voltages and/or powers and/or currents of the first-stage DC-to-DC unit and the second-stage DC-to-DC unit; or

the first interface is coupled to the second node, the second interface is coupled to the positive input terminal of the first-stage DC-to-AC unit, and the third interface is coupled to the negative input terminal of the second-stage DC-to-AC unit, to balance input voltages and/or powers and/or
15 currents of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit.

15. The power system according to claim 14, wherein the first equalization circuit unit further comprises a fourth interface; and

when the first interface is coupled to the first node, the fourth interface is coupled to the second node; or

20 when the first interface is coupled to the second node, the fourth interface is coupled to the first node.

16. The power system according to claim 9, further comprising a second equalization circuit unit, wherein the second equalization circuit unit is configured with a fifth interface and a sixth interface;

25 the fifth interface is coupled to the first node, and the sixth interface is coupled to the positive output terminal of the first-stage DC-to-DC unit, or the sixth interface is coupled to the negative output terminal of the second-stage DC-to-DC unit, to balance output voltages and/or powers and/or currents of the first-stage DC-to-DC unit and the second-stage DC-to-DC unit; or

the fifth interface is coupled to the second node, and the sixth interface is coupled to the
30 positive input terminal of the first-stage DC-to-AC unit, or the sixth interface is coupled to the negative input terminal of the second-stage DC-to-AC unit, to balance input voltages and/or

powers and/or currents of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit.

17. The power system according to claim 9, wherein the output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different transformers; or

5 the output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different windings of a same transformer.

18. The power system according to claim 9, wherein the power system specifically comprises at least one pair of power supplies, at least one pair of direct current conversion units, and at least one pair of DC-to-AC conversion units, wherein one pair of power supplies comprises the first
10 power supply and the second power supply, one pair of direct current conversion units comprises the first-stage DC-to-DC unit and the second-stage DC-to-DC unit, and one pair of DC-to-AC conversion units comprises the first-stage DC-to-AC unit and the second-stage DC-to-AC unit;

when the at least one pair of power supplies, the at least one pair of direct current conversion units, and the at least one pair of DC-to-AC conversion units are coupled, each pair of direct current
15 conversion units is coupled to one pair of power supplies; or same-type input terminals of each pair of direct current conversion units are coupled in parallel, and then coupled to each pair of power supplies; and

each pair of DC-to-AC conversion units is coupled to one pair of direct current conversion units; or same-type input terminals of each pair of DC-to-AC conversion units are coupled in
20 parallel, and then coupled to each pair of direct current conversion units.

19. The power system according to claim 9, wherein an insulation monitoring device IMD is coupled between a ground point and the output terminal of the first-stage DC-to-AC unit and/or the output terminal of the second-stage DC-to-AC unit, and is configured to detect insulation impedance to ground of the power system.

20. The power system according to claim 9, wherein any two of the first power supply, the second power supply, the first-stage DC-to-DC unit, the second-stage DC-to-DC unit, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit communicate with each other by using a communication signal coupled to a direct current cable.

21. The power system according to claim 9, wherein the output terminal of the first-stage DC-
30 to-AC unit is connected in parallel to a first alternating current device, and the first alternating current device communicates with the first-stage DC-to-AC unit by using a communication signal

coupled to an alternating current cable connected to the first alternating current device and the first-stage DC-to-AC unit; and/or

the output terminal of the second-stage DC-to-AC unit is connected in parallel to a second alternating current device, and the second alternating current device communicates with the second-stage DC-to-AC unit by using a communication signal coupled to an alternating current cable connected to the second alternating current device and the second-stage DC-to-AC unit.

22. The power system according to claim 9, wherein

a positive output terminal of the first power supply and a negative output terminal of the first power supply are coupled to a leakage current sensor; and/or

a positive output terminal of the second power supply and a negative output terminal of the second power supply are coupled to a leakage current sensor; and/or

a positive input terminal of the first-stage DC-to-DC unit and a negative input terminal of the first-stage DC-to-DC unit are coupled to a leakage current sensor; and/or

a positive input terminal of the second-stage DC-to-DC unit and a negative input terminal of the second-stage DC-to-DC unit are coupled to a leakage current sensor; and/or

the positive output terminal of the first-stage DC-to-DC unit and the negative output terminal of the first-stage DC-to-DC unit are coupled to a leakage current sensor; and/or

the positive output terminal of the second-stage DC-to-DC unit and the negative output terminal of the second-stage DC-to-DC unit are coupled to a leakage current sensor; and/or

the positive input terminal of the first-stage DC-to-AC unit and the negative input terminal of the first-stage DC-to-AC unit are coupled to a leakage current sensor; and/or

the positive input terminal of the second-stage DC-to-AC unit and the negative input terminal of the second-stage DC-to-AC unit are coupled to a leakage current sensor; and/or

an internal output phase wire of the first-stage DC-to-AC unit is coupled to a leakage current sensor; and/or

an internal output phase wire of the second-stage DC-to-AC unit is coupled to a leakage current sensor; and

when the leakage current sensor detects that a leakage current value is greater than a preset threshold, the power supply and/or the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit and/or the first-stage DC-to-DC unit and/or the second-stage DC-to-DC unit report/reports an alarm and/or the power system stops working.

23. The power system according to claim 9, wherein at least one switch is connected in series to an internal output phase wire of the first-stage DC-to-AC unit and/or an internal output phase wire of the second-stage DC-to-AC unit, and the switch is a relay, a circuit breaker, or a contactor.

24. The power system according to claim 9, wherein the first power supply and/or the second power supply are/is a photovoltaic array and/or an energy storage power supply and/or a wind power generation direct current source; and

the photovoltaic array is formed by connecting photovoltaic cell panels in series or in parallel combinations, or is formed by connecting an output of the photovoltaic cell panel to an optimizer or a shutdown device, and then connecting in series or in parallel combinations.

25. The power system according to claim 24, wherein a negative input terminal of the first-stage DC-to-DC unit and the negative output terminal of the first-stage DC-to-DC unit are directly coupled, or connected with only a small voltage drop, and a negative input terminal of the second-stage DC-to-DC unit and the positive output terminal of the second-stage DC-to-DC unit are directly coupled, or connected with only a small voltage drop; or

a positive input terminal of the first-stage DC-to-DC unit and the negative output terminal of the first-stage DC-to-DC unit are directly coupled, or connected with only a small voltage drop, and a positive input terminal of the second-stage DC-to-DC unit and the positive output terminal of the second-stage DC-to-DC unit are directly coupled, or connected with only a small voltage drop.

26. The power system according to claim 24, wherein the first power supply and the second power supply are the photovoltaic array, and the first node and/or the second node are coupled to ground.

27. The power system according to claim 24, wherein a voltage source is coupled between a ground point and a neutral point of a transformer winding corresponding to the output terminal of the first-stage DC-to-AC unit or the second-stage DC-to-AC unit, to adjust a potential to ground of the neutral point; or

a voltage source is coupled between a ground point and an internal phase wire at the output terminal of the first-stage DC-to-AC unit or the second-stage DC-to-AC unit, to adjust a potential to ground of a corresponding output phase wire; or

a voltage source is coupled between a ground point and an external phase wire at the output terminal of the first-stage DC-to-AC unit or the second-stage DC-to-AC unit, to adjust a potential

to ground of a corresponding output phase wire.

28. The power system according to claim 24, wherein a neutral point of a transformer winding corresponding to the output terminal of the first-stage DC-to-AC unit or the second-stage DC-to-AC unit is coupled to ground or coupled to ground by using a current-limiting device, so that a
5 voltage to ground of the neutral point is close to or equal to 0 V.

29. The power system according to claim 24, wherein when the output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different windings of a same transformer, a neutral point of a winding corresponding to the output terminal of the first-stage DC-to-AC unit and a neutral point of a winding corresponding to the output
10 terminal of the second-stage DC-to-AC unit are coupled by using two series resistors or current-limiting devices, and a middle point between the two series resistors or the two current-limiting devices is coupled to ground.

30. The power system according to claim 24, wherein the first-stage DC-to-AC unit further internally comprises a first AC-to-DC isolation unit;

15 the first power supply and the second power supply are the photovoltaic array;

an input terminal of the first AC-to-DC isolation unit is coupled to an internal phase wire at the output terminal of the first-stage DC-to-AC unit, a first output terminal of the first AC-to-DC isolation unit is coupled to ground, and a second output terminal of the first AC-to-DC isolation unit is coupled to the positive input terminal and/or the negative input terminal of the first-stage
20 DC-to-AC unit; and

the first AC-to-DC isolation unit is configured to adjust an output voltage to ground of the first power supply and/or the second power supply; and/or

the second-stage DC-to-AC unit further internally comprises a second AC-to-DC isolation unit;

25 an input terminal of the second AC-to-DC isolation unit is coupled to an internal phase wire at the output terminal of the second-stage DC-to-AC unit, a first output terminal of the second AC-to-DC isolation unit is coupled to ground, and a second output terminal of the second AC-to-DC isolation unit is coupled to the positive input terminal and/or the negative input terminal of the second-stage DC-to-AC unit; and

30 the second AC-to-DC isolation unit is configured to adjust an output voltage to ground of the first power supply and/or the second power supply.

31. The power system according to claim 24, wherein when the first power supply and/or the second power supply are/is the photovoltaic array formed by connecting the output of the photovoltaic cell panel to the optimizer or the shutdown device, and then connecting in series or in parallel combinations, a communication signal is coupled to a direct current cable at the output terminal of the optimizer or the shutdown device, and is used by any one of the first-stage DC-to-AC unit, the second-stage DC-to-AC unit, the first-stage DC-to-DC unit, and the second-stage DC-to-DC unit to control the optimizer or the shutdown device by using the communication signal, so as to implement fast shutdown.

32. The power system according to claim 24, wherein a communication signal is coupled to a direct current cable between the first-stage DC-to-AC unit, the second-stage DC-to-AC unit, the first-stage DC-to-DC unit, and the second-stage DC-to-DC unit; and

the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit control/controls the first-stage DC-to-DC unit and/or the second-stage DC-to-DC unit by using the communication signal, to implement fast shutdown of the input terminal of the first-stage DC-to-DC unit and/or the second-stage DC-to-DC unit.

33. The power system according to claim 24, further comprising at least one energy storage unit, wherein

at least two direct current cables connected to the first-stage DC-to-DC unit, the second-stage DC-to-DC unit, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit are coupled in parallel to the energy storage unit.

34. The power system according to claim 33, wherein any two of the first power supply, the second power supply, the energy storage unit, the first-stage DC-to-DC unit, the second-stage DC-to-DC unit, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit communicate with each other by using a communication signal coupled to a connected direct current cable.

35. A power system, comprising N first power supplies, M second power supplies, N DC-to-DC units, and S DC-to-AC units, wherein

an output terminal of the first power supply is coupled to an input terminal of the DC-to-DC unit;

a positive terminal formed by serially coupling output terminals of the N DC-to-DC units and output terminals of the M second power supplies is coupled to a positive terminal formed by serially coupling input terminals of the S DC-to-AC units; or

a negative terminal formed by serially coupling the output terminals of the N DC-to-DC units and the output terminals of the M second power supplies is coupled to a negative terminal formed by serially coupling the input terminals of the S DC-to-AC units;

a first node formed by series coupling points for the output terminals of the N DC-to-DC units and the output terminals of the M second power supplies is coupled to a second node formed by series coupling points for the input terminals of the S DC-to-AC units by using at least one cable; and

an output terminal of the DC-to-AC unit is isolated.

36. The power system according to claim 35, wherein the first power supply and/or the second power supply are/is a photovoltaic array and/or an energy storage power supply and/or a wind power generation direct current source; and

the photovoltaic array is formed by connecting photovoltaic cell panels in series or in parallel combinations, or is formed by connecting an output of the photovoltaic cell panel to an optimizer or a shutdown device, and then connecting in series or in parallel combinations.

37. The power system according to claim 35, wherein at least two groups of corresponding first nodes are connected in parallel, and at least two groups of corresponding second nodes are connected in parallel; and

at least one parallel-connected first node is coupled to at least one parallel-connected second node.

38. The power system according to claim 35, wherein any two of the first power supply, the second power supply, the DC-to-DC unit, and the DC-to-AC unit communicate with each other by using a communication signal coupled to a connected direct current cable.

39. The power system according to claim 35, wherein when the first power supply and/or the second power supply are/is a photovoltaic array formed by connecting an output of a photovoltaic cell panel to an optimizer or a shutdown device, and then connecting in series or in parallel combinations, a communication signal is coupled to a direct current cable connected between the first power supply, the second power supply, the DC-to-DC unit, and the DC-to-AC unit, and the DC-to-DC unit and/or the DC-to-AC unit control/controls the optimizer or the shutdown device by using the communication signal, to implement fast shutdown.

40. The power system according to claim 35, wherein a communication signal is coupled to a direct current cable connected between the DC-to-DC unit and the DC-to-AC unit, and the DC-

to-AC unit controls the DC-to-DC unit by using the communication signal, to implement fast shutdown of an input of the DC-to-DC unit.

41. The power system according to claim 35, further comprising at least one energy storage unit, wherein

5 the energy storage unit is coupled in parallel to at least two direct current cables connected between the DC-to-DC unit, the second power supply, and the DC-to-AC unit.

42. The power system according to claim 41, wherein the energy storage unit is an energy storage device, or the energy storage unit comprises a direct current conversion unit and the energy storage device; and the energy storage device comprises a supercapacitor or a battery.

10 43. The power system according to claim 41, wherein any two of the first power supply, the second power supply, the DC-to-DC unit, the DC-to-AC unit, and the energy storage unit communicate with each other by using a communication signal coupled to a connected direct current cable.

44. A power system, comprising a first power supply, a DC-to-DC unit, a second power supply,
15 a first-stage DC-to-AC unit, and a second-stage DC-to-AC unit, wherein

an output terminal of the first power supply is coupled to an input terminal of the DC-to-DC unit;

the DC-to-DC unit is coupled in series to an output terminal of the second power supply, and a coupling point is a first node;

20 a negative input terminal of the first-stage DC-to-AC unit is coupled to a positive input terminal of the second-stage DC-to-AC unit, and a coupling point is a second node;

a positive output terminal formed after the DC-to-DC unit is coupled in series to the output terminal of the second power supply is a first port, and the first port is coupled to a positive input terminal of the first-stage DC-to-AC unit; or

25 a negative output terminal formed after the DC-to-DC unit is coupled in series to the output terminal of the second power supply is a second port, and the second port is coupled to a negative input terminal of the second-stage DC-to-AC unit; and

outputs of output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are isolated.

30 45. The power system according to claim 44, wherein

the first port is coupled to the positive input terminal of the first-stage DC-to-AC unit by

using a first conducting wire, the second port is coupled to the negative input terminal of the second-stage DC-to-AC unit by using a second conducting wire, and the first node is coupled to the second node by using a third conducting wire; and

a current value of the third conducting wire is less than or equal to a current value of the first
5 conducting wire; or

a current value of the third conducting wire is less than or equal to a current value of the second conducting wire.

46. The power system according to claim 45, wherein

the first conducting wire, the second conducting wire, and the third conducting wire are direct
10 current conducting wires;

the first conducting wire, the second conducting wire, and the third conducting wire form a distributed double bus, the first conducting wire and the second conducting wire form a positive bus, and the second conducting wire and the third conducting wire form a negative bus; and

the third conducting wire is a neutral wire of the distributed double bus.

15 47. The power system according to claim 44, wherein

both the first node and the second node are coupled to ground.

48. The power system according to claim 44, wherein the first node is coupled to the second node, and when an input voltage and/or an input current and/or an input power of the DC-to-DC unit are/is less than a preset value or an output voltage and/or an output current and/or an output
20 power of the second power supply are/is less than a preset value, the corresponding DC-to-DC unit or the second power supply stops working; and

at least one of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit works.

49. The power system according to claim 44, wherein

the power system further comprises a first equalization circuit unit, wherein the first
25 equalization circuit unit is configured with a first interface, a second interface, and a third interface; and

the first interface is coupled to the first node, the second interface is coupled to the first port, and the third interface is coupled to the second port, to balance output voltages and/or powers and/or currents of the DC-to-DC unit and the second power supply; or

30 the first interface is coupled to the second node, the second interface is coupled to the positive input terminal of the first-stage DC-to-AC unit, and the third interface is coupled to the negative

input terminal of the second-stage DC-to-AC unit, to balance input voltages and/or powers and/or currents of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit.

50. The power system according to claim 49, wherein the first equalization circuit unit further comprises a fourth interface; and

5 when the first interface is coupled to the first node, the fourth interface is coupled to the second node; or

when the first interface is coupled to the second node, the fourth interface is coupled to the first node.

51. The power system according to claim 44, wherein the power system further comprises a second equalization circuit unit, and the second equalization circuit unit is configured with a fifth interface and a sixth interface;

the fifth interface is coupled to the first node, and the sixth interface is coupled to the first port, or the sixth interface is coupled to the second port, to balance output voltages and/or powers and/or currents of the DC-to-DC unit and the second power supply; or

15 the fifth interface is coupled to the second node, and the sixth interface is coupled to the positive input terminal of the first-stage DC-to-AC unit, or the sixth interface is coupled to the negative input terminal of the second-stage DC-to-AC unit, to balance input voltages and/or powers and/or currents of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit.

52. The power system according to claim 44, wherein the output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different transformers; or

the output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different windings of a same transformer.

53. The power system according to claim 44, wherein the power system specifically comprises at least one pair of power supplies, at least one DC-to-DC unit, and at least one pair of DC-to-AC conversion units, wherein one pair of power supplies comprises the first power supply and the second power supply, and one pair of DC-to-AC conversion units comprises the first-stage DC-to-AC unit and the second-stage DC-to-AC unit;

when the at least one pair of power supplies, the at least one DC-to-DC unit, and the at least one pair of DC-to-AC conversion units are coupled, each DC-to-DC unit is coupled to at least one first power supply; and

each pair of DC-to-AC conversion units is coupled to at least one DC-to-DC unit and one second power supply; or same-type input terminals of each pair of DC-to-AC conversion units are coupled in parallel, and then coupled to the at least one DC-to-DC unit and at least one second power supply.

5 54. The power system according to claim 44, wherein an insulation monitoring device IMD is coupled between a ground point and the output terminal of the first-stage DC-to-AC unit and/or the output terminal of the second-stage DC-to-AC unit, and is configured to detect insulation impedance to ground of the power system.

10 55. The power system according to claim 44, wherein any two of the first power supply, the second power supply, the DC-to-DC unit, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit communicate with each other by using a communication signal coupled to a direct current cable.

15 56. The power system according to claim 44, wherein the output terminal of the first-stage DC-to-AC unit is connected in parallel to a first alternating current device, and the first alternating current device communicates with the first-stage DC-to-AC unit by using a communication signal coupled to an alternating current cable connected to the first alternating current device and the first-stage DC-to-AC unit; and/or

20 the output terminal of the second-stage DC-to-AC unit is connected in parallel to a second alternating current device, and the second alternating current device communicates with the second-stage DC-to-AC unit by using a communication signal coupled to an alternating current cable connected to the second alternating current device and the second-stage DC-to-AC unit.

 57. The power system according to claim 44, wherein
a positive output terminal of the first power supply and a negative output terminal of the first power supply are coupled to a leakage current sensor; and/or

25 a positive output terminal of the second power supply and a negative output terminal of the second power supply are coupled to a leakage current sensor; and/or

a positive input terminal of the DC-to-DC unit and a negative input terminal of the DC-to-DC unit are coupled to a leakage current sensor; and/or

30 a positive output terminal of the DC-to-DC unit and a negative output terminal of the DC-to-DC unit are coupled to a leakage current sensor; and/or

the positive input terminal of the first-stage DC-to-AC unit and the negative input terminal

of the first-stage DC-to-AC unit are coupled to a leakage current sensor; and/or

the positive input terminal of the second-stage DC-to-AC unit and the negative input terminal of the second-stage DC-to-AC unit are coupled to a leakage current sensor; and/or

an internal output phase wire of the first-stage DC-to-AC unit is coupled to a leakage current
5 sensor; and/or

an internal output phase wire of the second-stage DC-to-AC unit is coupled to a leakage current sensor; and

when the leakage current sensor detects that a leakage current value is greater than a preset threshold, the first power supply and/or the first-stage DC-to-AC unit and/or the second-stage DC-
10 to-AC unit and/or the DC-to-DC unit and/or the second power supply report/reports an alarm and/or the power system stops working.

58. The power system according to claim 44, wherein at least one switch is connected in series to an internal output phase wire of the first-stage DC-to-AC unit and/or an internal output phase wire of the second-stage DC-to-AC unit, and the switch is a relay, a circuit breaker, or a
15 contactor.

59. The power system according to claim 44, wherein the first power supply and/or the second power supply are/is a photovoltaic array and/or an energy storage power supply and/or a wind power generation direct current source; and

the photovoltaic array is formed by connecting photovoltaic cell panels in series or in parallel
20 combinations, or is formed by connecting an output of the photovoltaic cell panel to an optimizer or a shutdown device, and then connecting in series or in parallel combinations.

60. The power system according to claim 59, wherein a negative input terminal and a positive output terminal of the DC-to-DC unit are directly coupled, or connected with only a small voltage drop; or

25 a positive input terminal and a negative output terminal of the DC-to-DC unit are directly coupled, or connected with only a small voltage drop.

61. The power system according to claim 59, wherein the first node and/or the second node are/is coupled to ground.

62. The power system according to claim 59, wherein a voltage source is coupled between a
30 ground point and a neutral point of a transformer winding corresponding to the output terminal of the first-stage DC-to-AC unit or the second-stage DC-to-AC unit, to adjust a potential to ground

of the neutral point; or

a voltage source is coupled between a ground point and an internal phase wire at the output terminal of the first-stage DC-to-AC unit or the second-stage DC-to-AC unit, to adjust a potential to ground of a corresponding output phase wire; or

5 a voltage source is coupled between a ground point and an external phase wire at the output terminal of the first-stage DC-to-AC unit or the second-stage DC-to-AC unit, to adjust a potential to ground of a corresponding output phase wire.

63. The power system according to claim 59, wherein a neutral point of a transformer winding corresponding to the output terminal of the first-stage DC-to-AC unit or the second-stage DC-to-AC unit is coupled to ground or coupled to ground by using a current-limiting device, so that a
10 voltage to ground of the neutral point is close to or equal to 0 V.

64. The power system according to claim 59, wherein when the output terminals of the first-stage DC-to-AC unit and the second-stage DC-to-AC unit are respectively coupled to different windings of a same transformer, a neutral point of a transformer winding corresponding to the
15 output terminal of the first-stage DC-to-AC unit and a neutral point of a winding corresponding to the output terminal of the second-stage DC-to-AC unit are coupled by using two series resistors or current-limiting devices, and a middle point between the two series resistors or the two current-limiting devices is coupled to ground.

65. The power system according to claim 59, wherein the first-stage DC-to-AC unit further
20 internally comprises a first AC-to-DC isolation unit;

the first power supply and the second power supply are the photovoltaic array;

an input terminal of the first AC-to-DC isolation unit is coupled to an internal phase wire at the output terminal of the first-stage DC-to-AC unit;

a first output terminal of the first AC-to-DC isolation unit is coupled to ground, and a second
25 output terminal of the first AC-to-DC isolation unit is coupled to the positive input terminal and/or the negative input terminal of the first-stage DC-to-AC unit; and

the first AC-to-DC isolation unit is configured to adjust an output voltage to ground of the first power supply and/or the second power supply; and/or

the second-stage DC-to-AC unit further internally comprises a second AC-to-DC isolation
30 unit;

an input terminal of the second AC-to-DC isolation unit is coupled to an internal phase wire

at the output terminal of the second-stage DC-to-AC unit, a first output terminal of the second AC-to-DC isolation unit is coupled to ground, and a second output terminal of the second AC-to-DC isolation unit is coupled to the positive input terminal and/or the negative input terminal of the second-stage DC-to-AC unit; and

5 the second AC-to-DC isolation unit is configured to adjust an output voltage to ground of the first power supply and/or the second power supply.

66. The power system according to claim 59, wherein when the first power supply and/or the second power supply are/is the photovoltaic array formed by connecting the output of the photovoltaic cell panel to the optimizer or the shutdown device, and then connecting in series or
10 in parallel combinations, a communication signal is coupled to a direct current cable at an output terminal of the optimizer or the shutdown device, and is used by any one of the first-stage DC-to-AC unit, the second-stage DC-to-AC unit and the DC-to-DC unit to control the optimizer or the shutdown device by using the communication signal, so as to implement fast shutdown.

67. The power system according to claim 59, wherein a communication signal is coupled to
15 a direct current cable between the first-stage DC-to-AC unit, the second-stage DC-to-AC unit, and the DC-to-DC unit; and

the first-stage DC-to-AC unit and/or the second-stage DC-to-AC unit control/controls the DC-to-DC unit by using the communication signal, to implement fast shutdown of the input terminal of the DC-to-DC unit.

20 68. The power system according to claim 59, further comprising a combiner box, wherein an input terminal of the combiner box is coupled to output terminals of a plurality of second power supplies, a positive output terminal of the combiner box is coupled in series to a negative output terminal of the DC-to-DC unit, a negative output terminal of the combiner box is coupled to the negative input terminal of the second-stage DC-to-AC unit, and a positive output terminal
25 of the DC-to-DC unit is coupled to the positive input terminal of the first-stage DC-to-AC unit; or

an input terminal of the combiner box is coupled to output terminals of a plurality of second power supplies, a negative output terminal of the combiner box is coupled in series to a positive output terminal of the DC-to-DC unit, a positive output terminal of the combiner box is coupled to the positive input terminal of the first-stage DC-to-AC unit, and a negative output terminal of
30 the DC-to-DC unit is coupled to the negative input terminal of the second-stage DC-to-AC unit.

69. The power system according to claim 59, further comprising at least one energy storage

unit, wherein

at least two direct current cables connected to the DC-to-DC unit, the second power supply, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit are coupled in parallel to the energy storage unit.

- 5 70. The power system according to claim 59, wherein any two of the first power supply, the second power supply, the energy storage unit, the DC-to-DC unit, the first-stage DC-to-AC unit, and the second-stage DC-to-AC unit communicate with each other by using a communication signal coupled to a connected direct current cable.

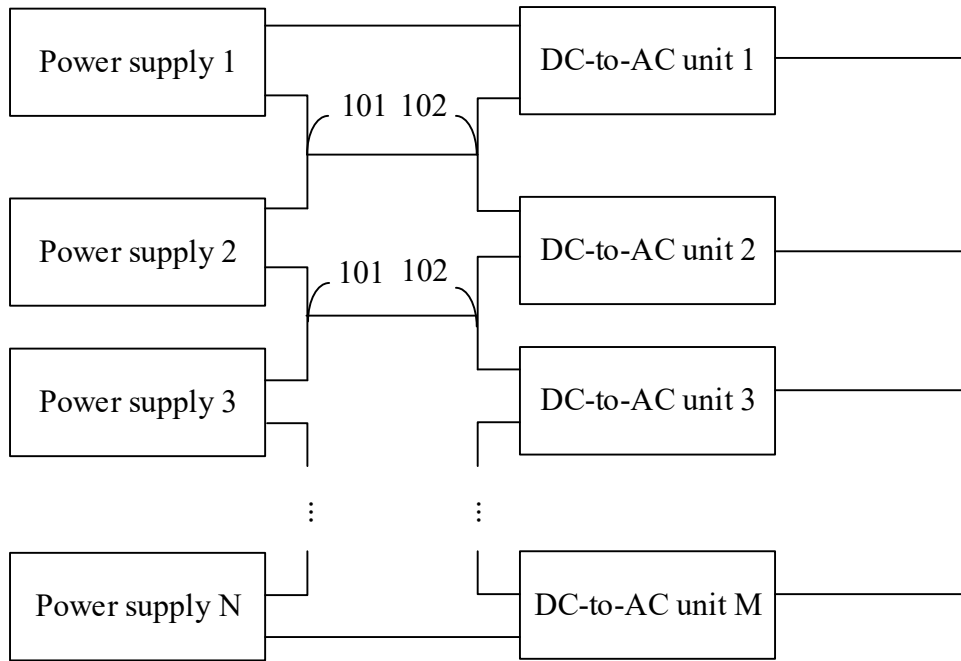


FIG. 1

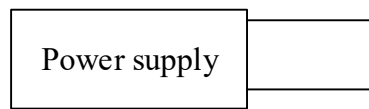


FIG. 2

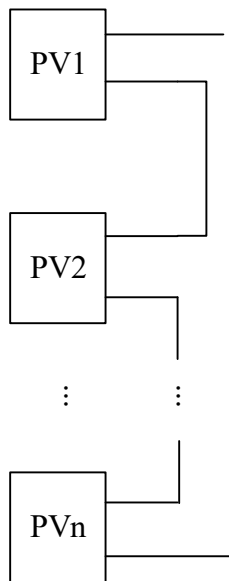


FIG. 3a

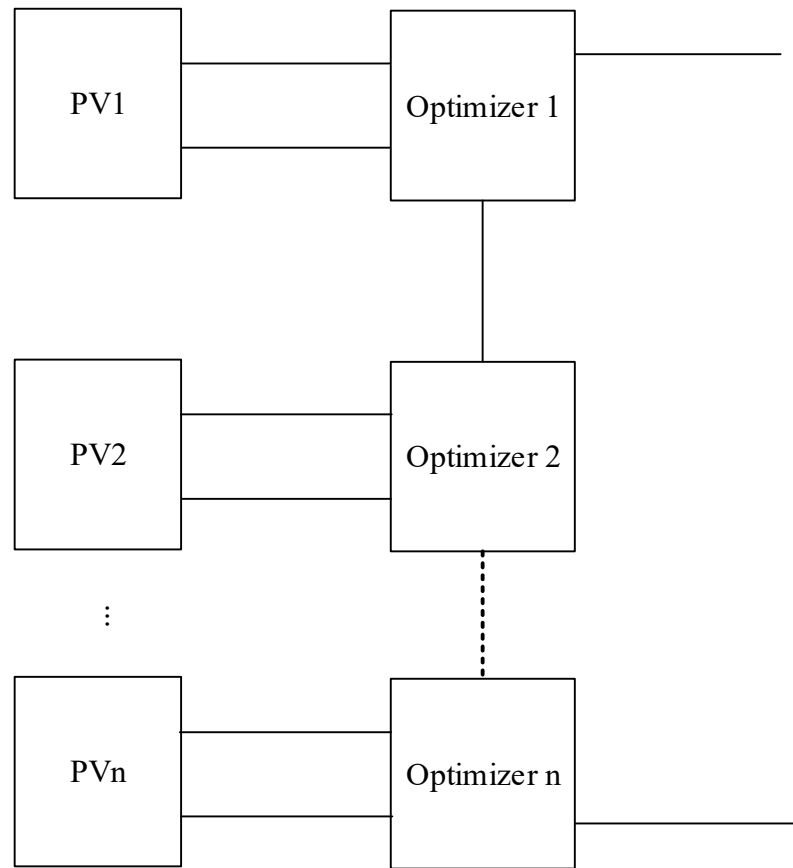


FIG. 3b

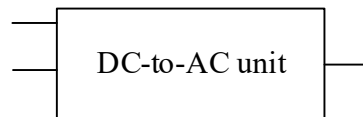


FIG. 4

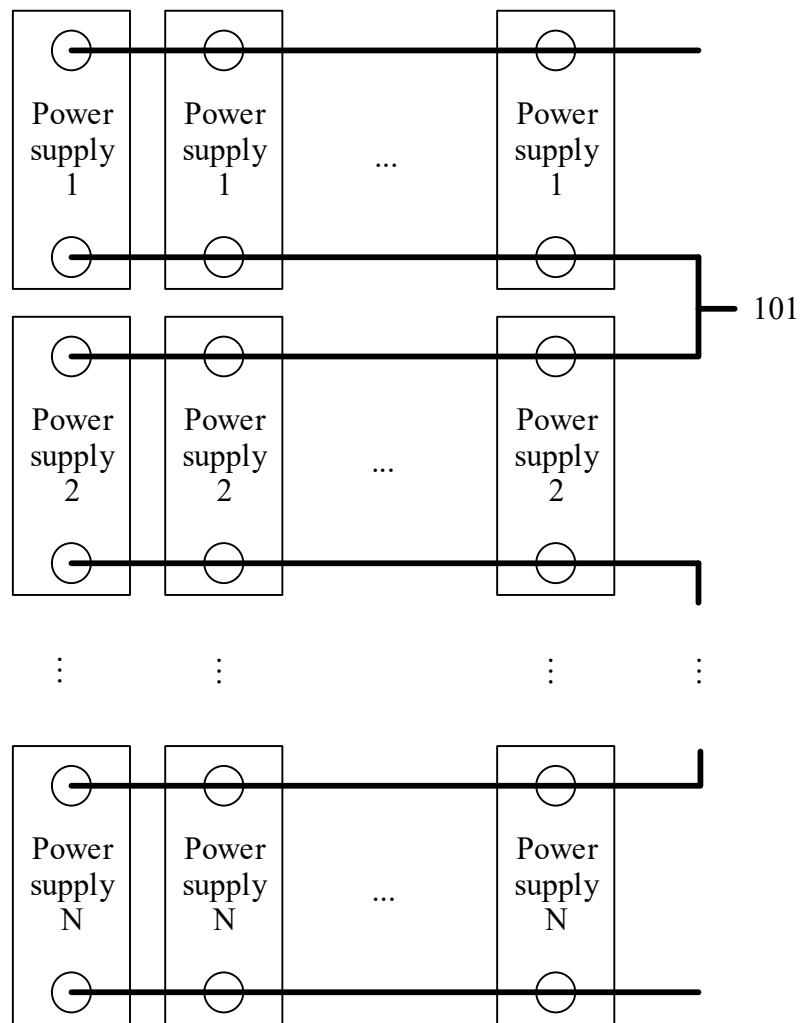


FIG. 5a

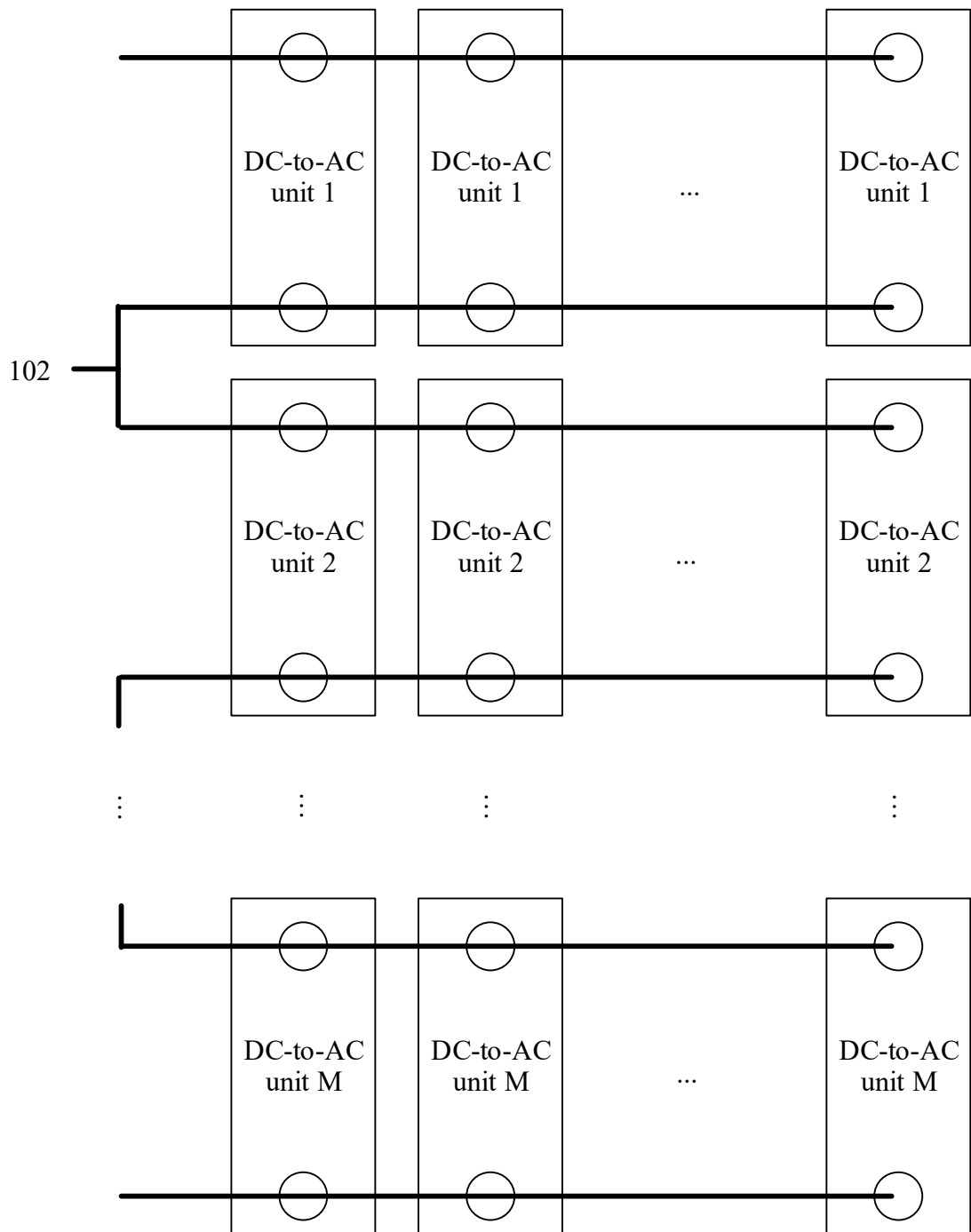


FIG. 5b

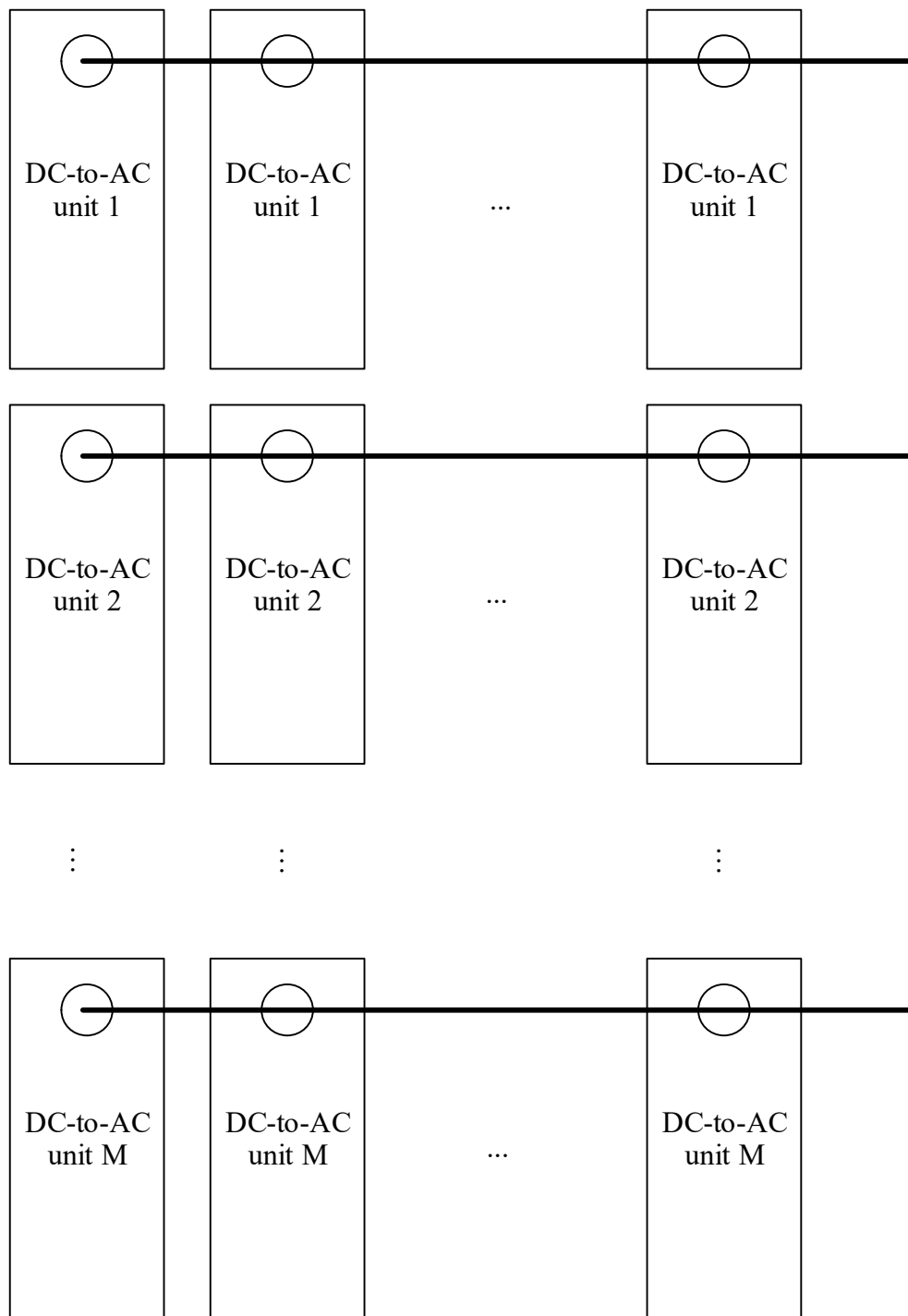


FIG. 5c

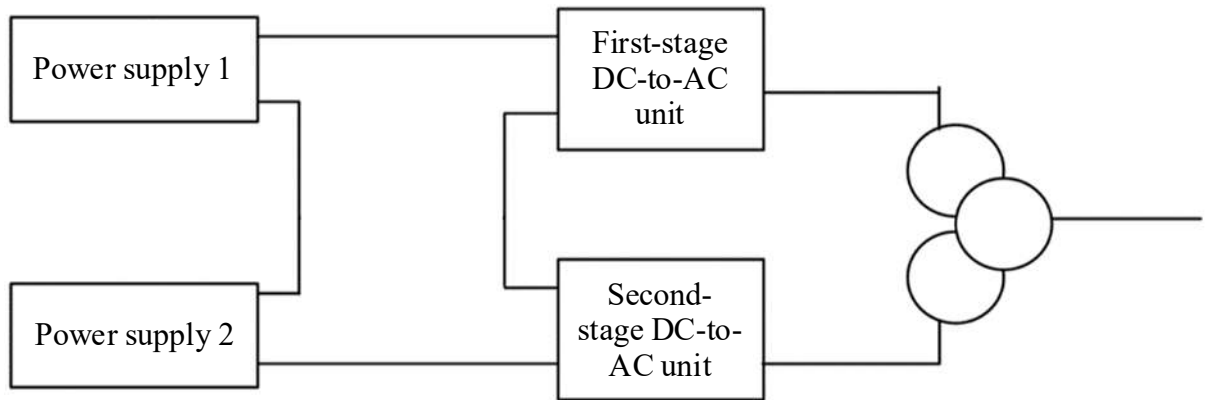


FIG. 6

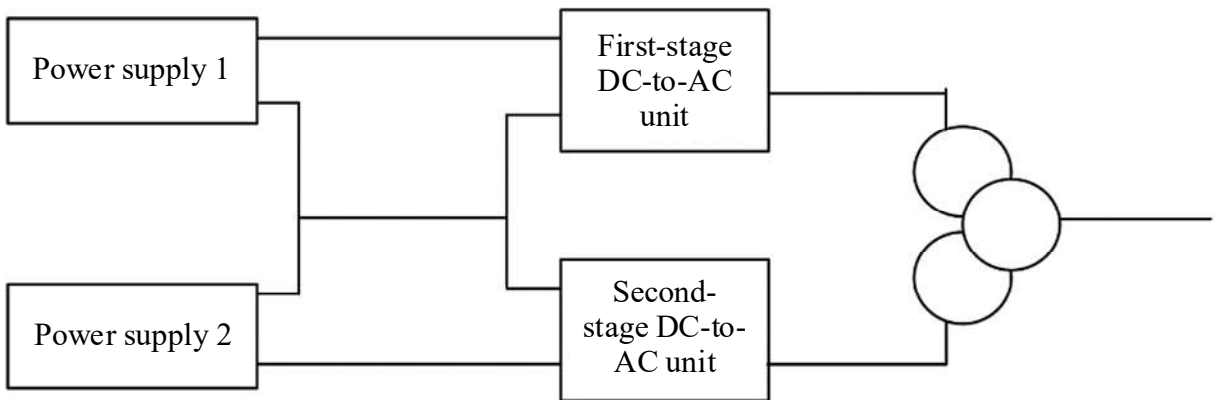


FIG. 7

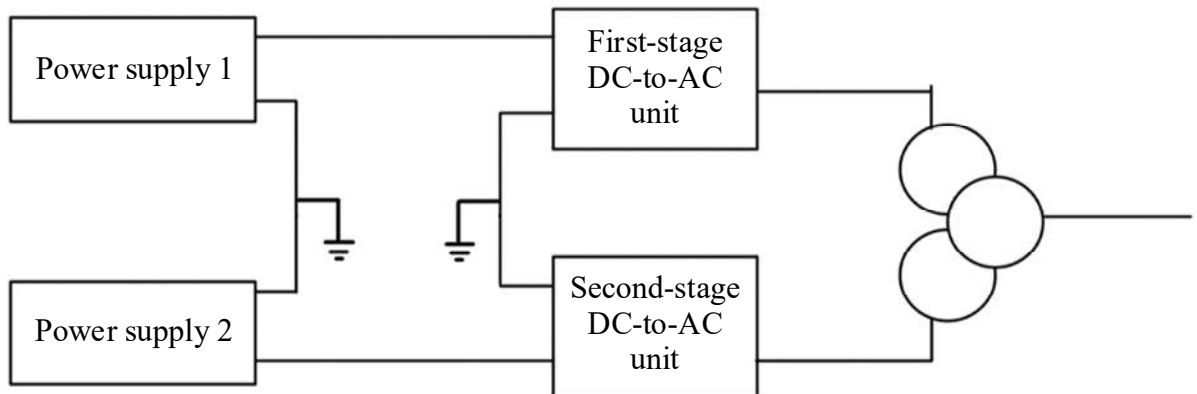


FIG. 8

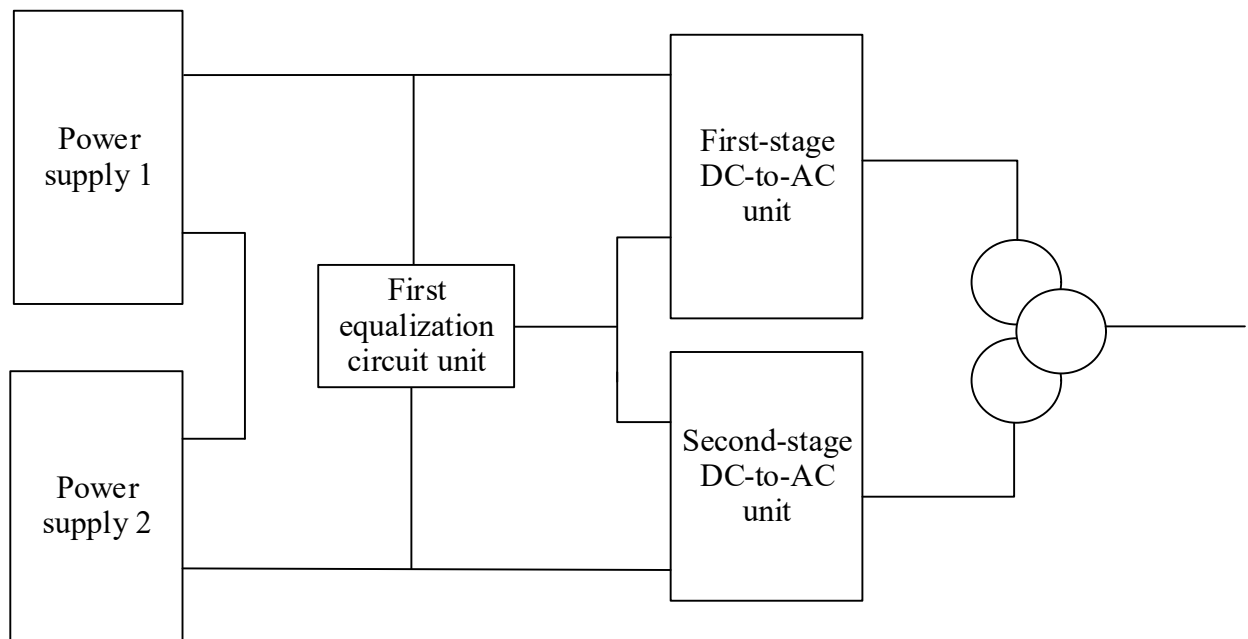


FIG. 9a

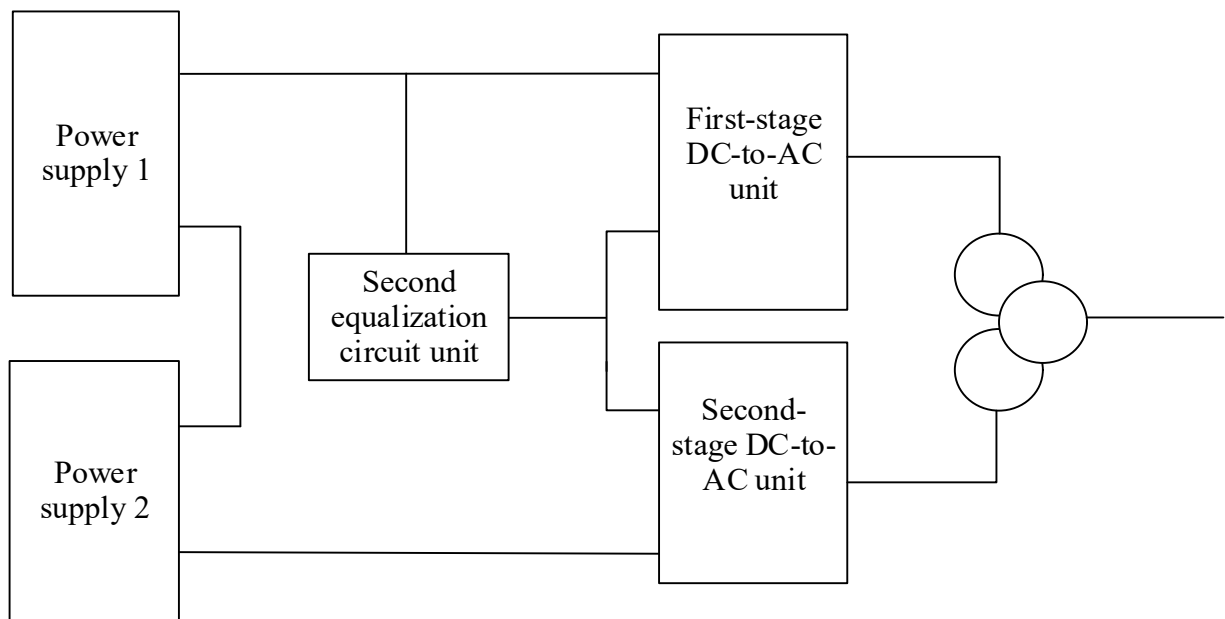


FIG. 9b1

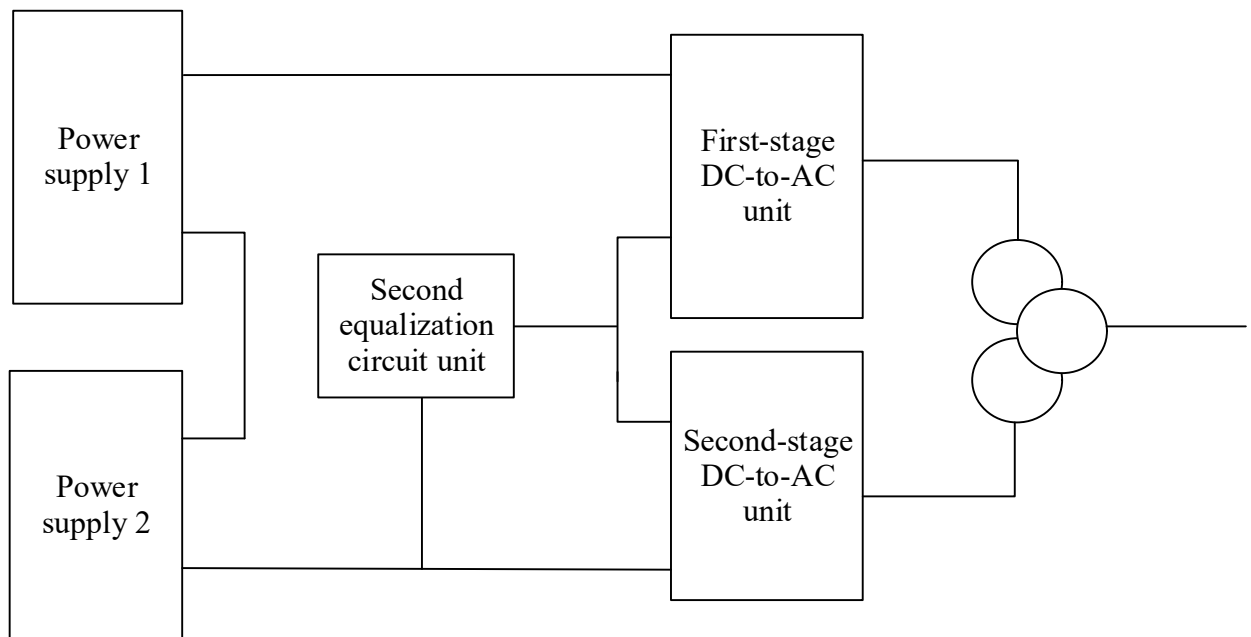


FIG. 9b2

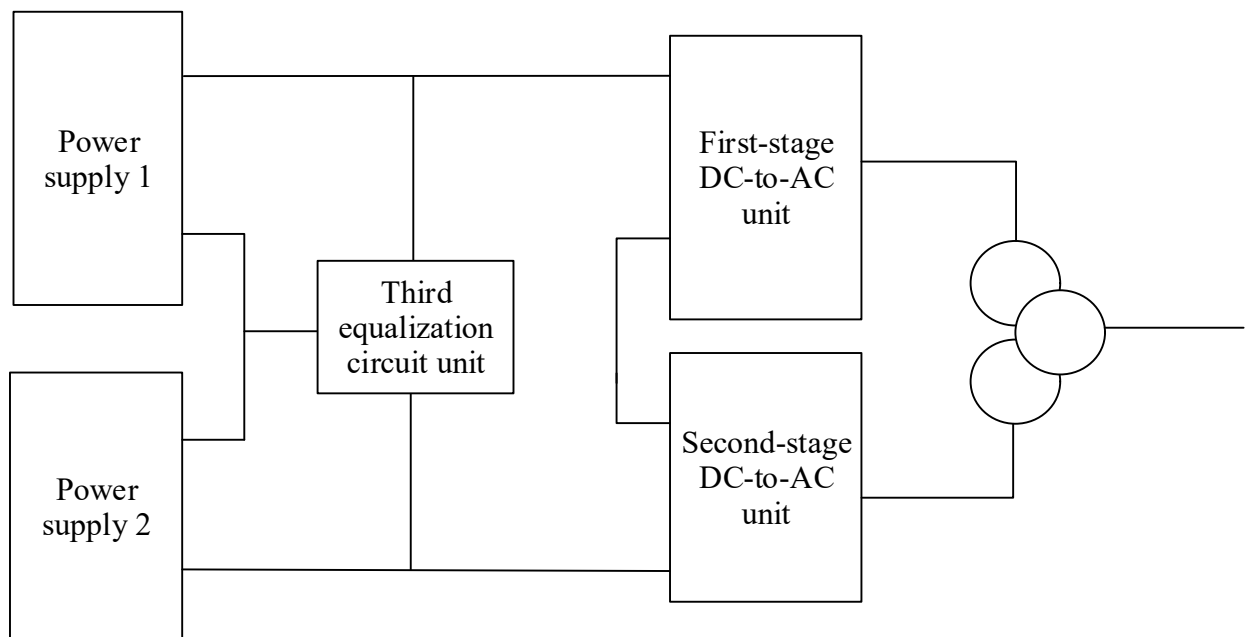


FIG. 9c

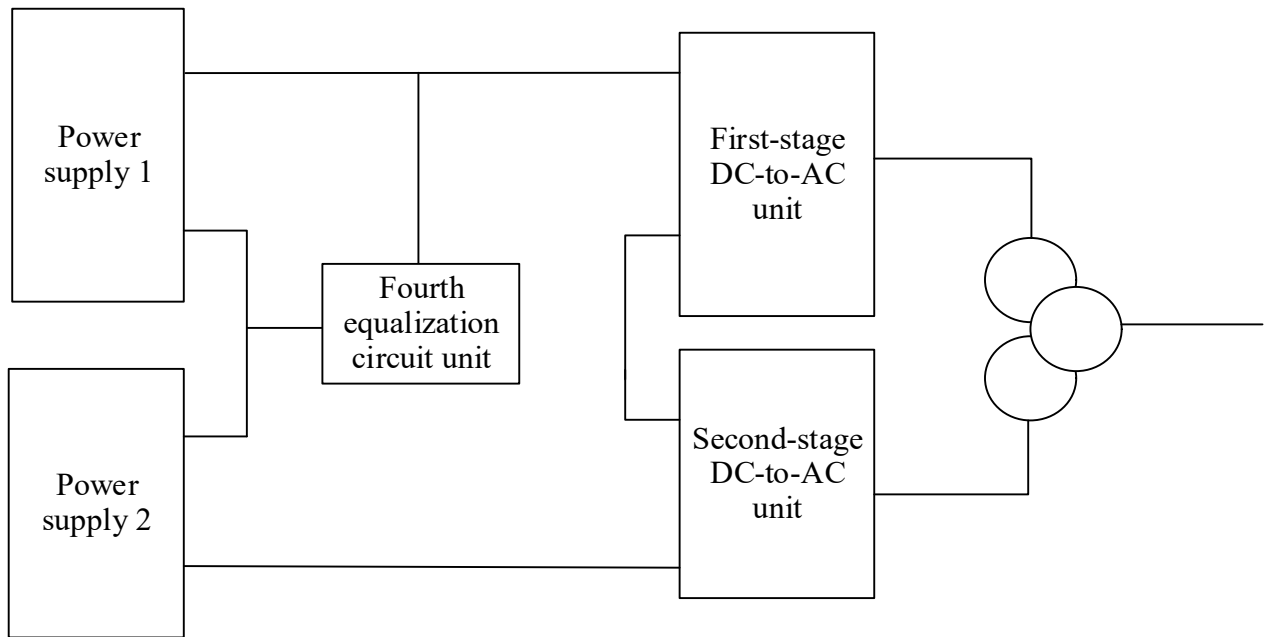


FIG. 9d1

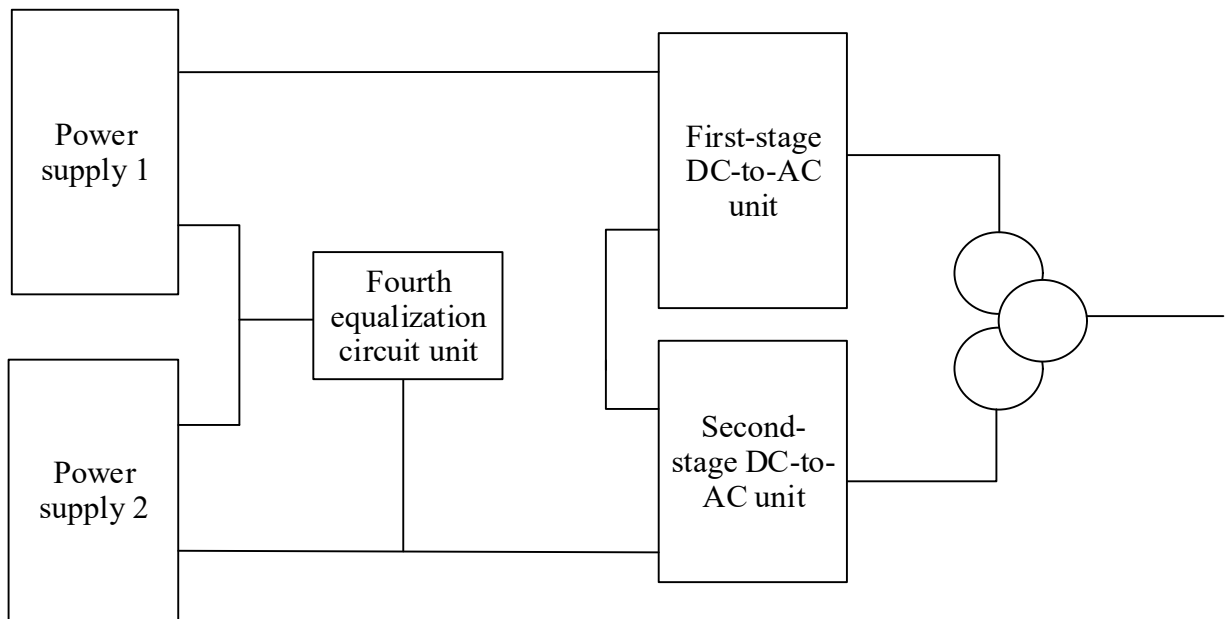


FIG. 9d2

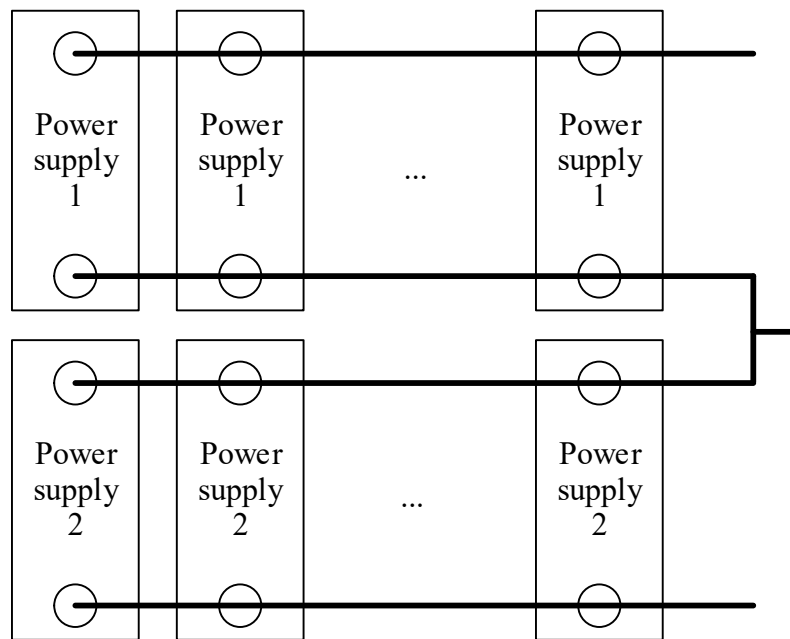


FIG. 10a

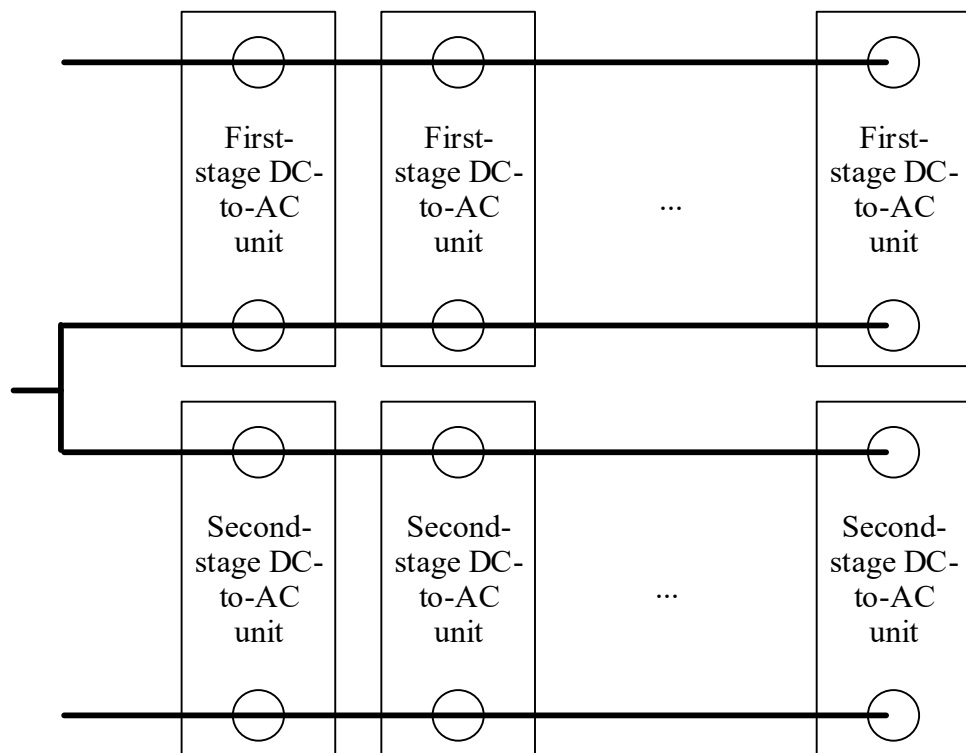


FIG. 10b

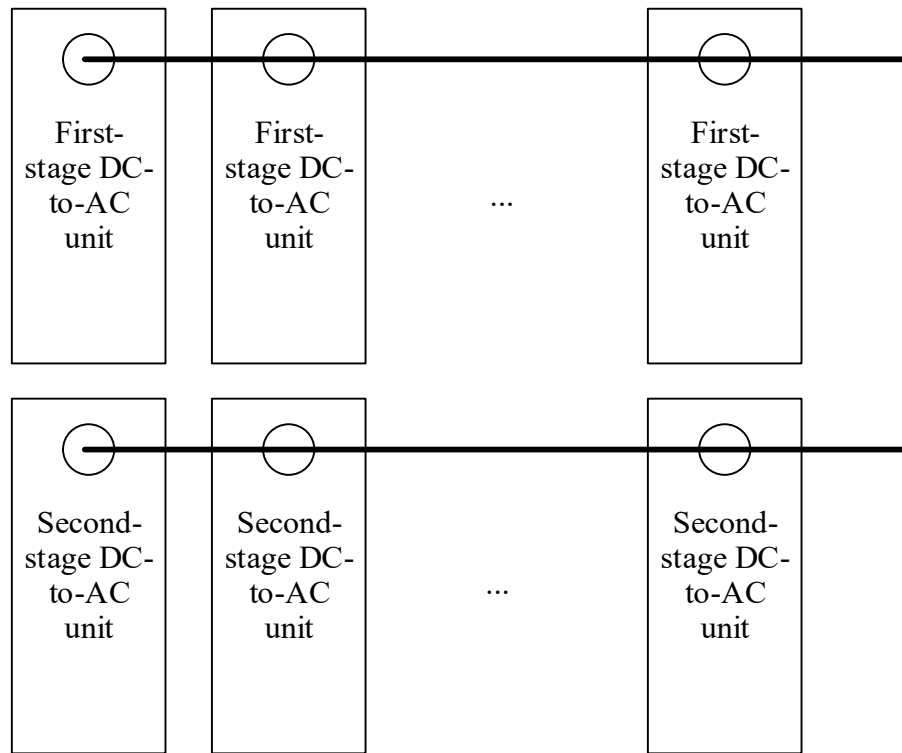


FIG. 10c

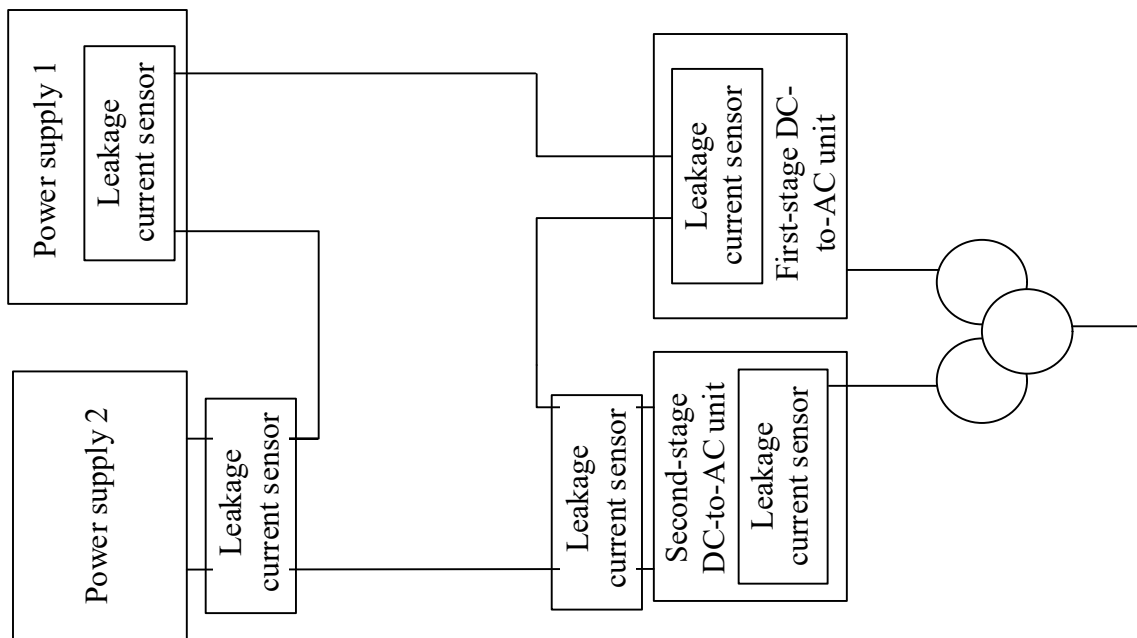


FIG. 11

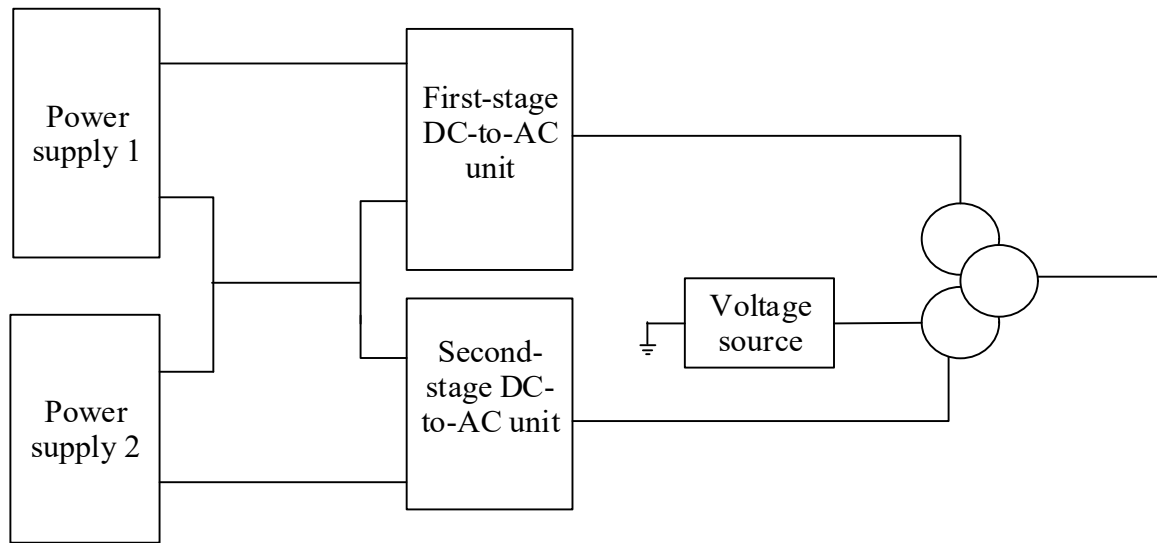


FIG. 12a

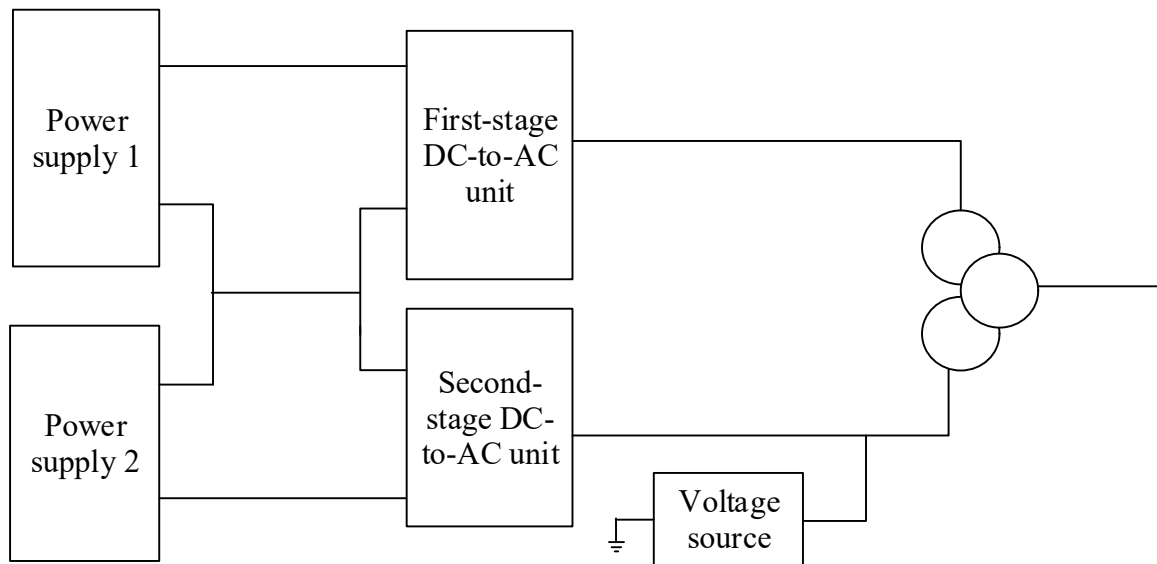


FIG. 12b

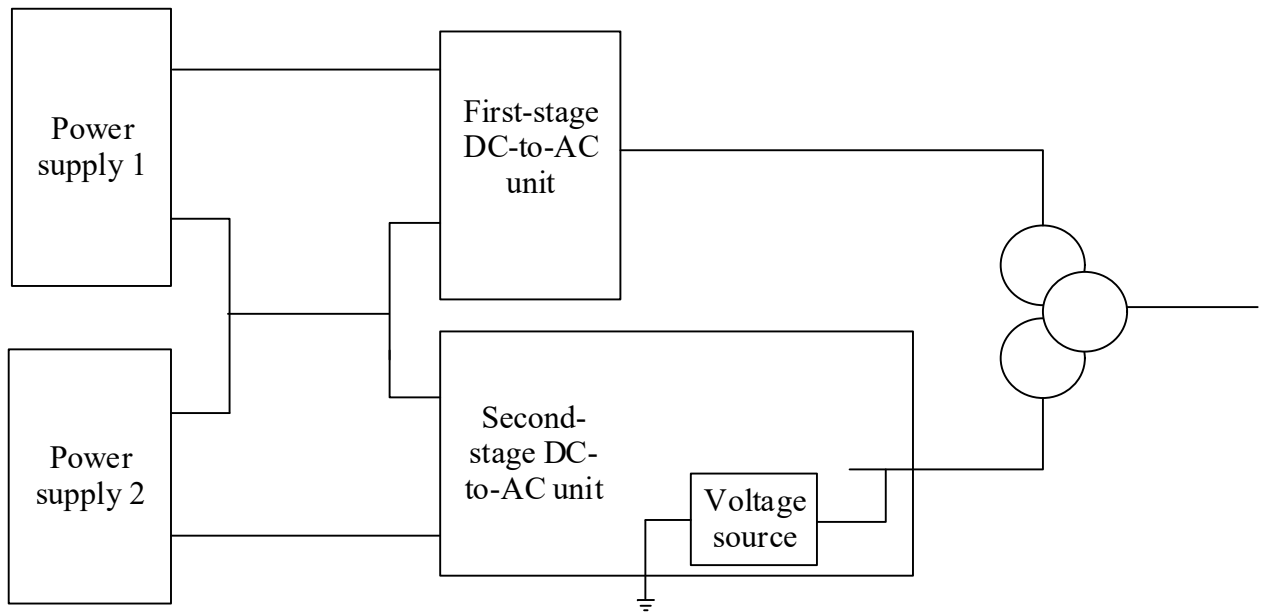


FIG. 12c

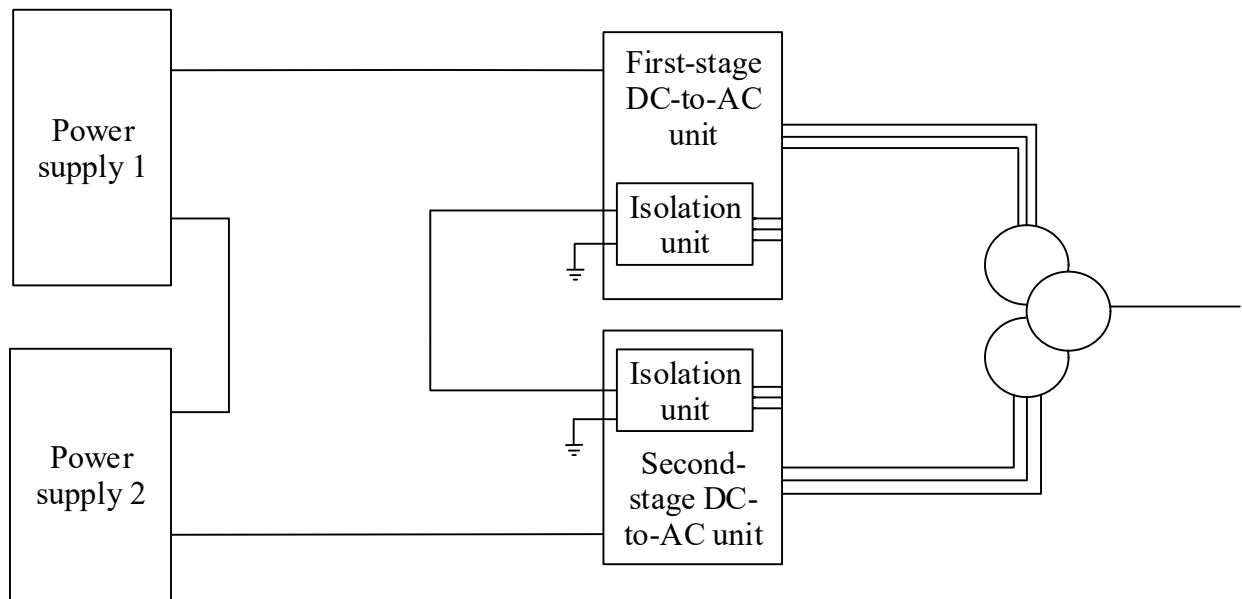


FIG. 13

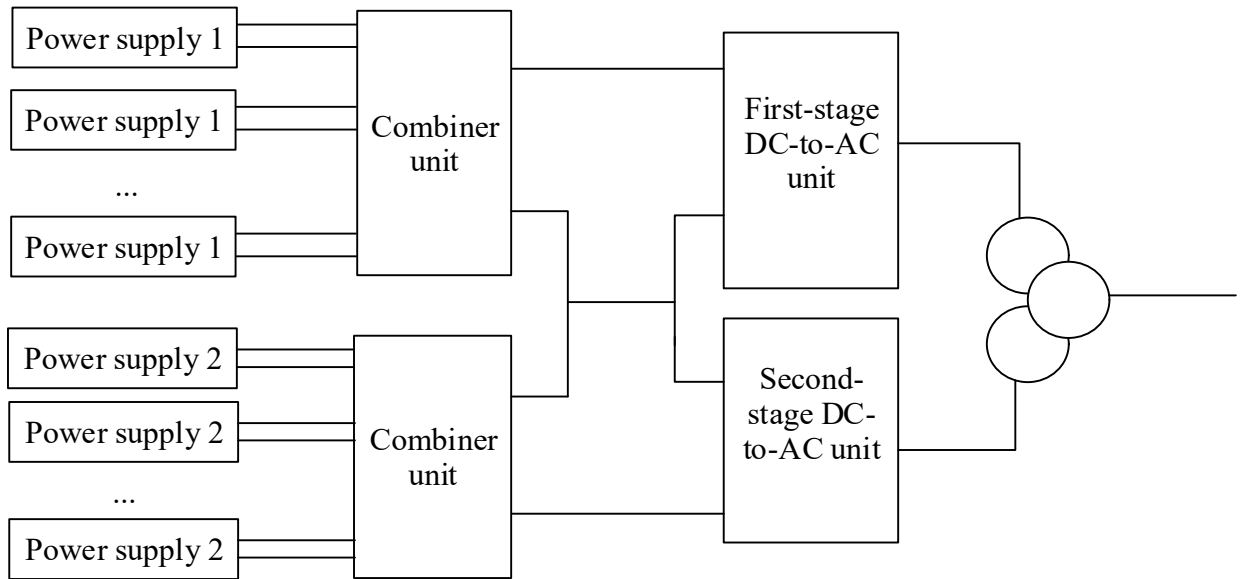


FIG. 14a

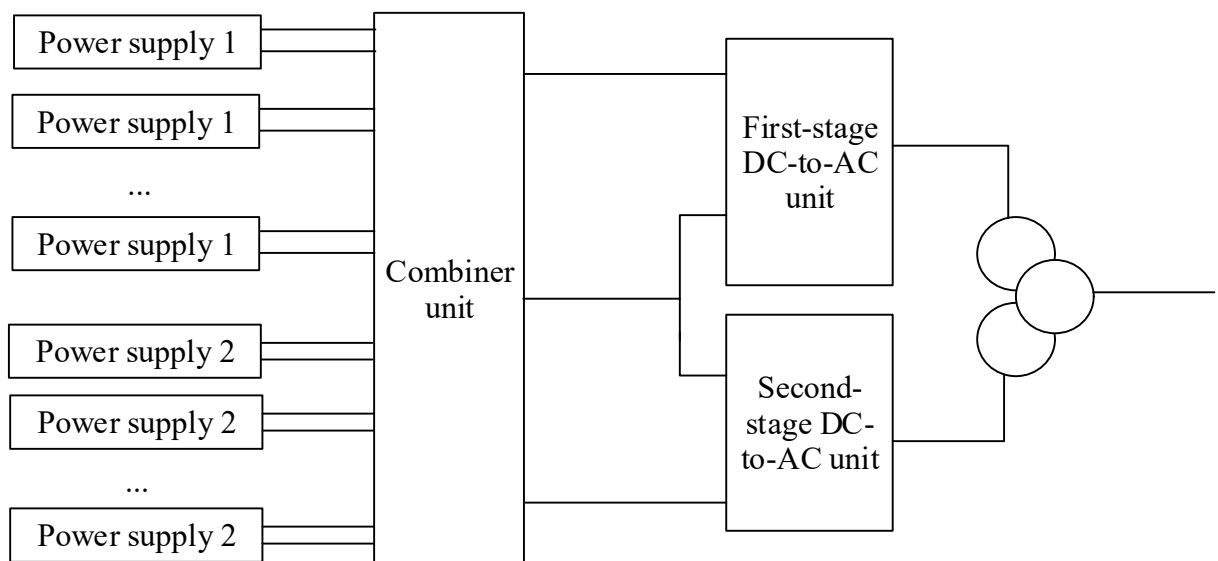


FIG. 14b

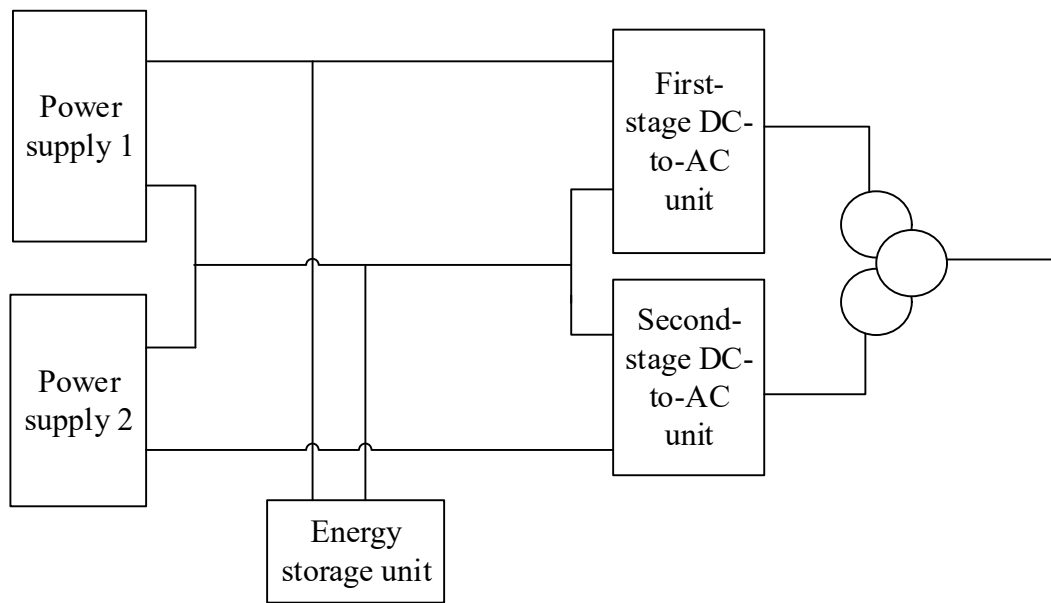


FIG. 15a

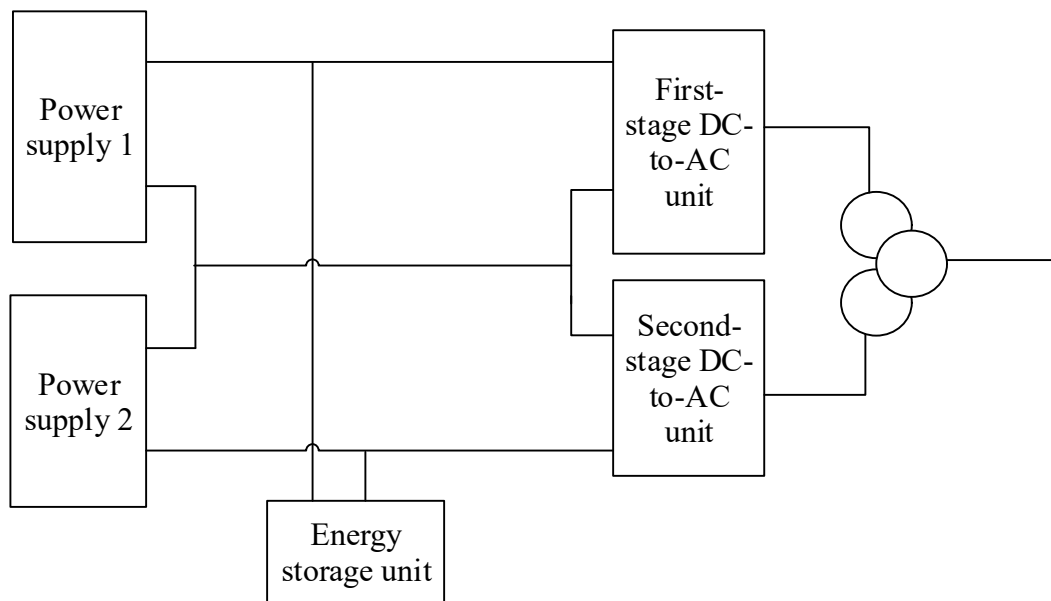


FIG. 15b

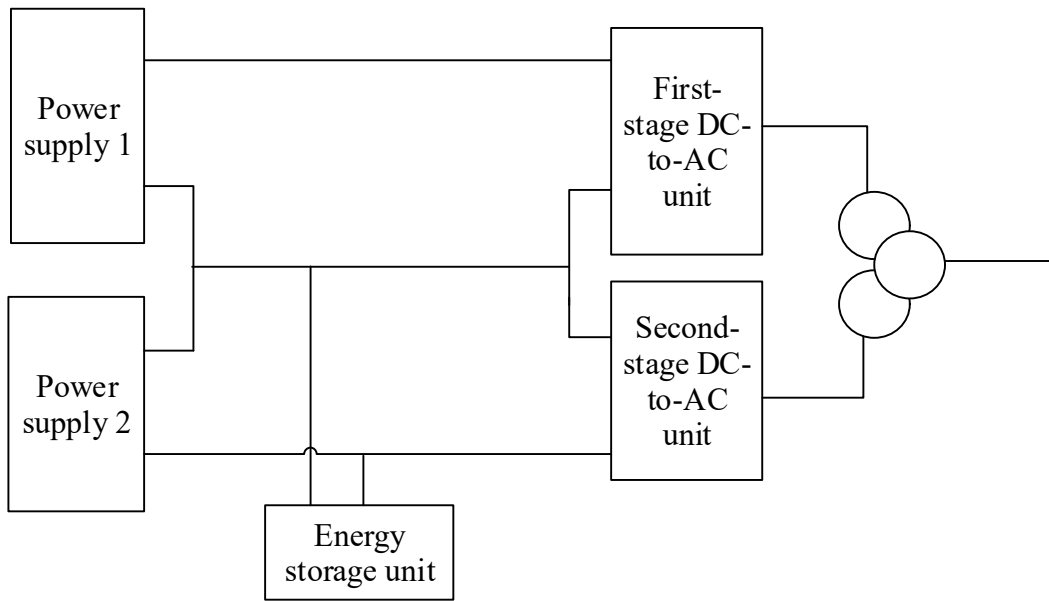


FIG. 15c

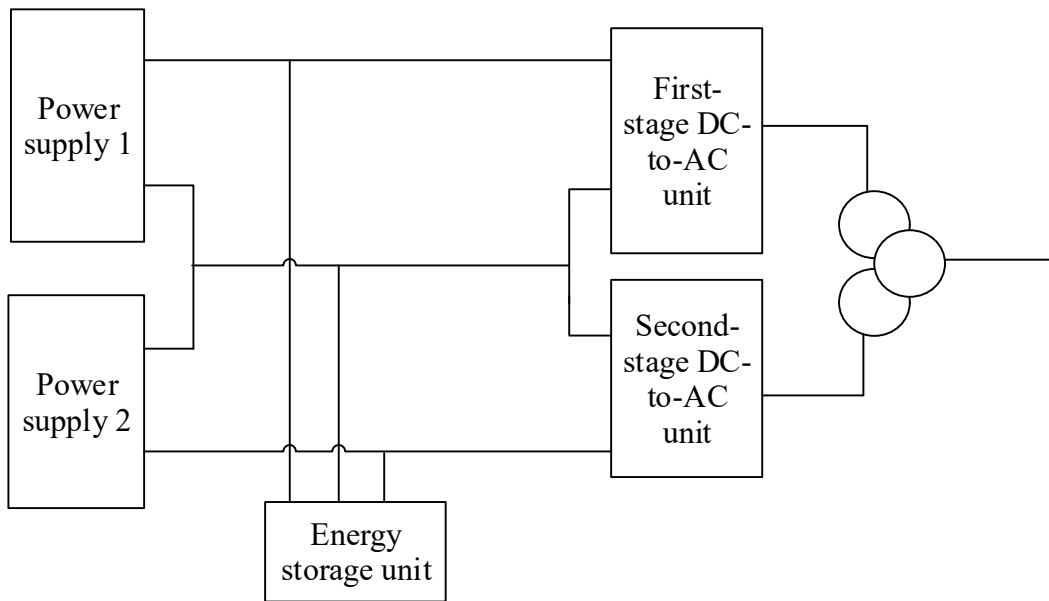


FIG. 15d

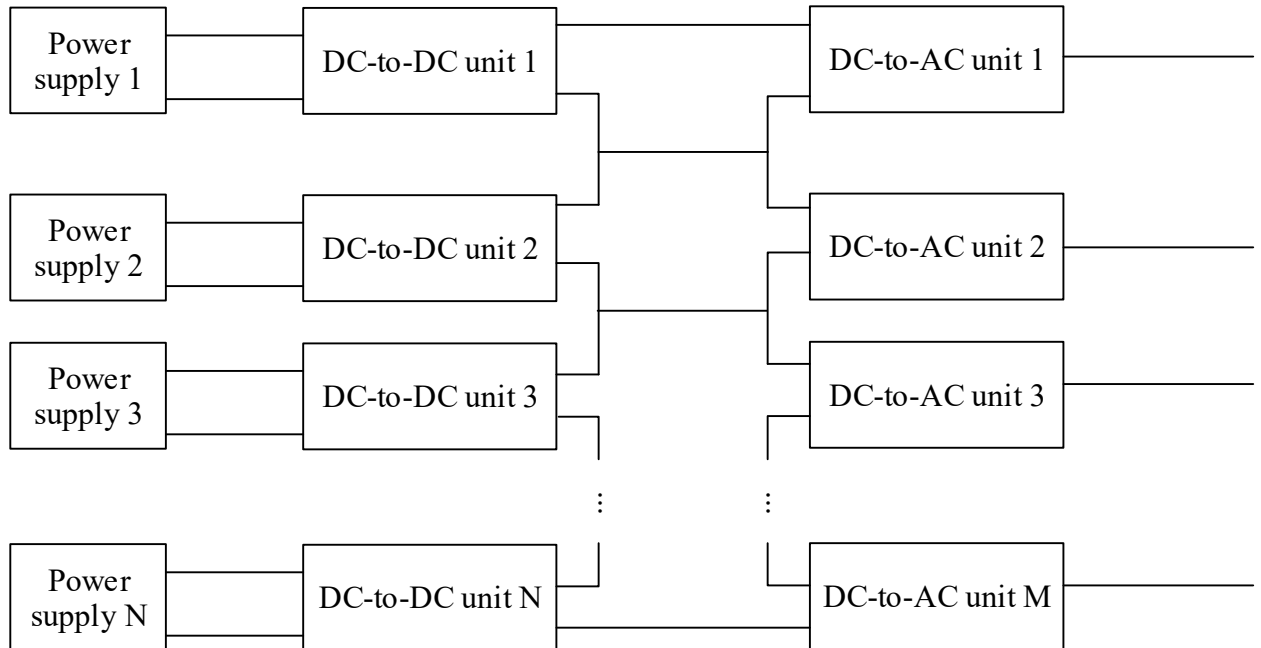


FIG. 16

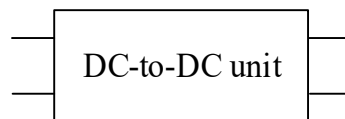


FIG. 17

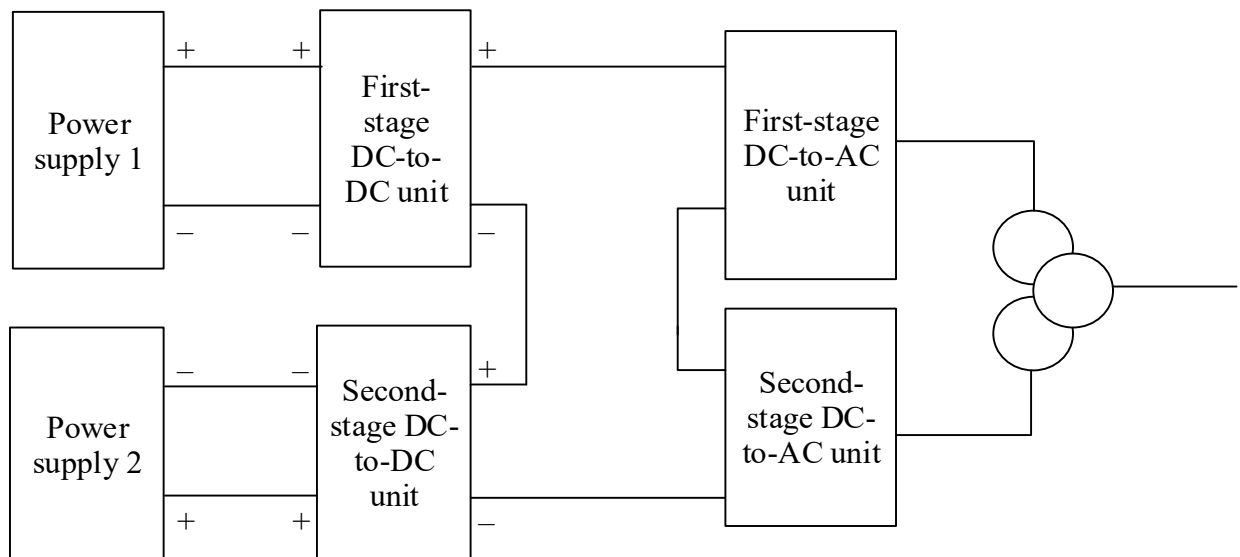


FIG. 18

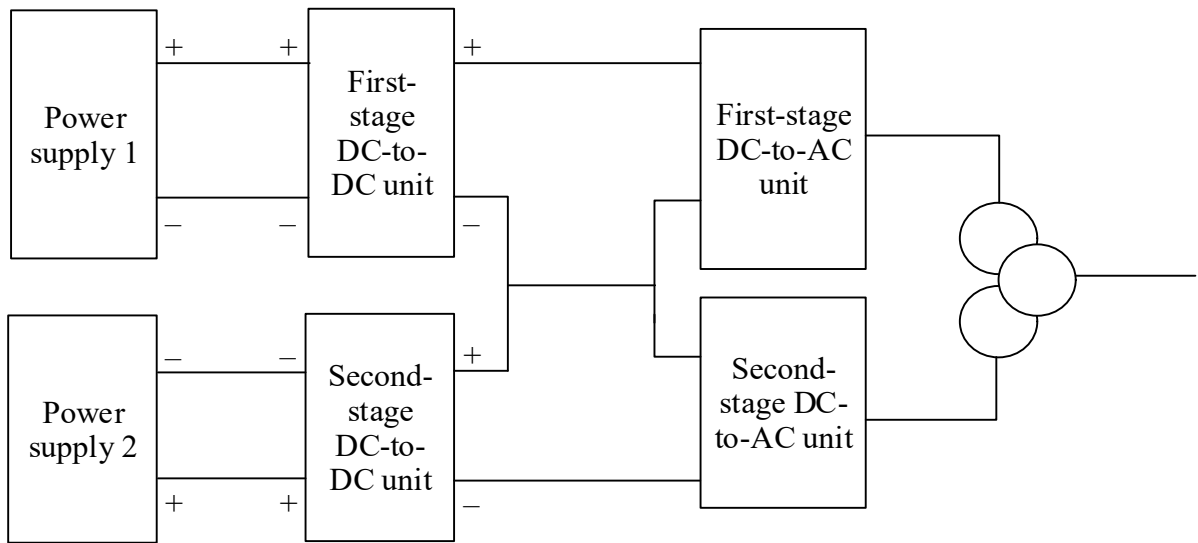


FIG. 19

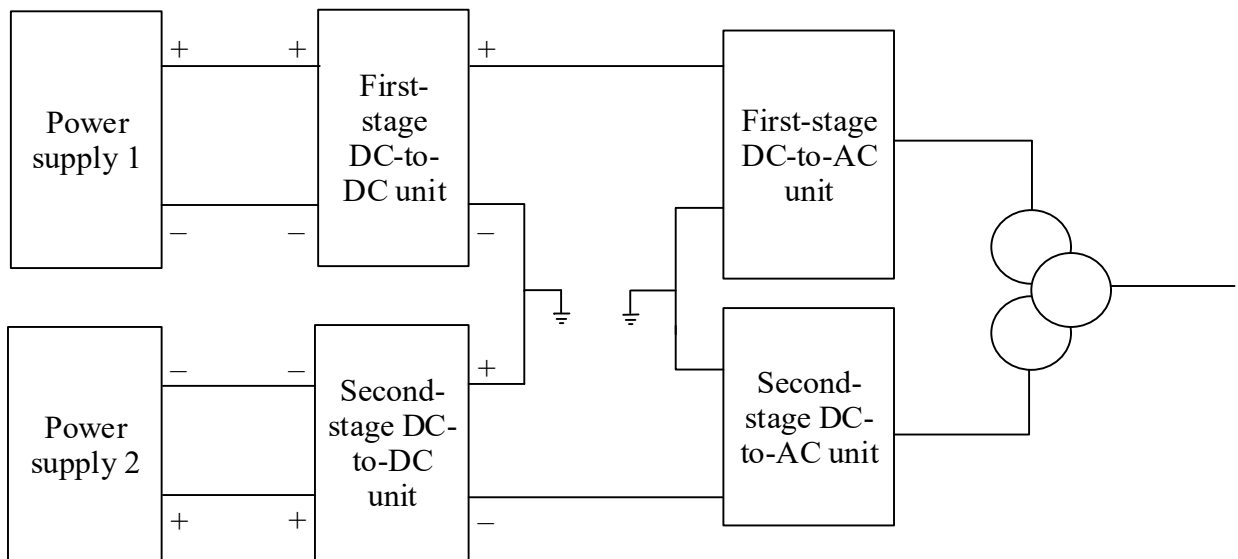


FIG. 20

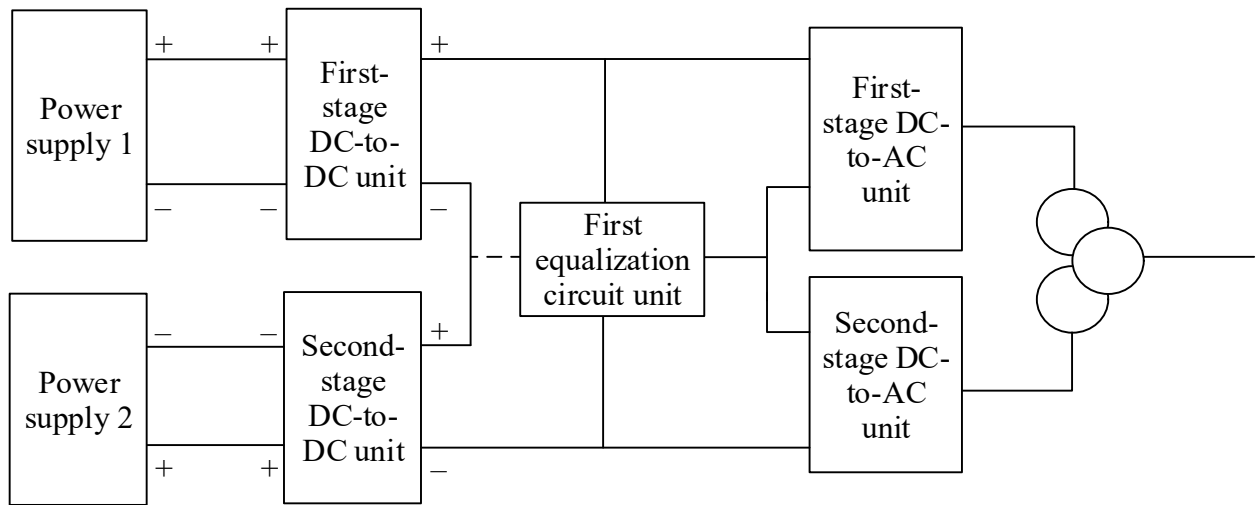


FIG. 21

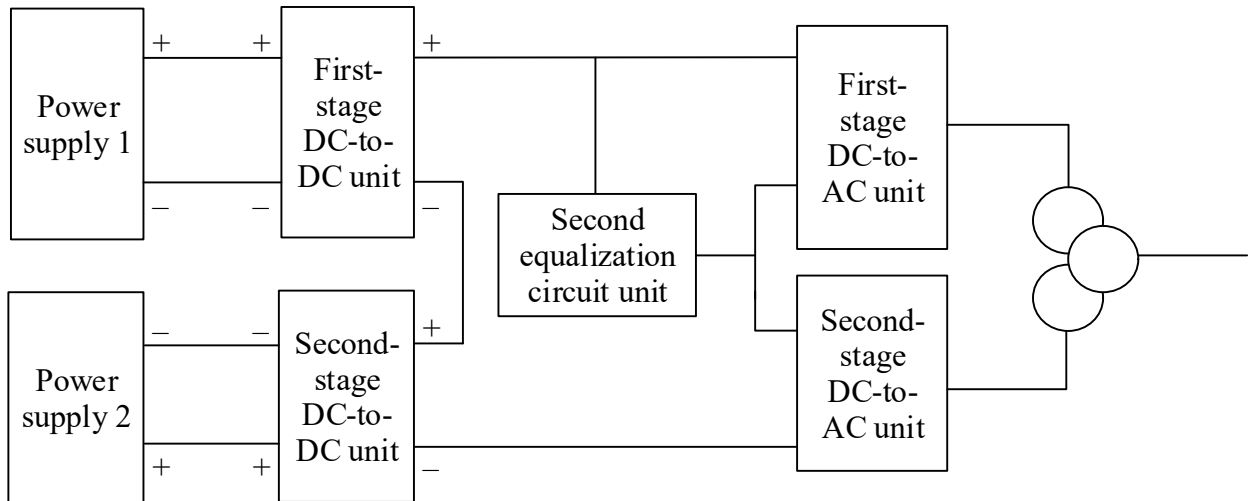


FIG. 22a

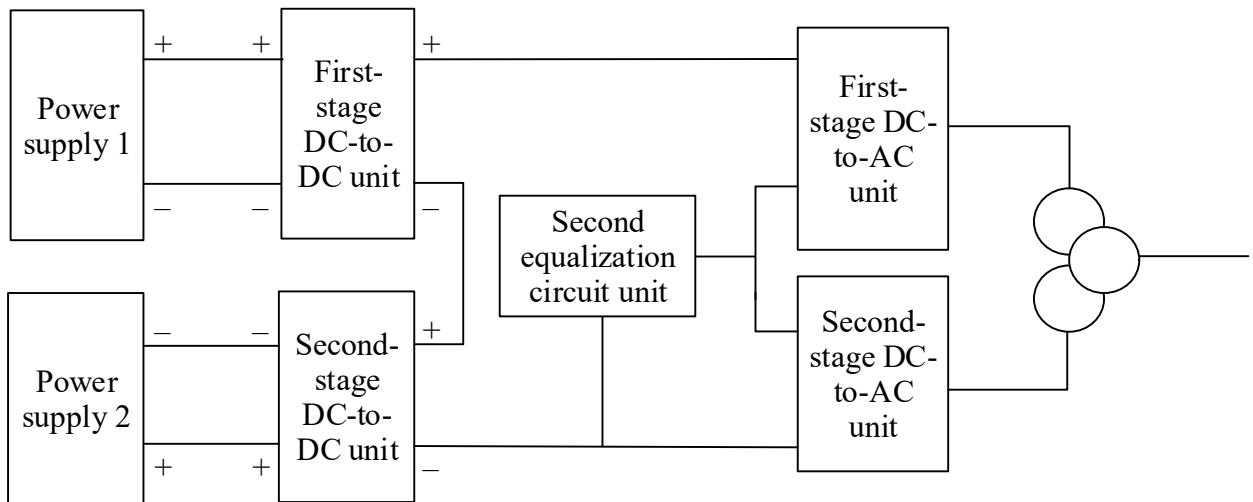


FIG. 22b

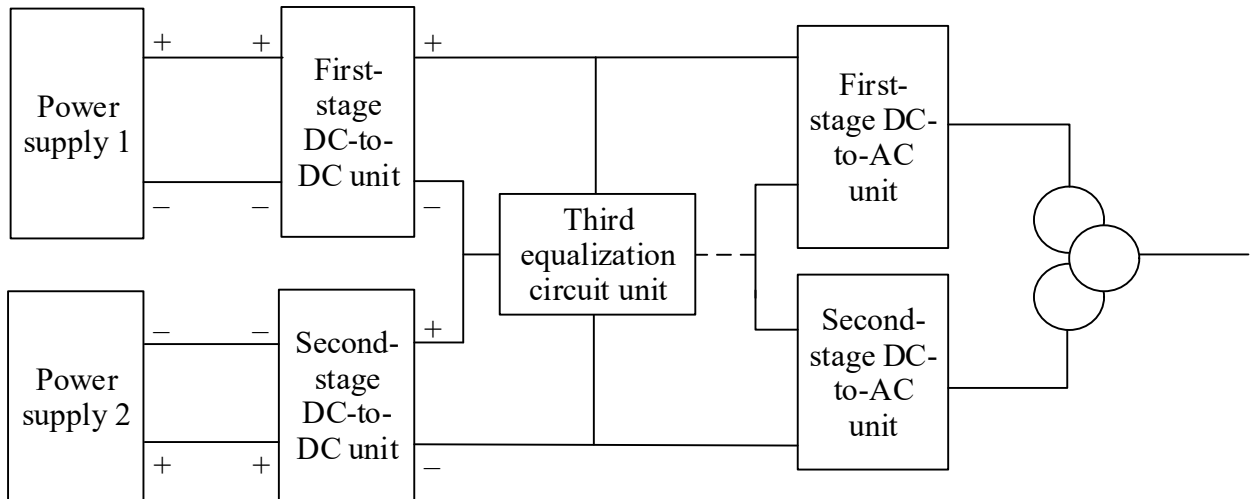


FIG. 23

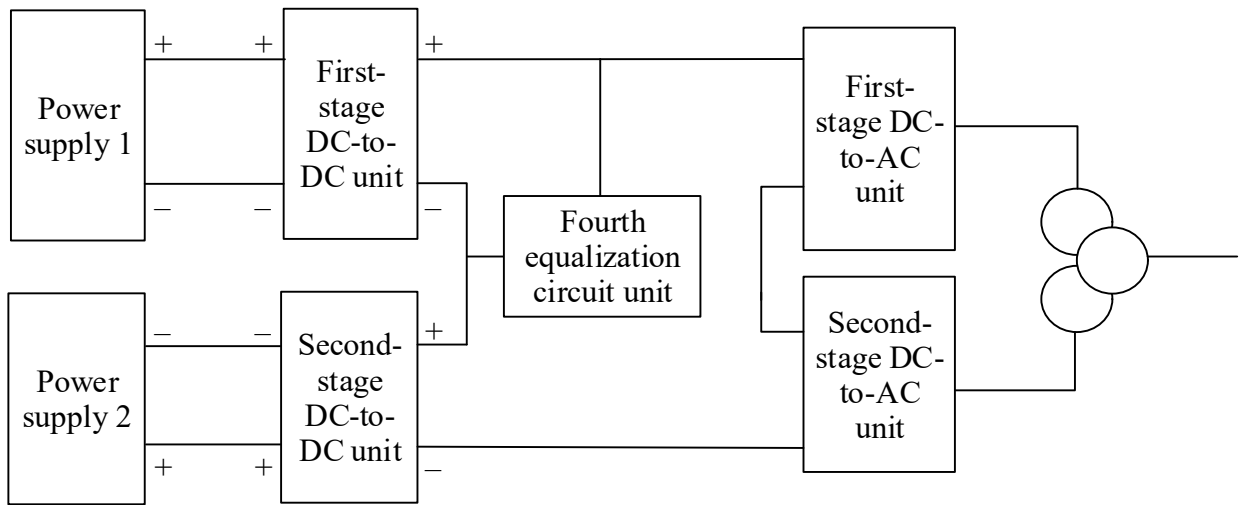


FIG. 24a

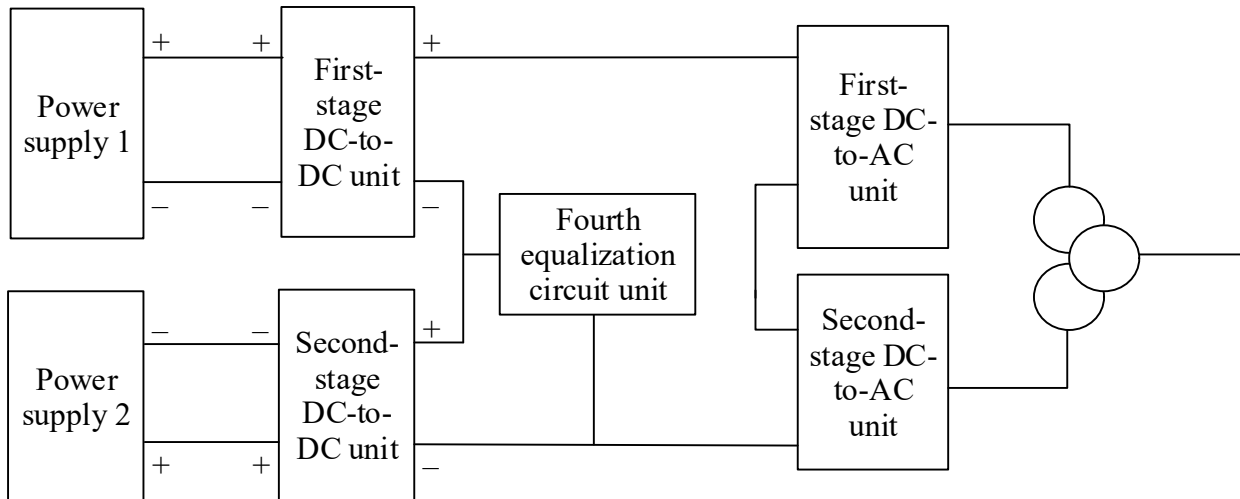


FIG. 24b

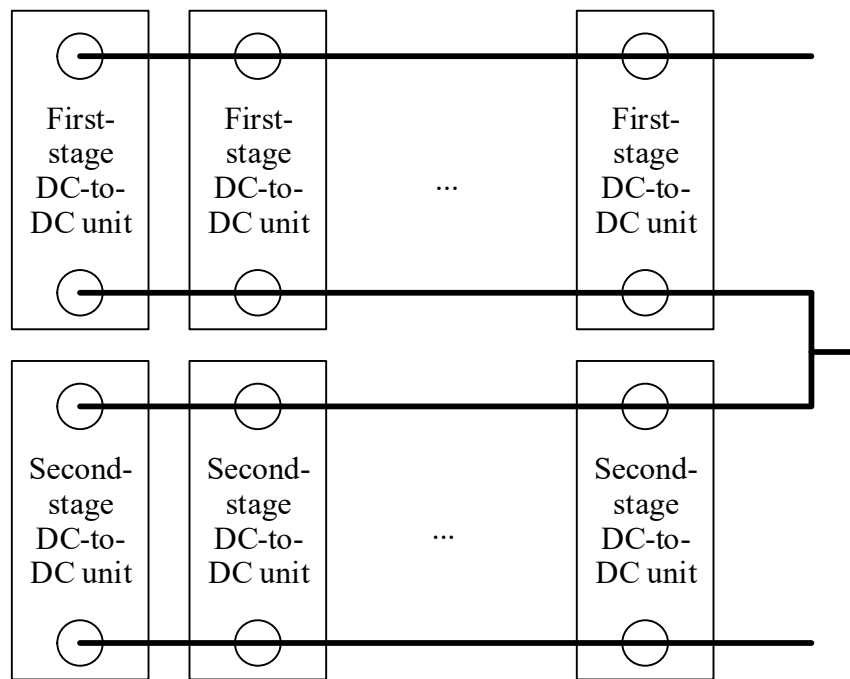


FIG. 25

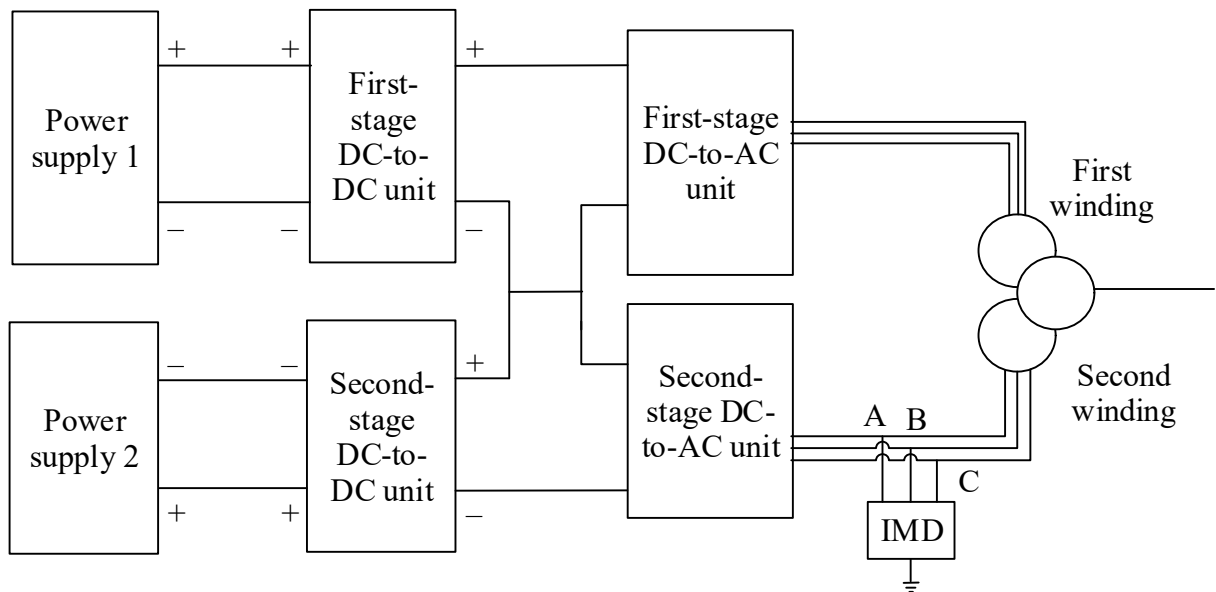


FIG. 26

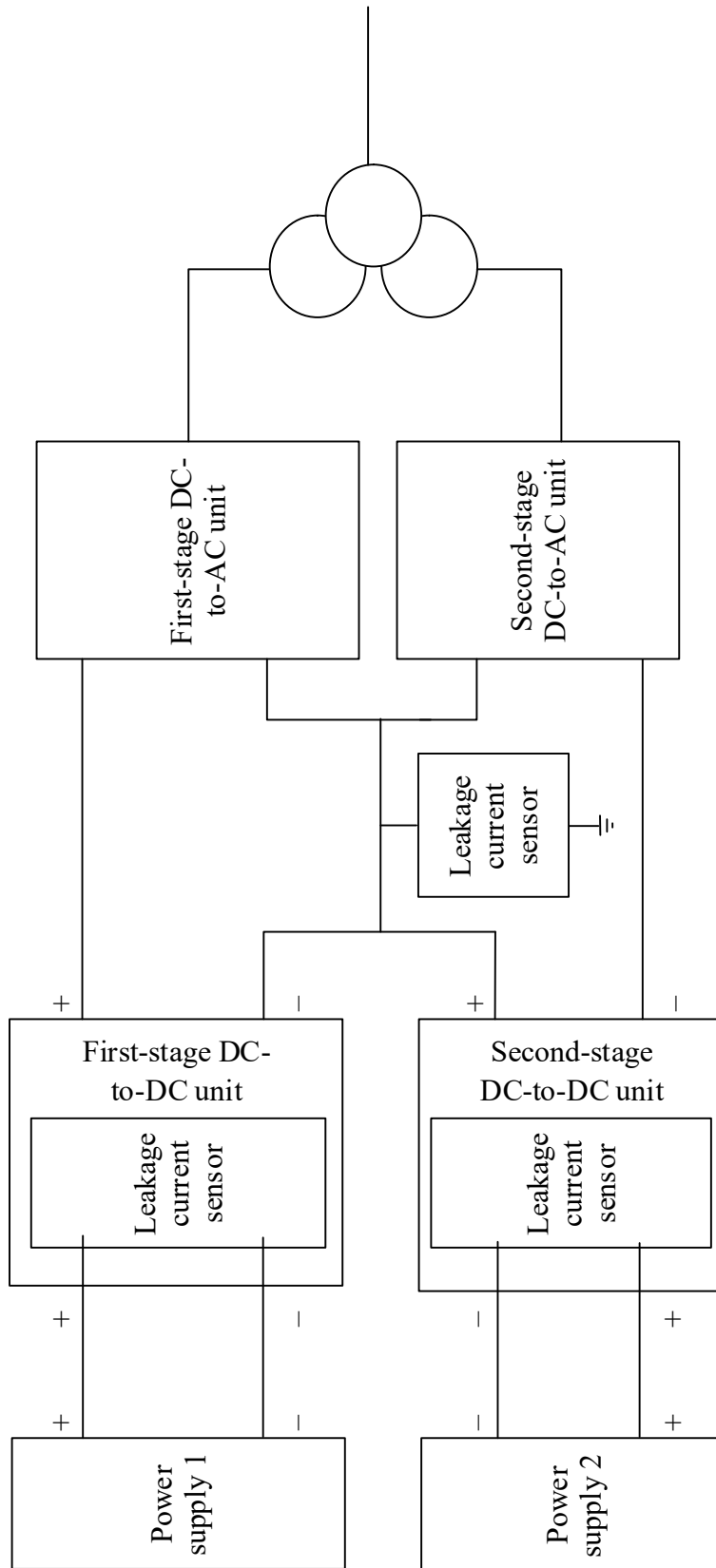


FIG. 27

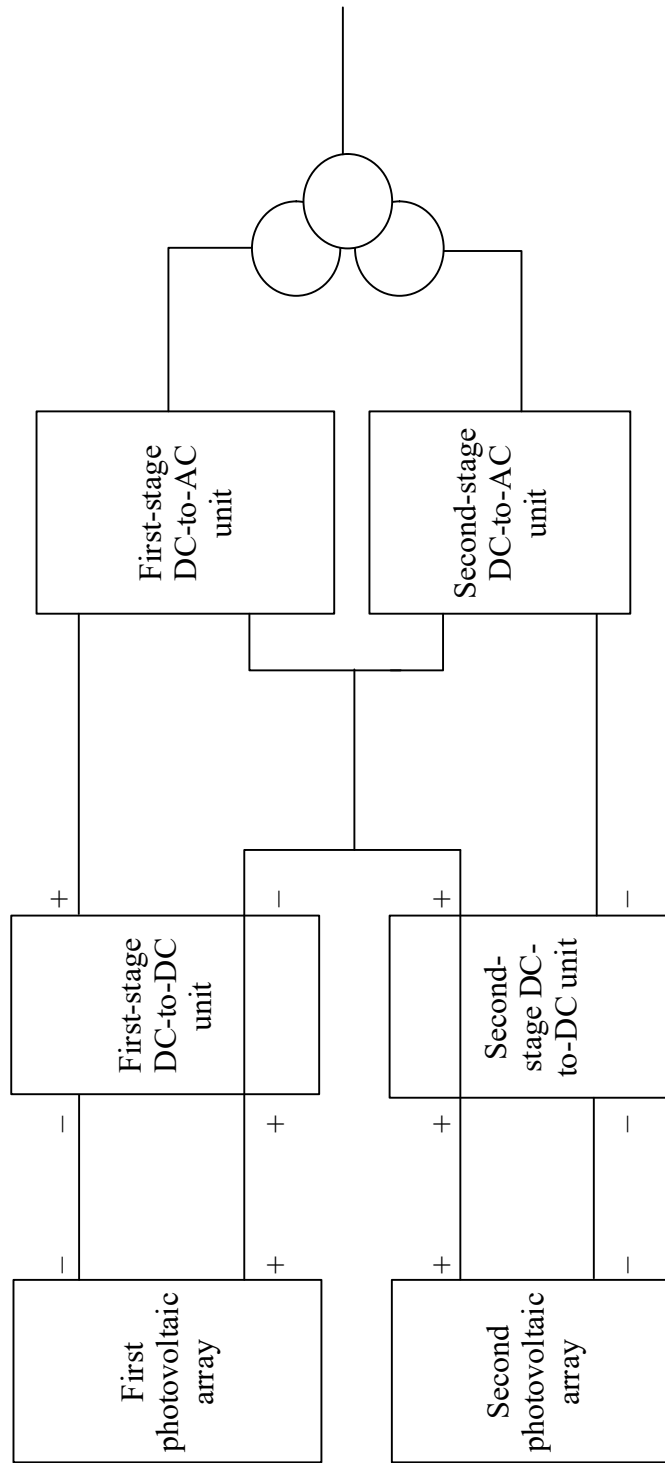


FIG. 28

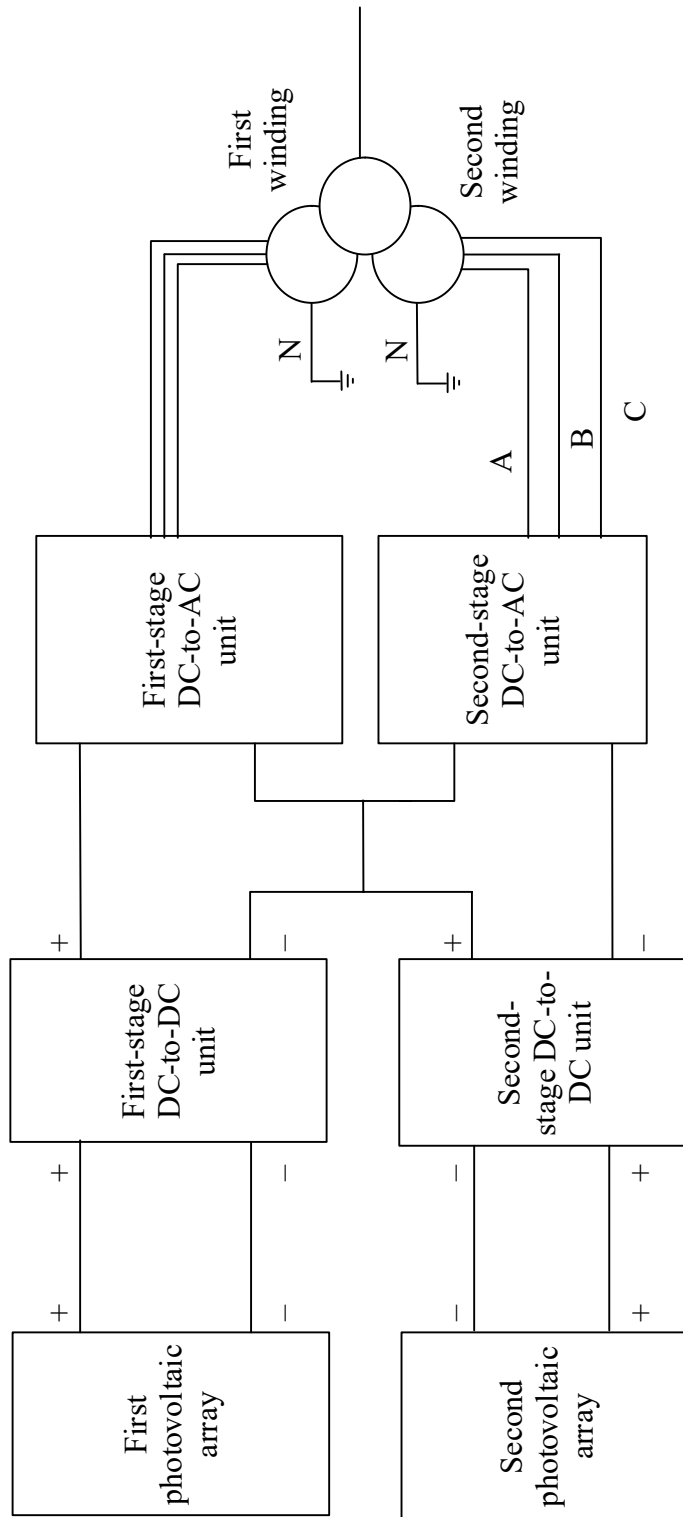


FIG. 29

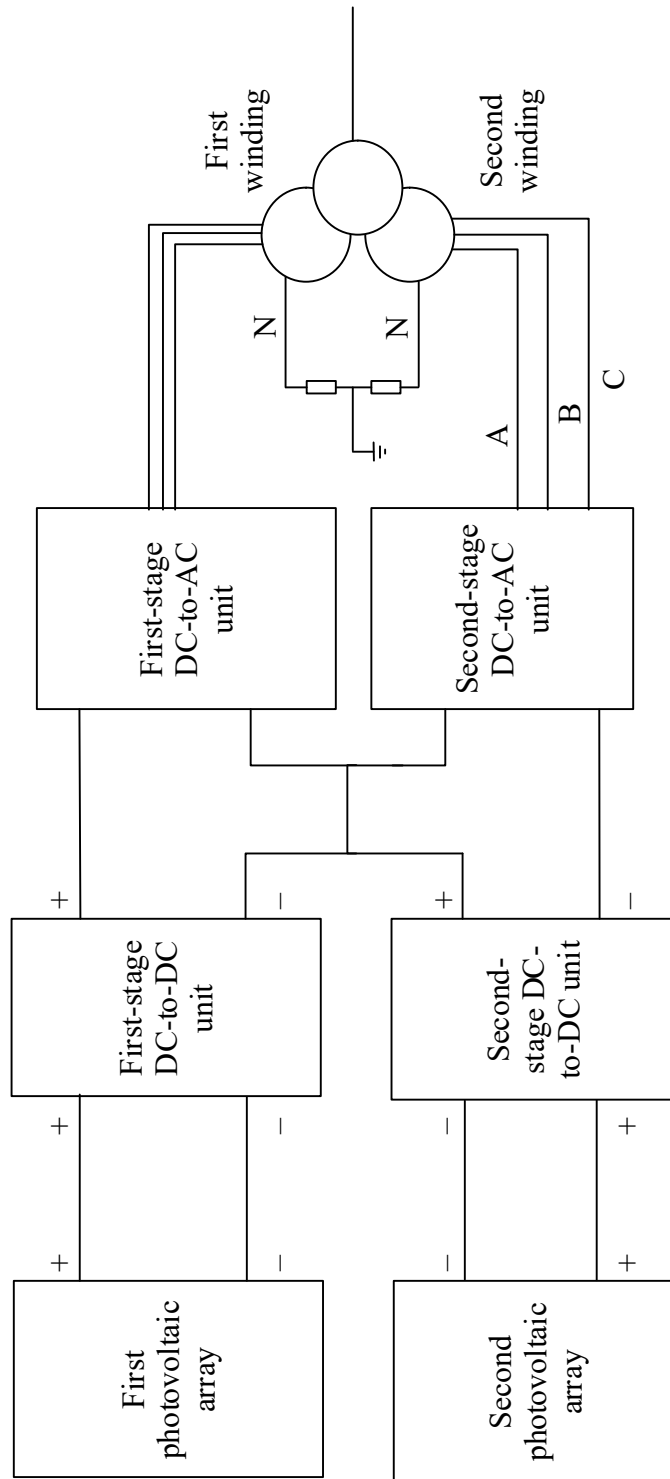


FIG. 30

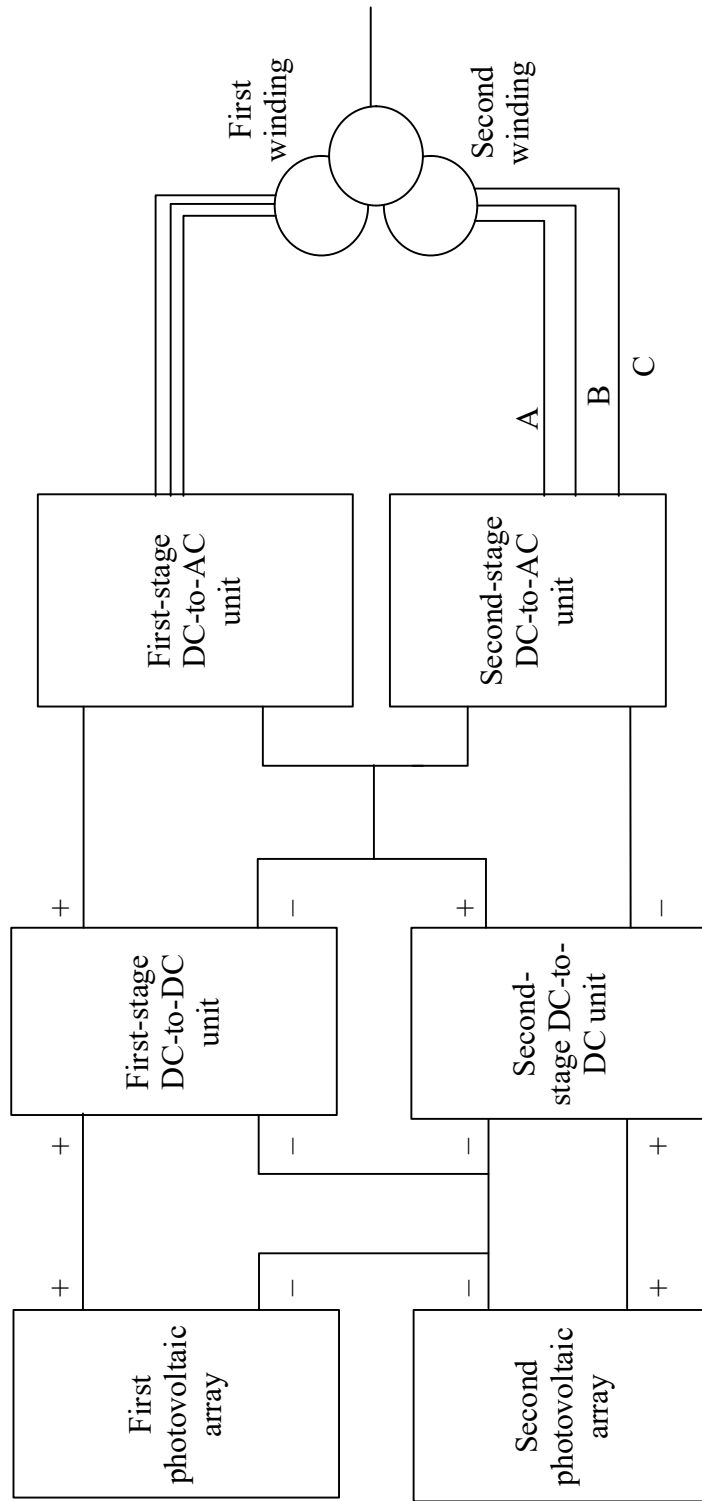


FIG. 31

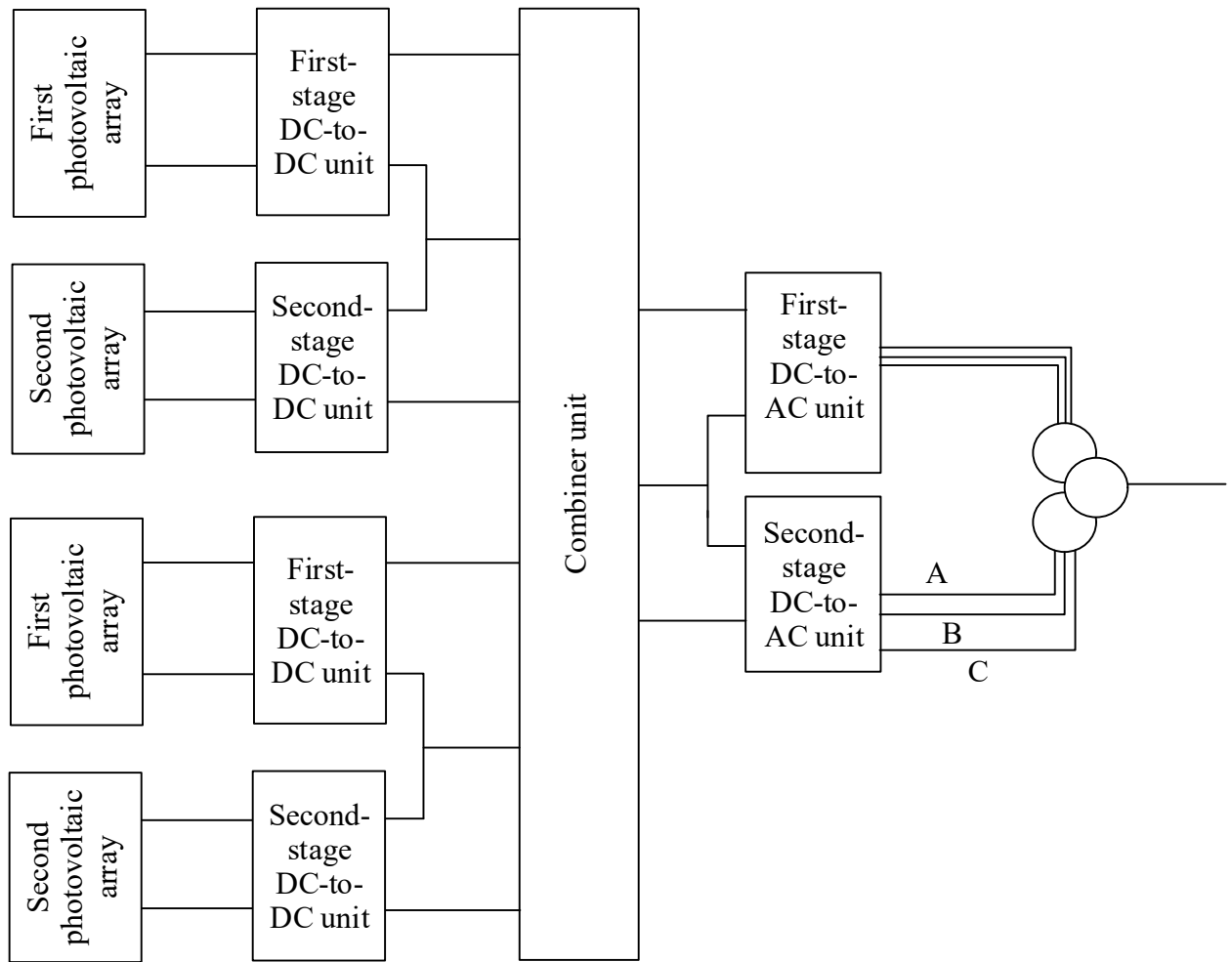


FIG. 32a

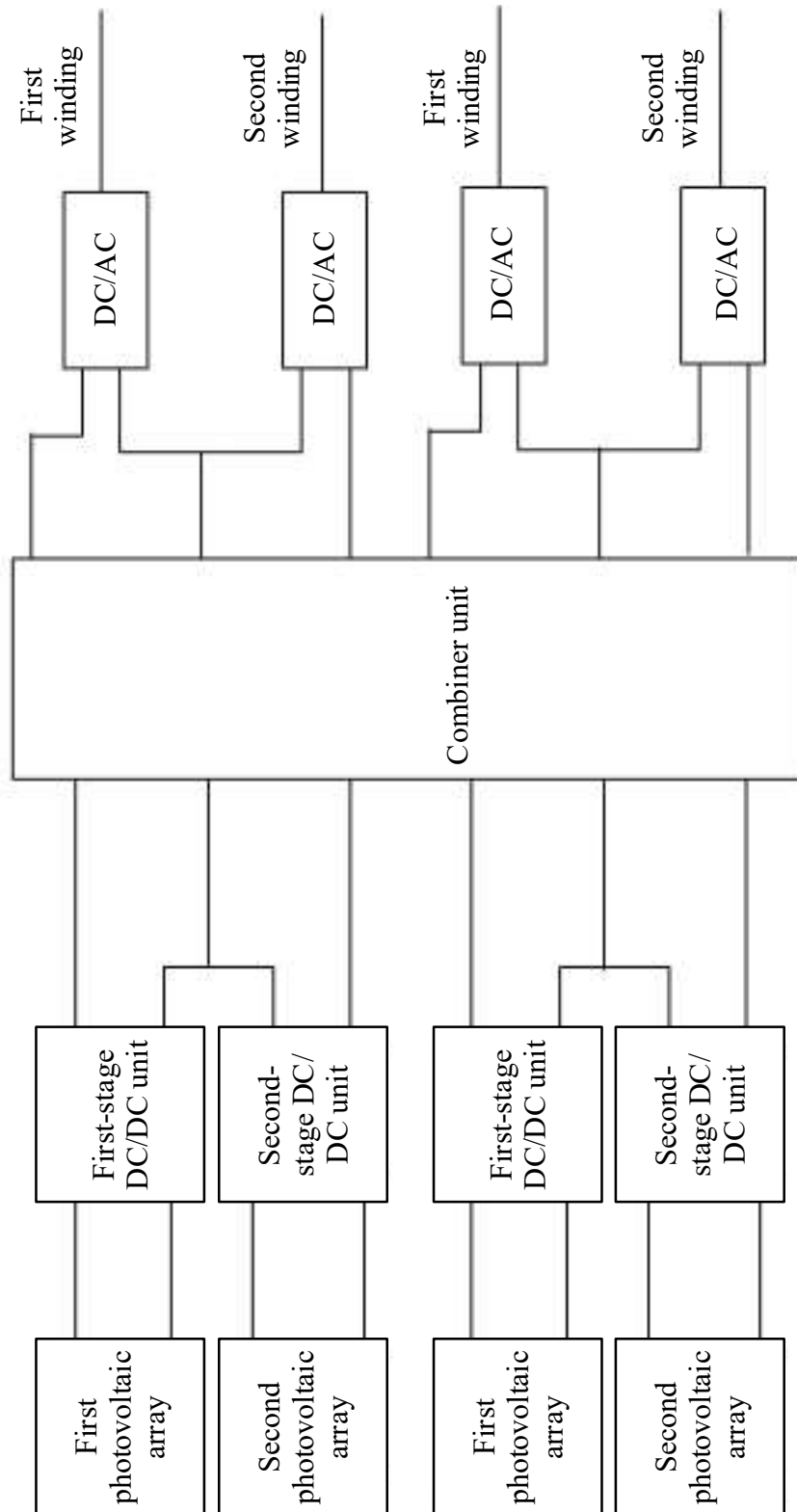


FIG. 32b

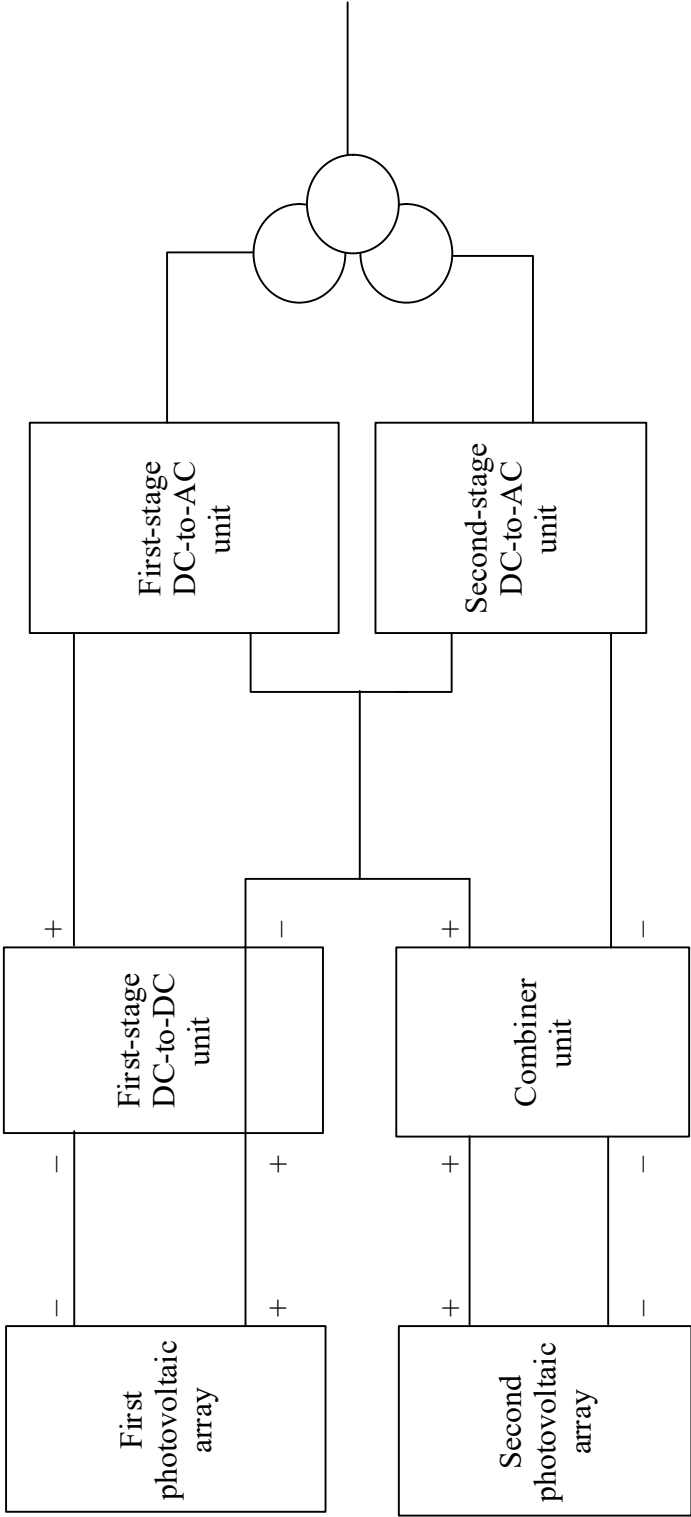


FIG. 33

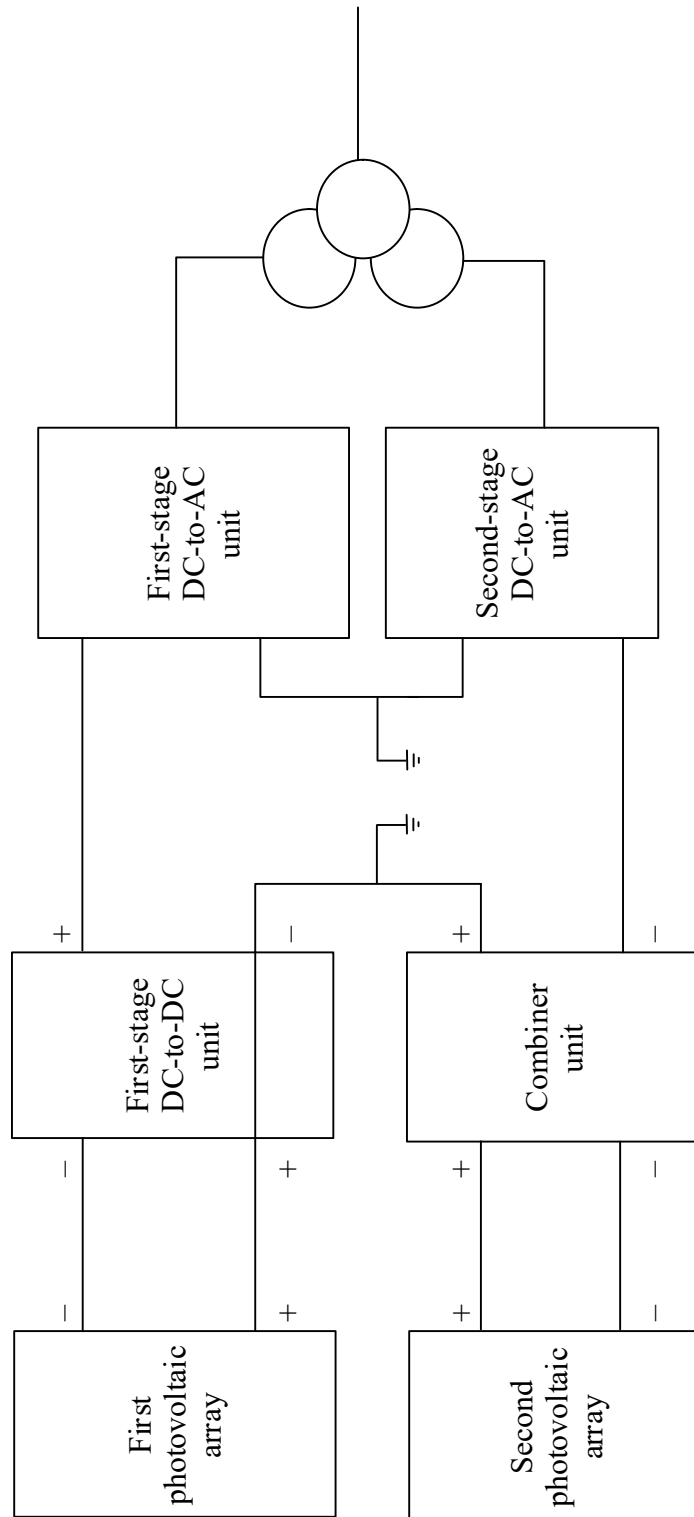


FIG. 34

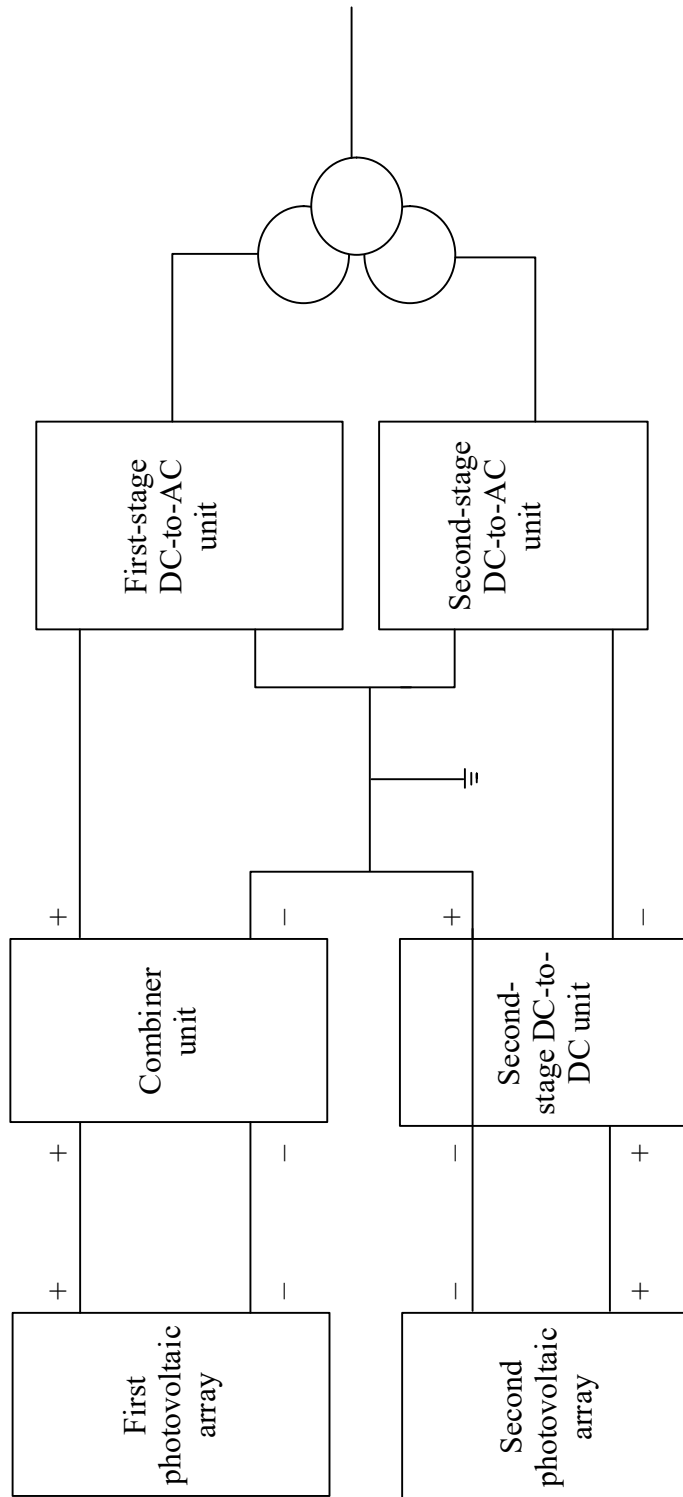


FIG 35

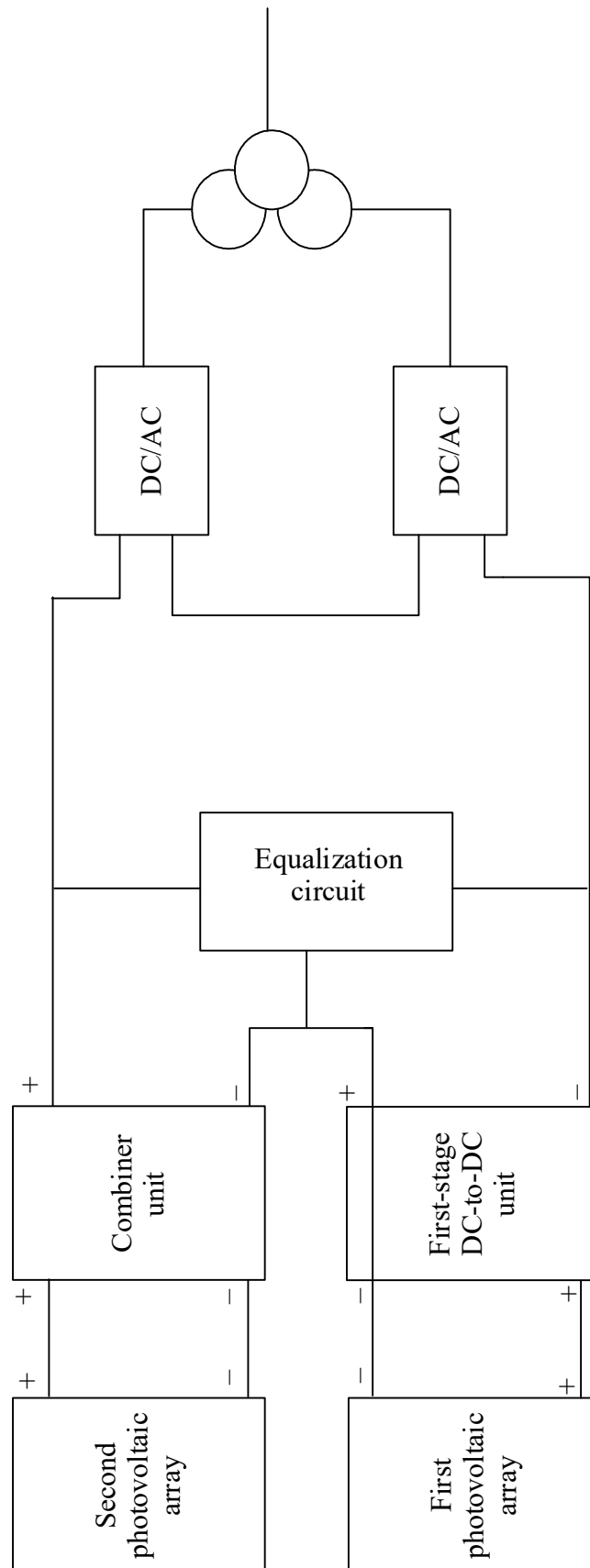


FIG 36

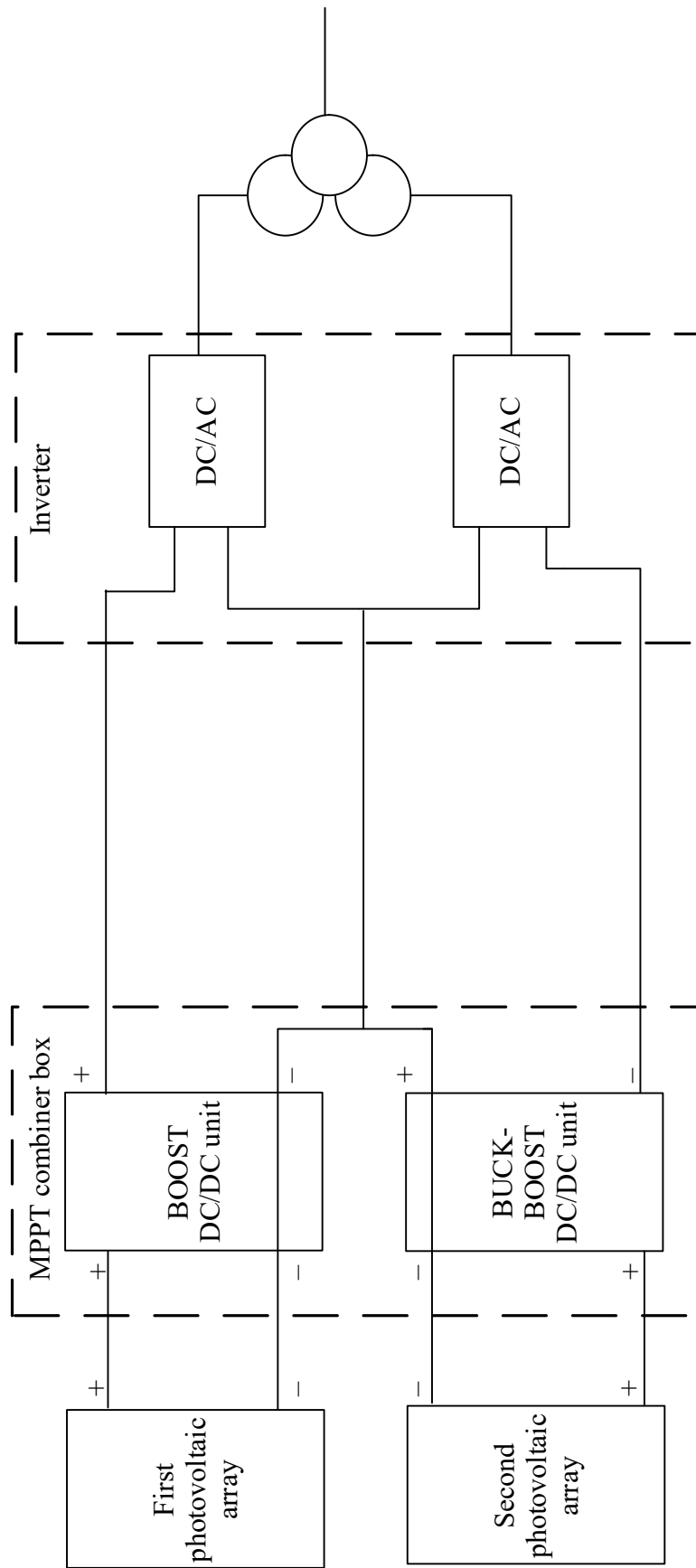


FIG. 37

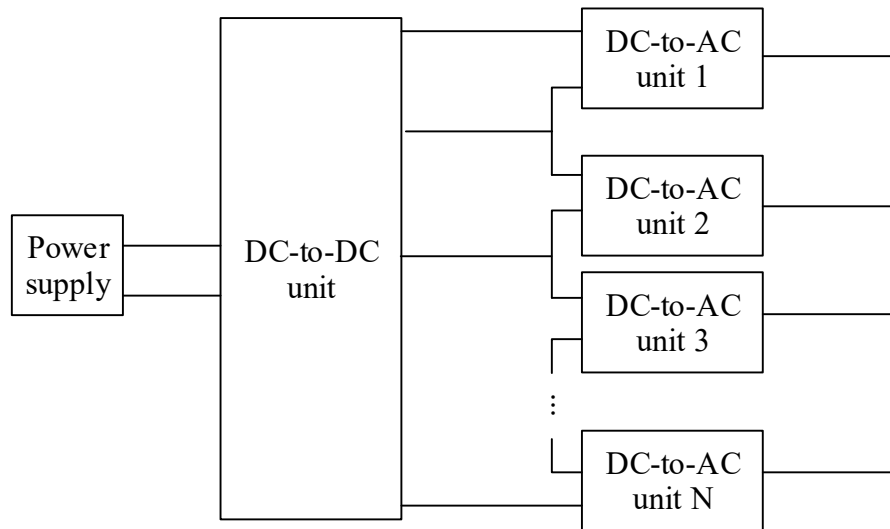


FIG. 38

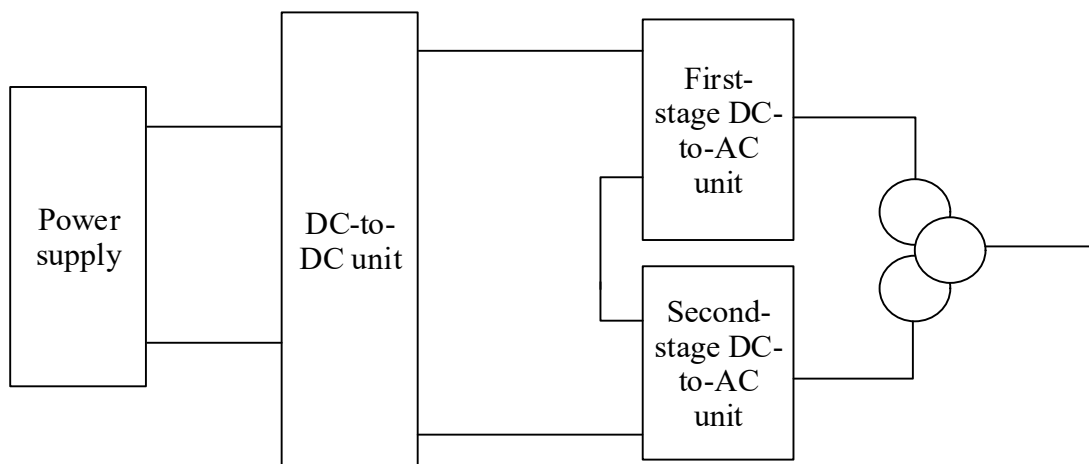


FIG. 39

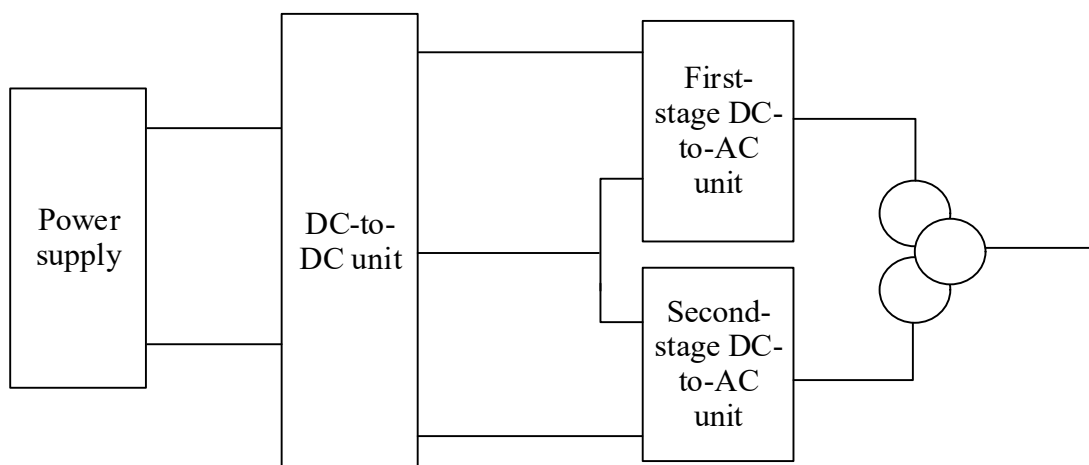


FIG. 40

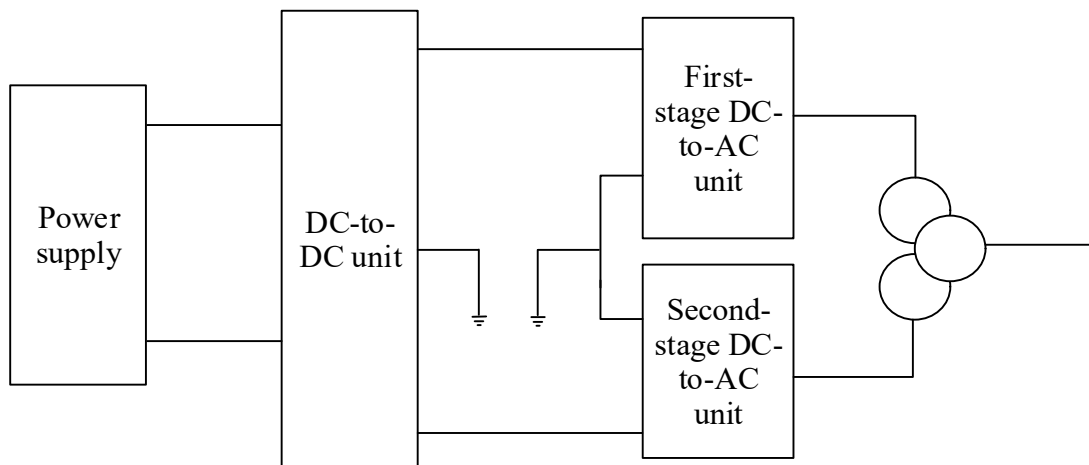


FIG. 41

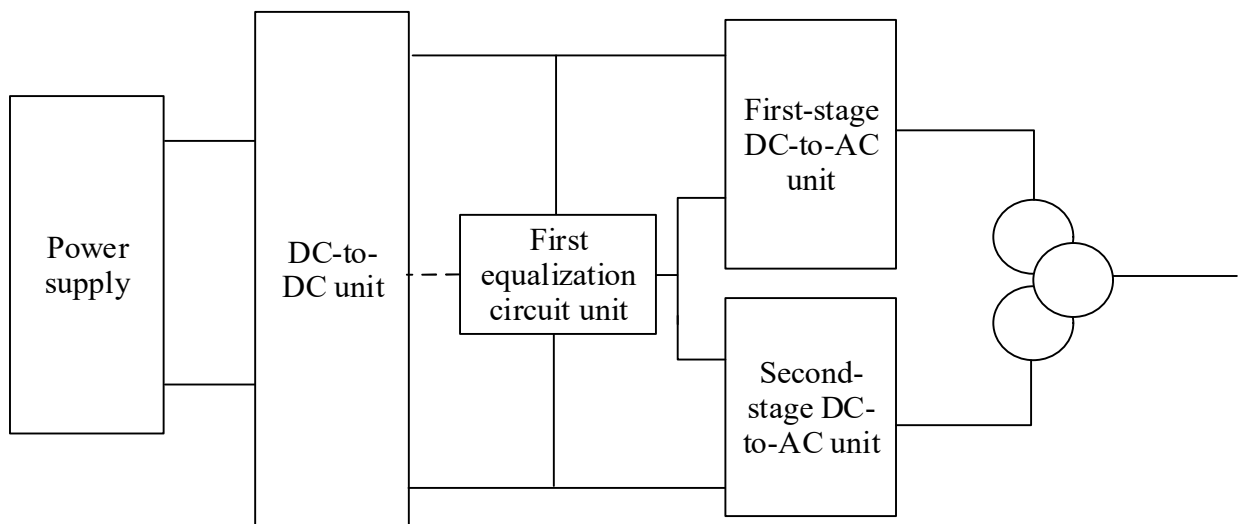


FIG. 42

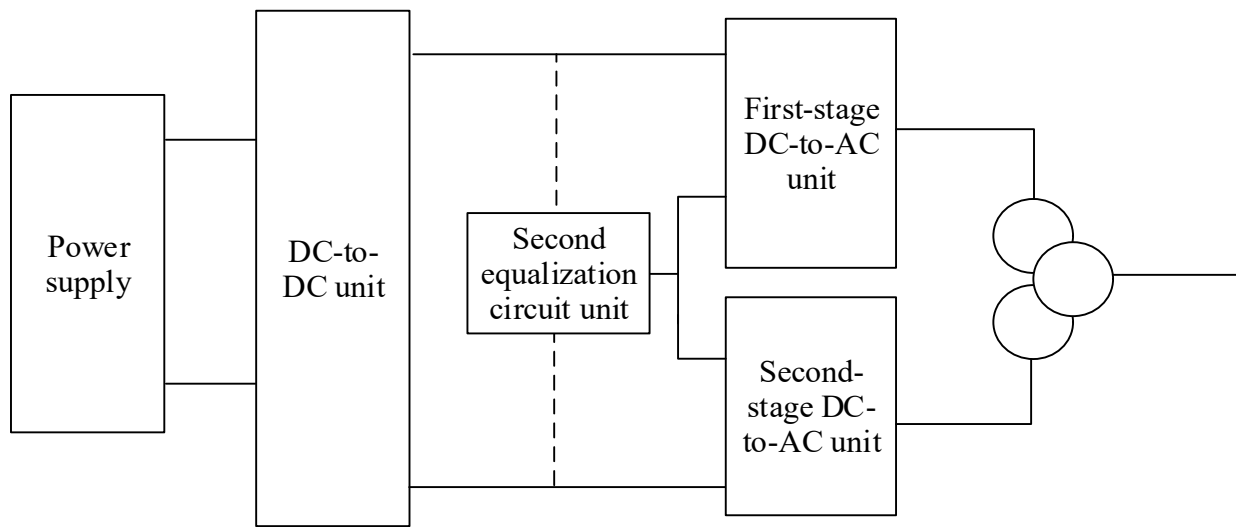


FIG. 43

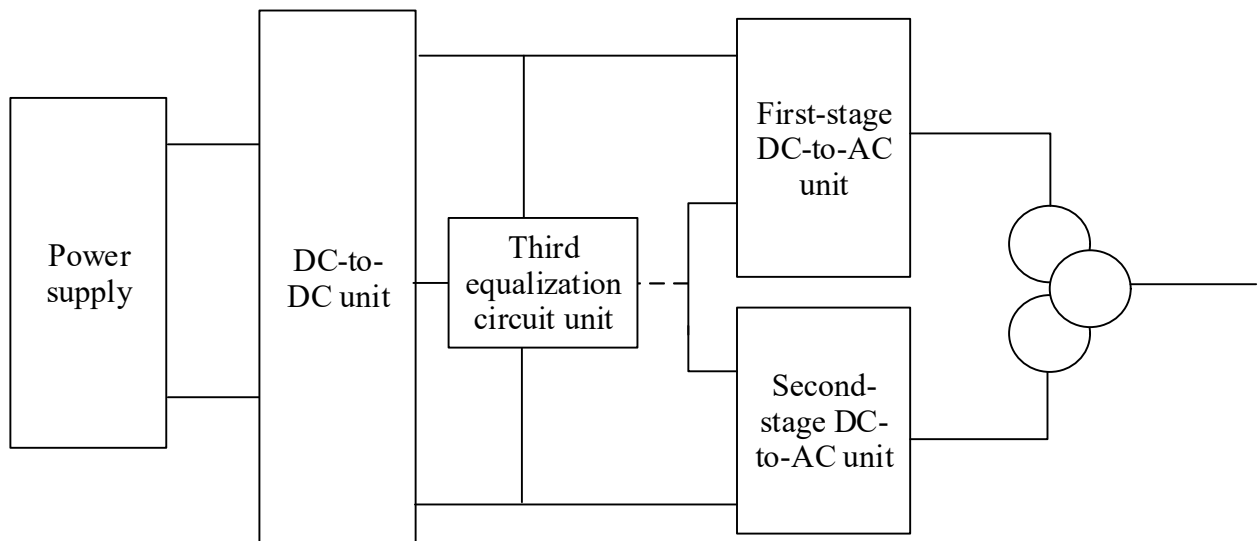


FIG. 44

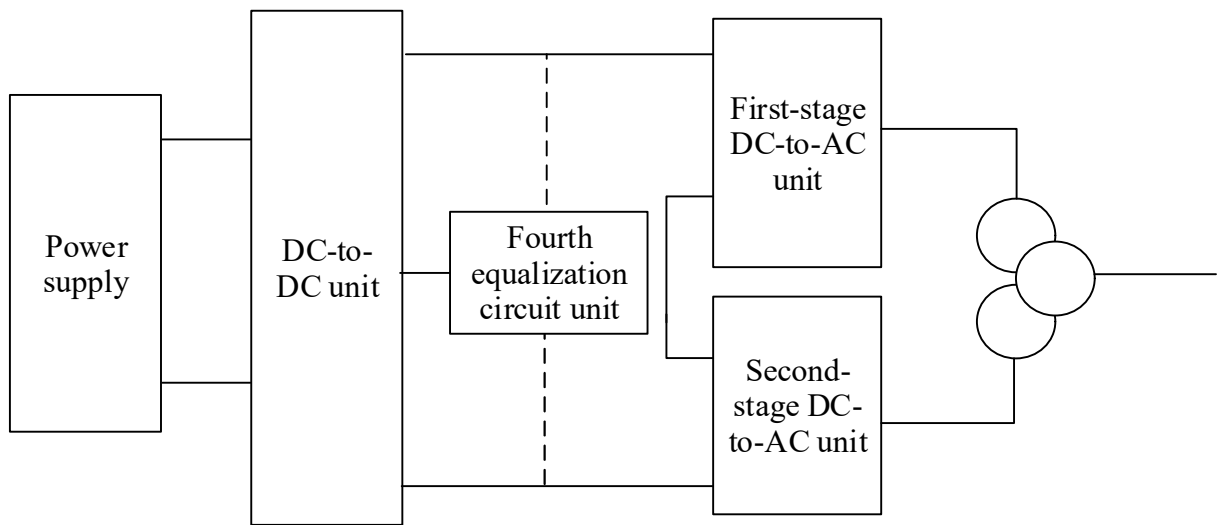


FIG. 45

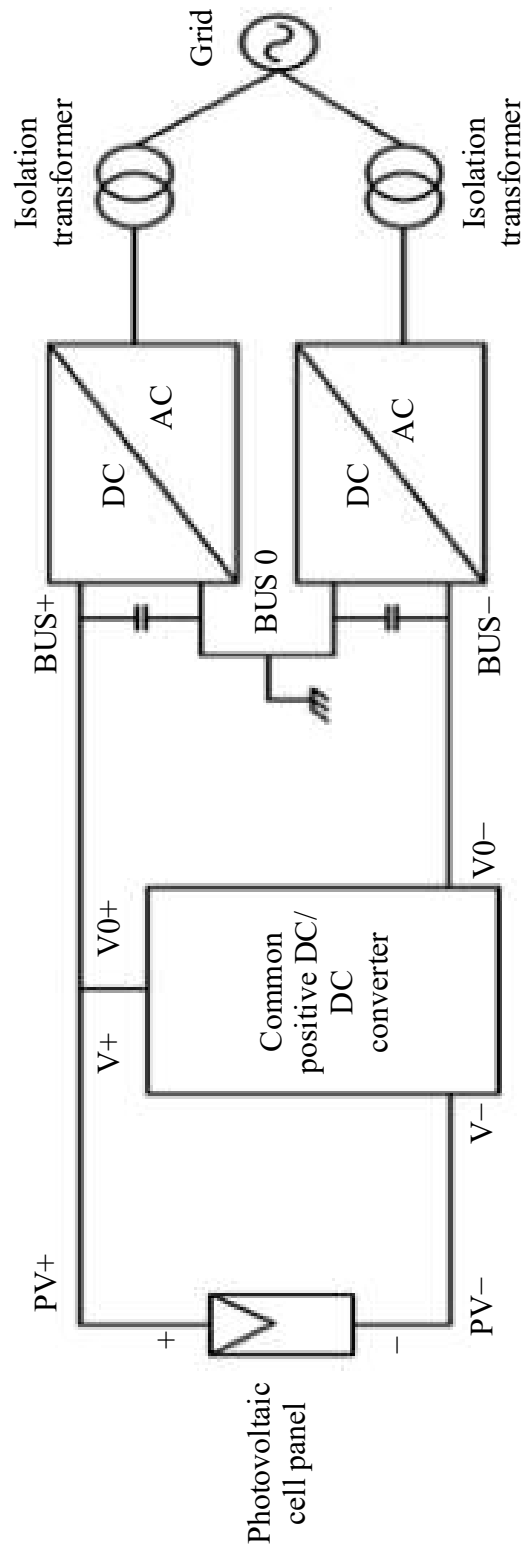


FIG. 46

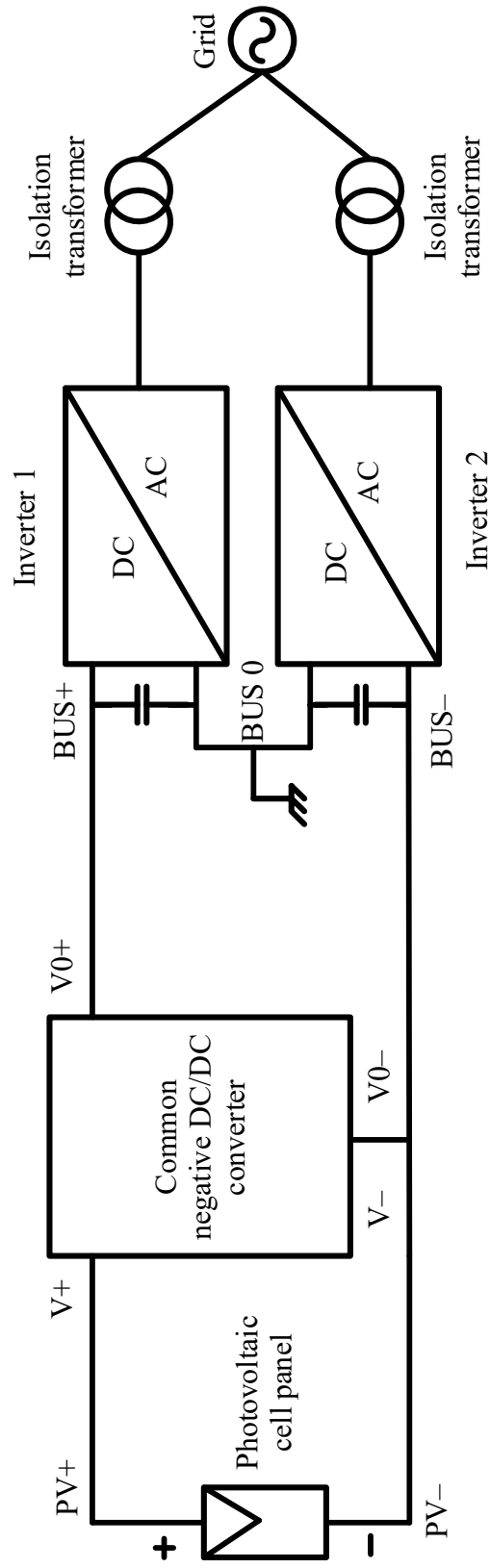


FIG. 47

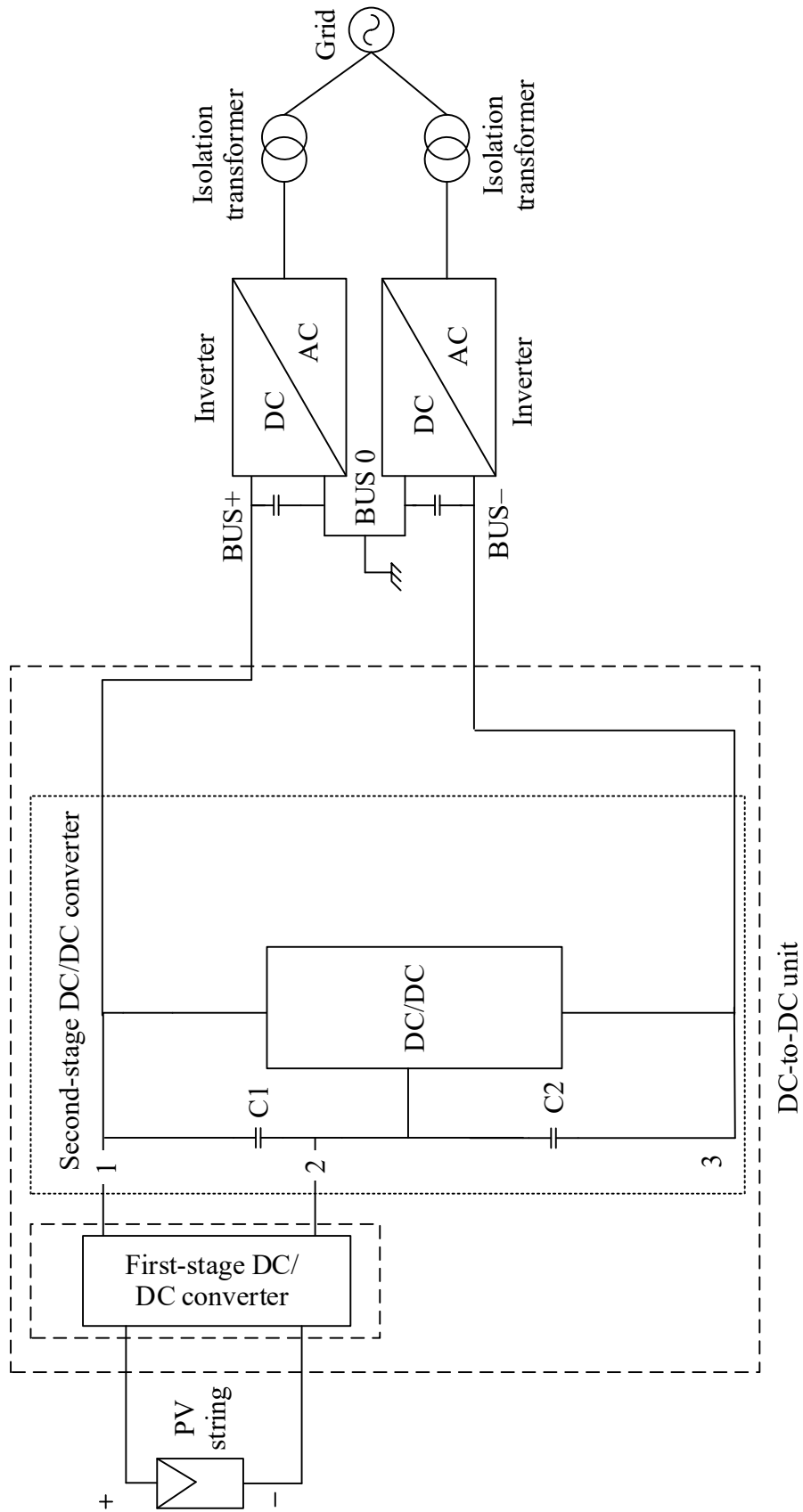


FIG. 48a

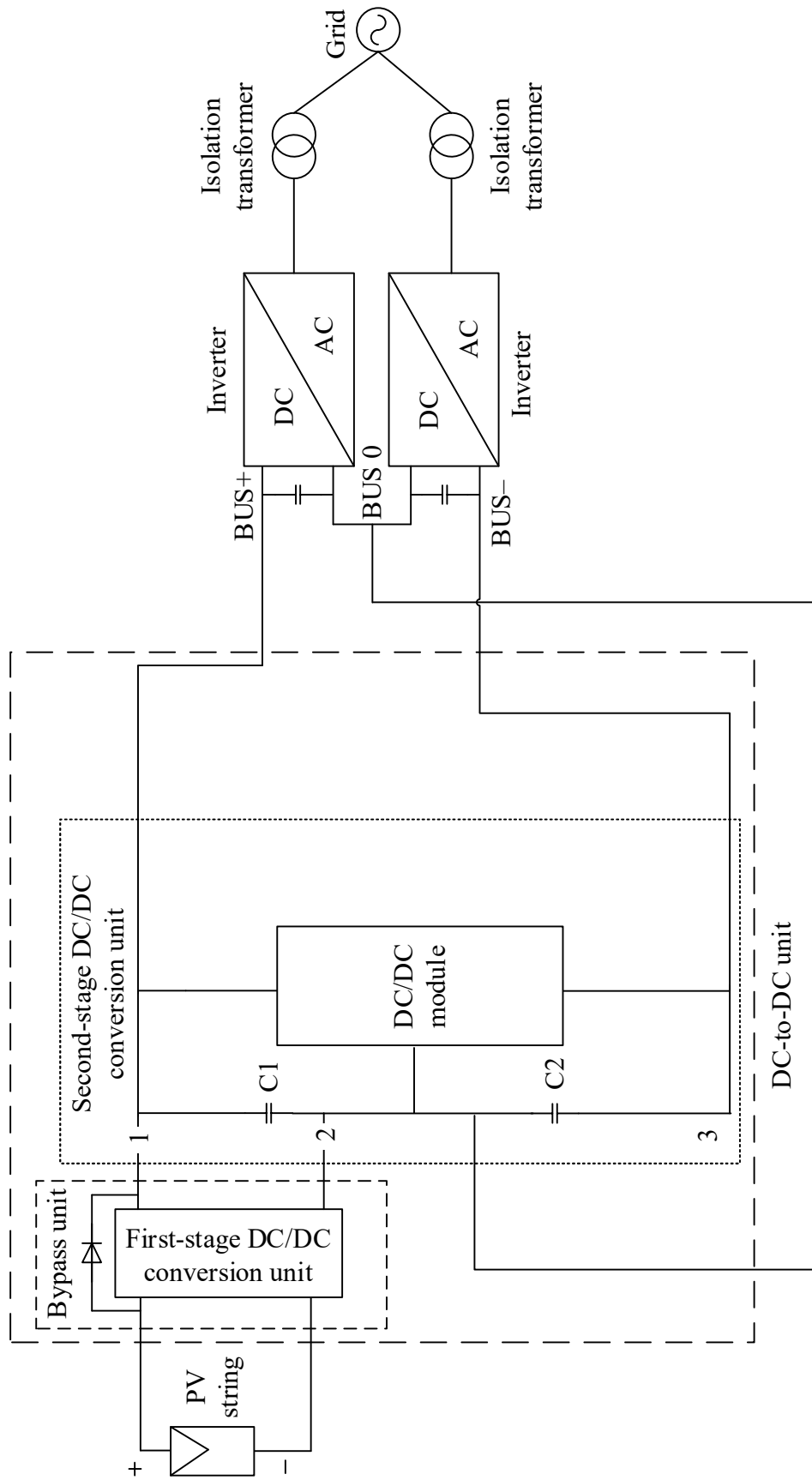


FIG. 48b

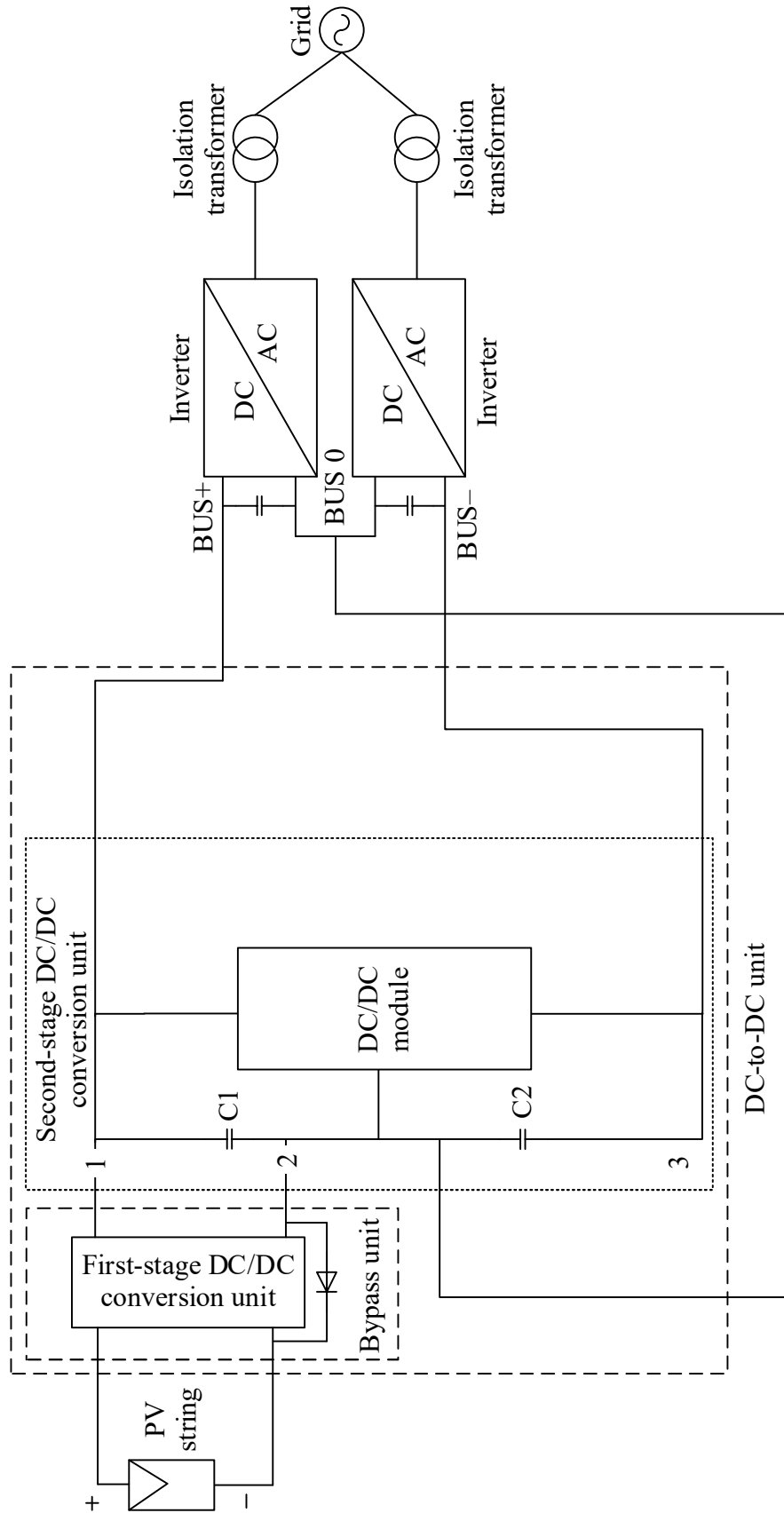


FIG. 48c

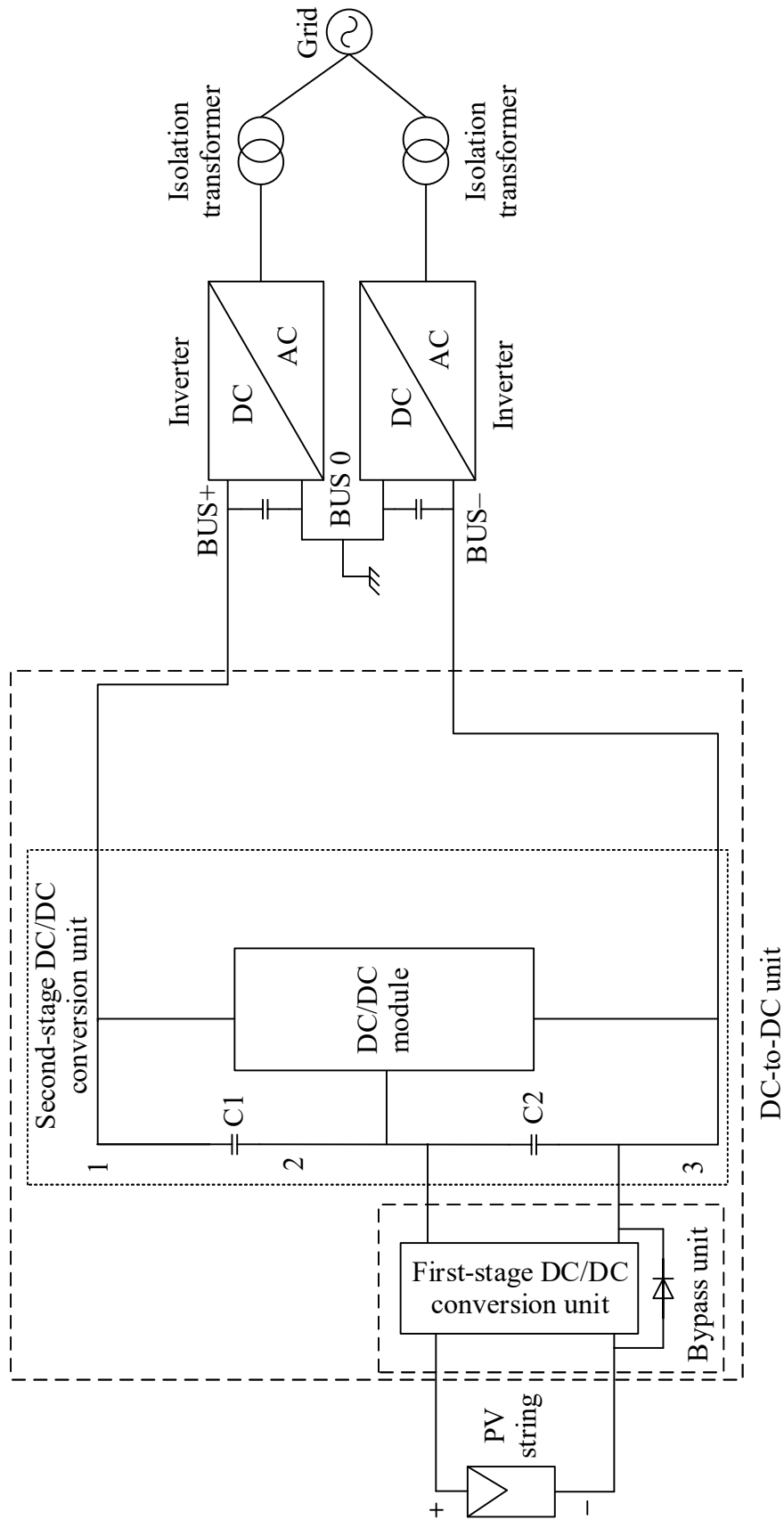


FIG. 49

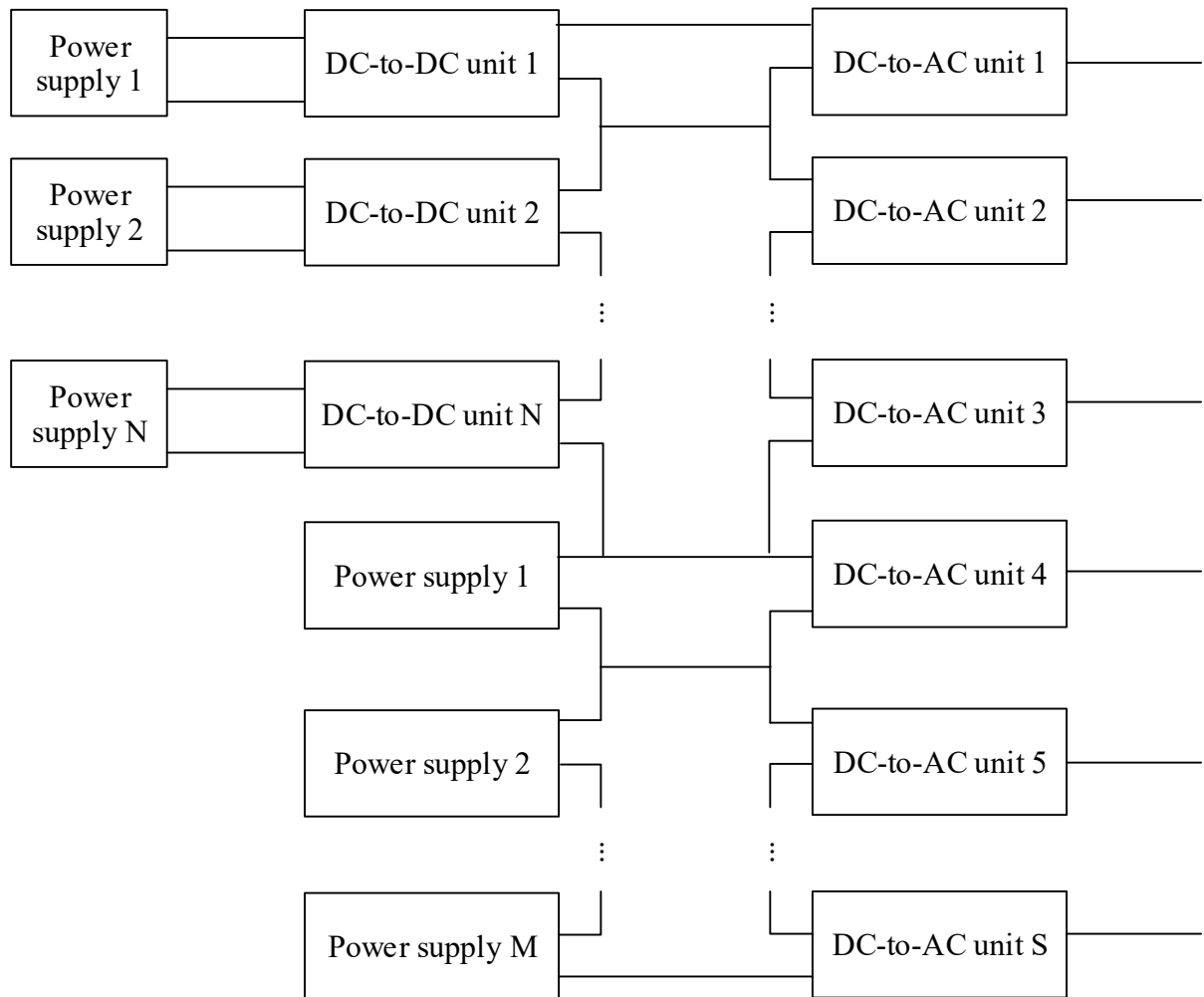


FIG. 50

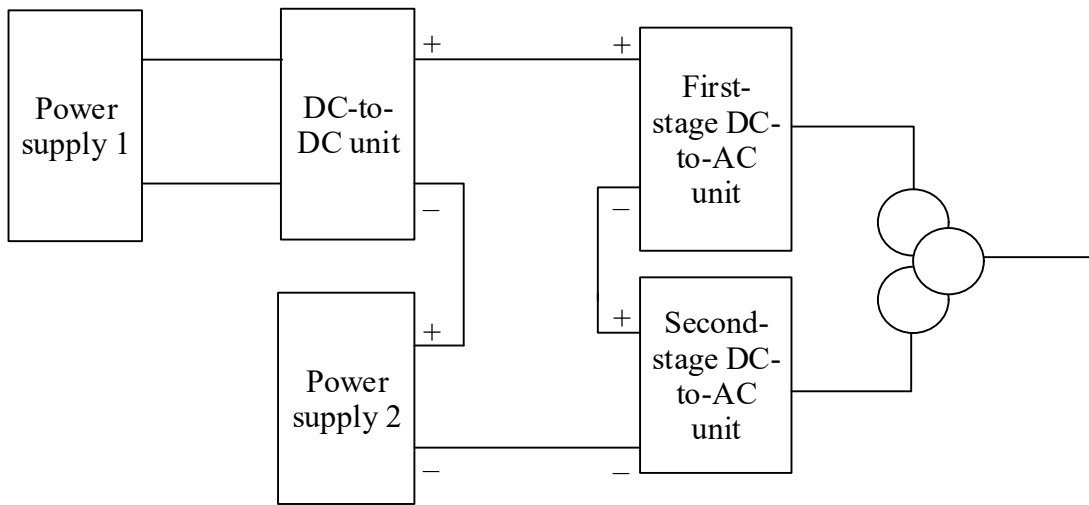


FIG. 51a

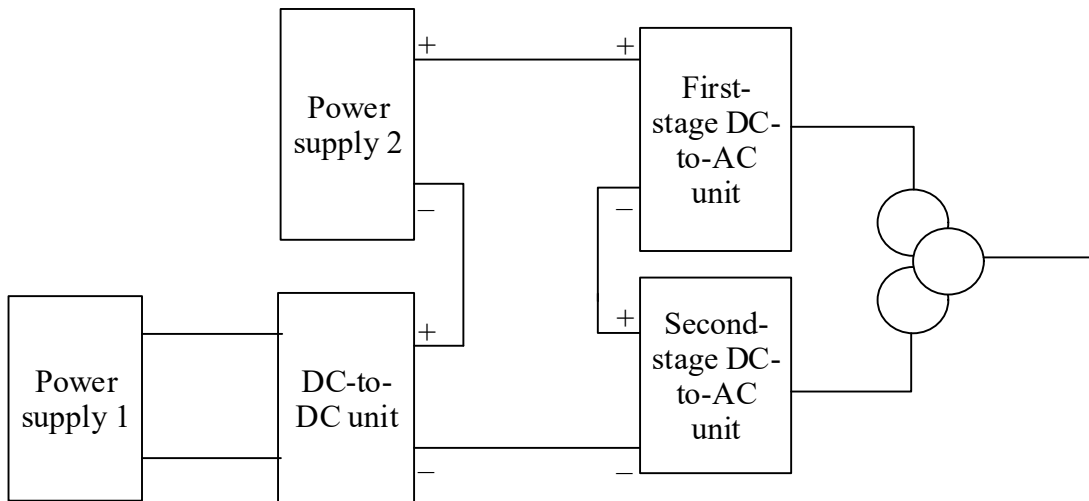


FIG. 51b

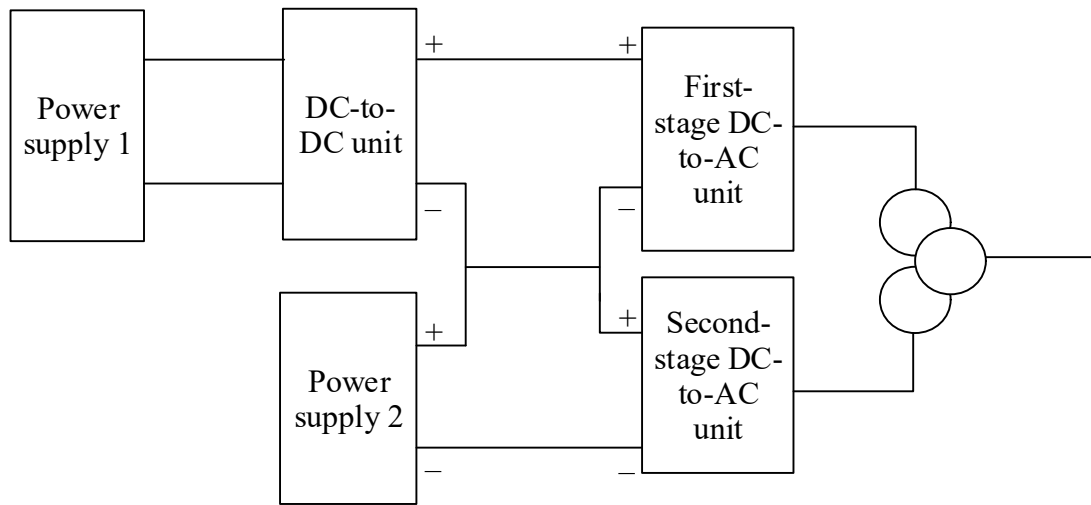


FIG. 52

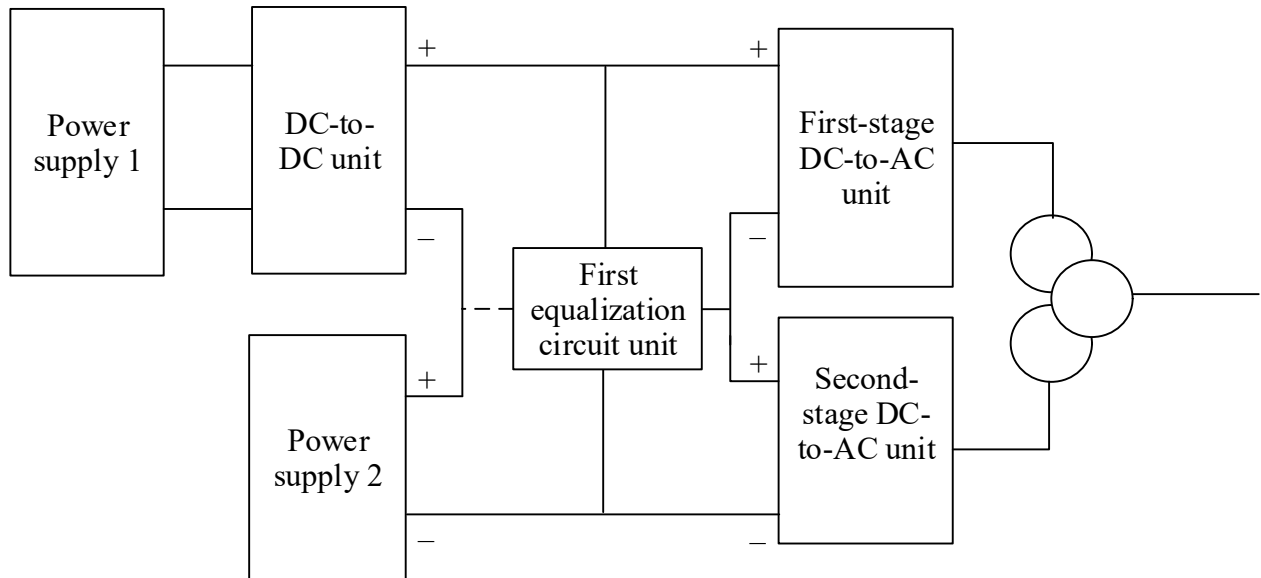


FIG. 53

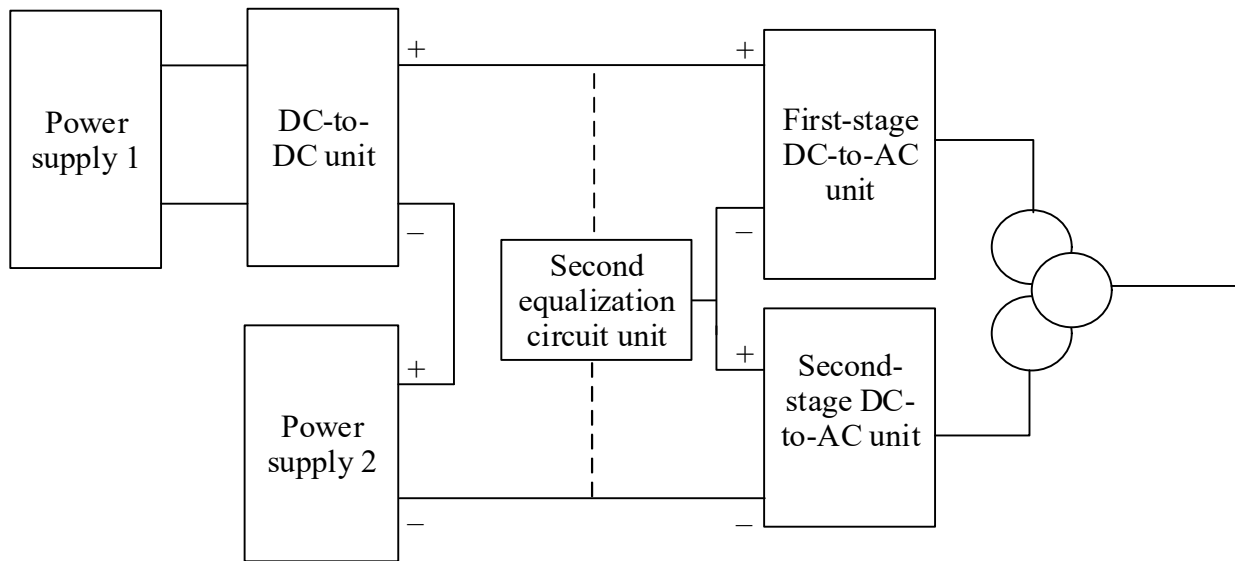


FIG. 54

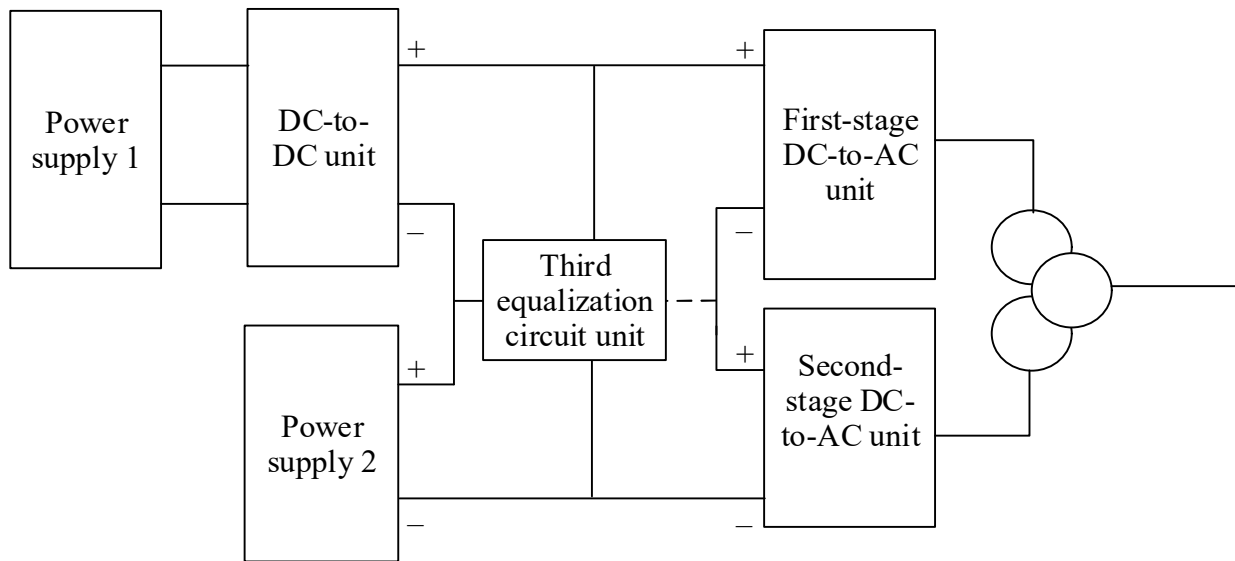


FIG. 55

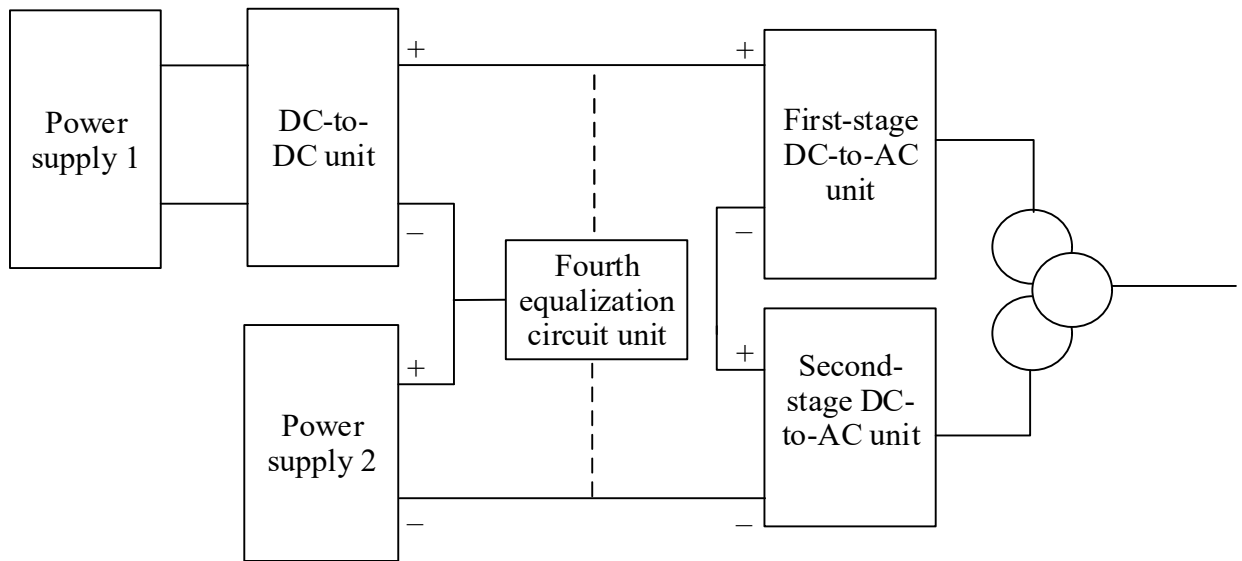


FIG. 56

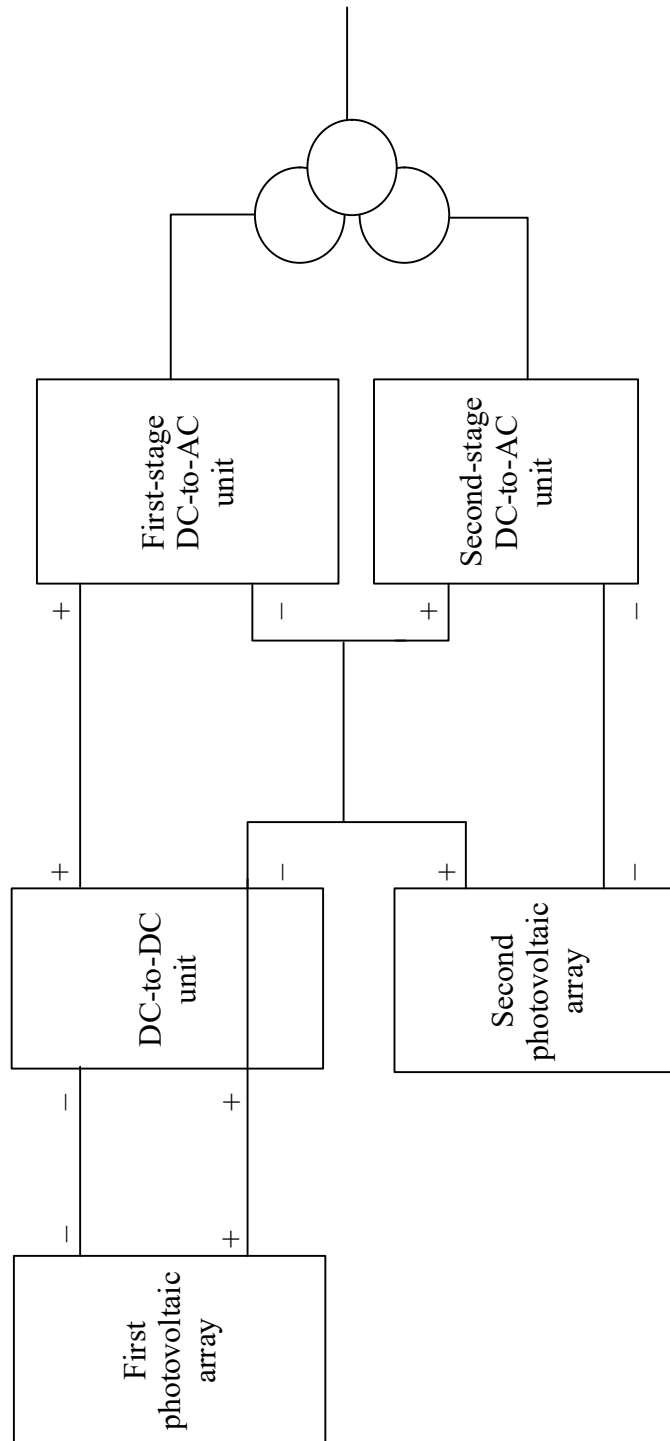


FIG. 57

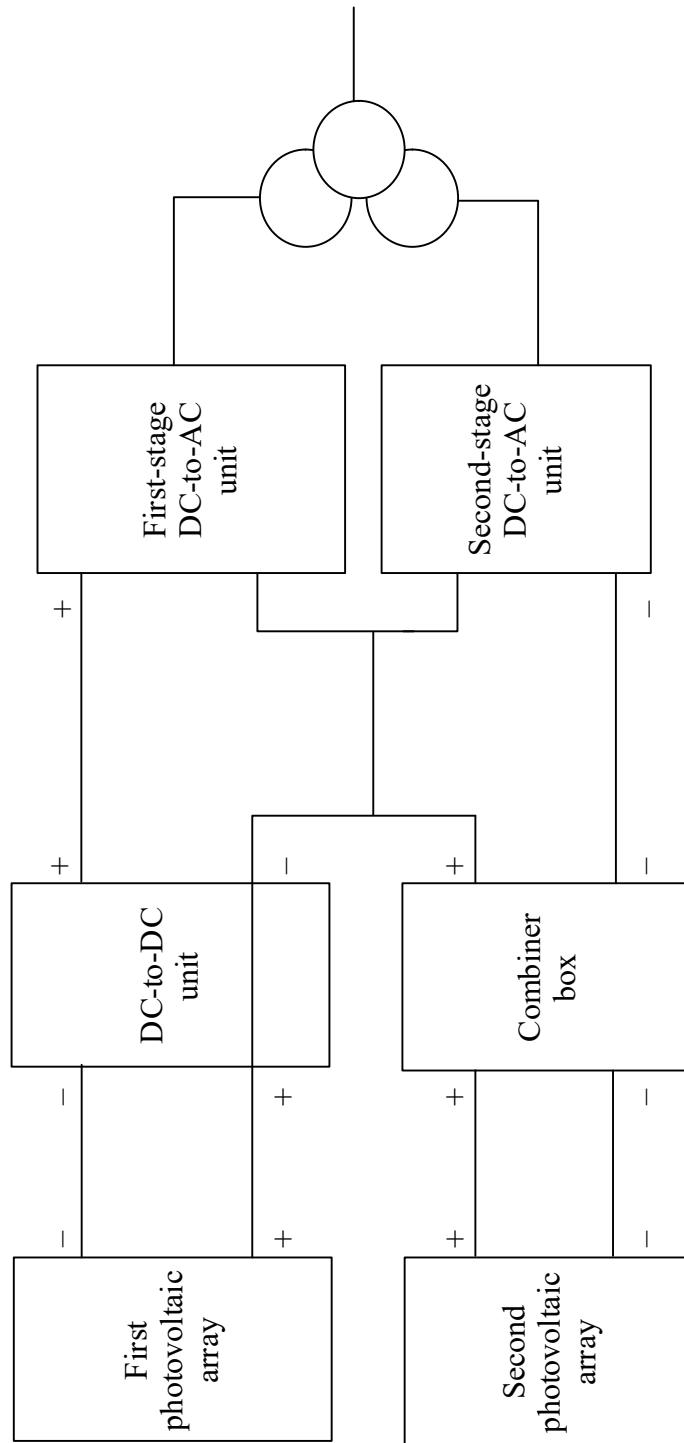


FIG. 58

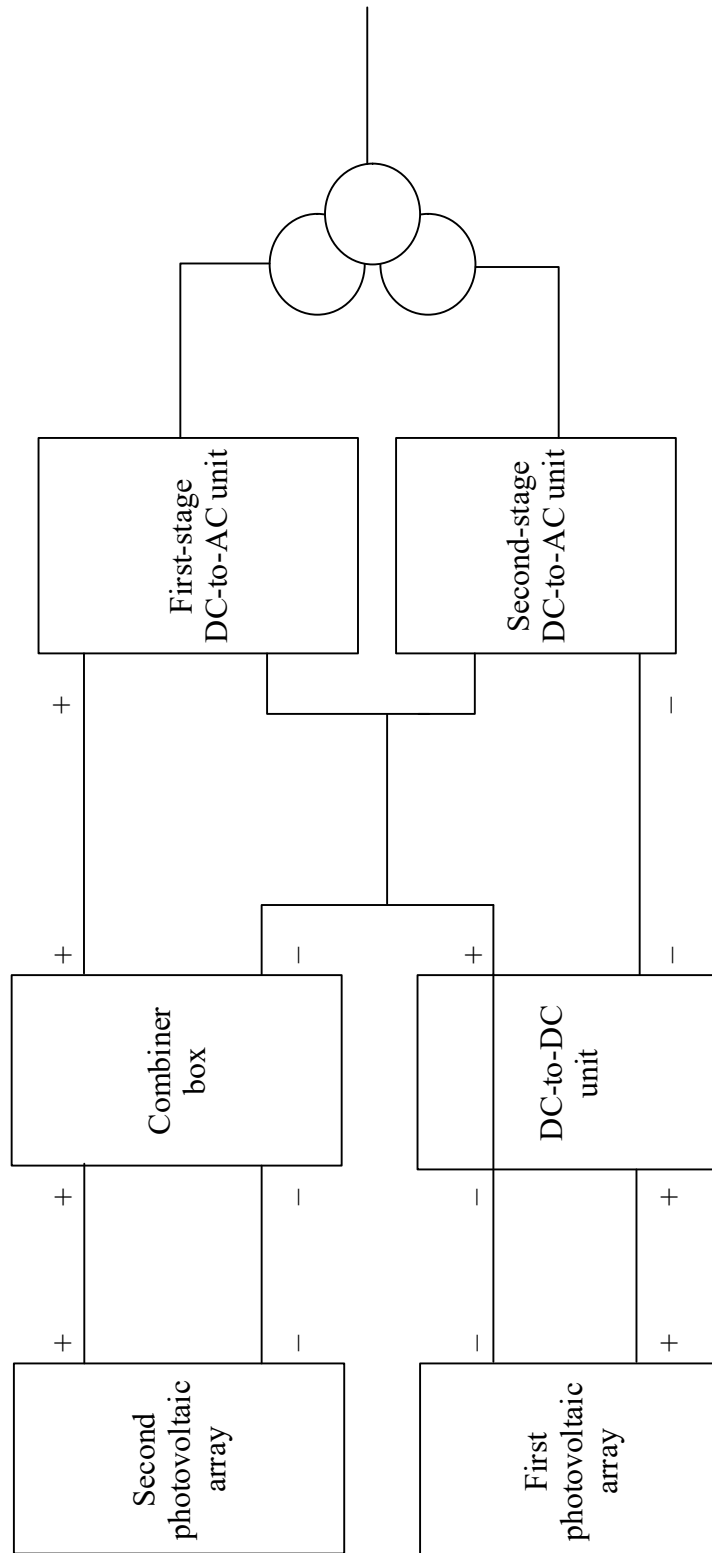


FIG. 59

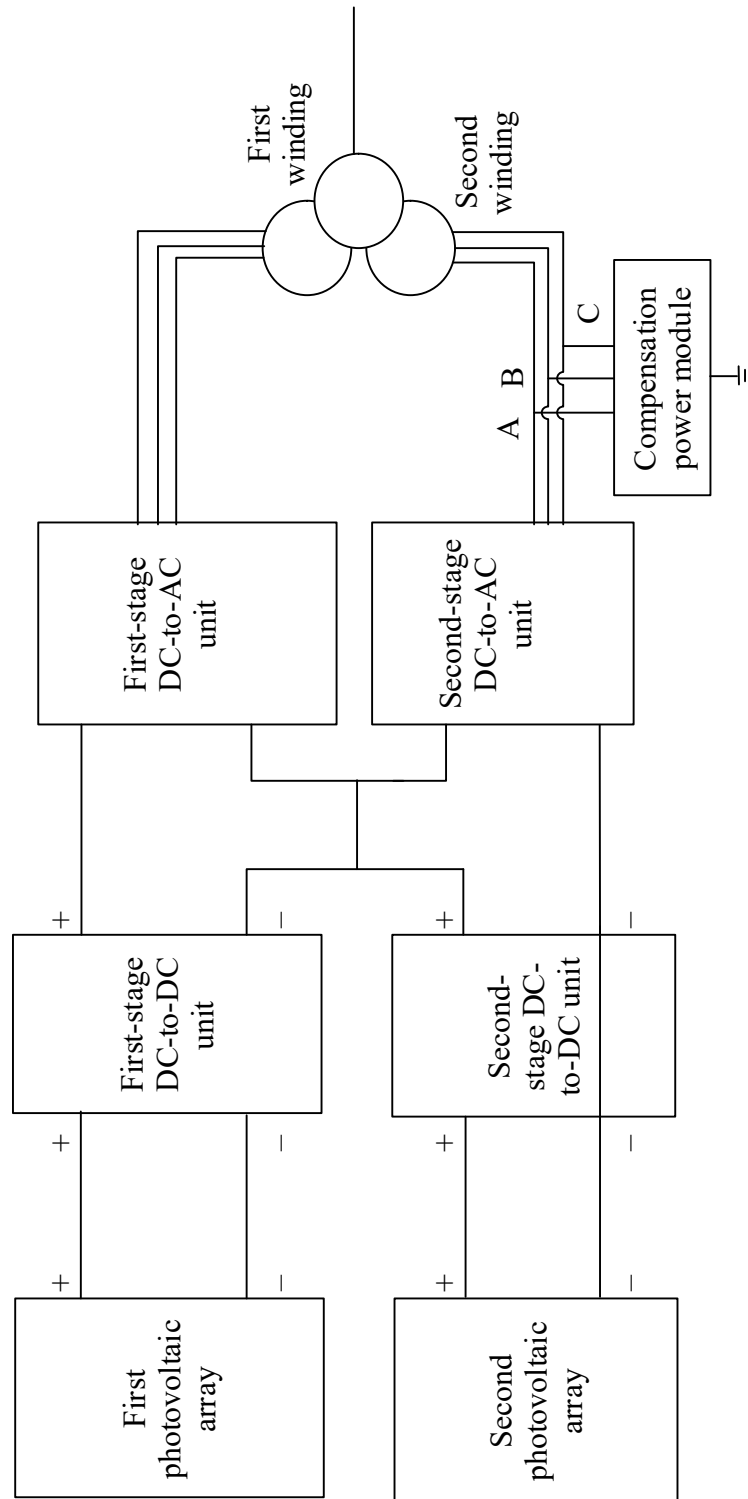


FIG. 60