(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 640 964 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
10.01.2024 Bulletin 2024/02

(21) Application number: **18817267.0**

(22) Date of filing: **14.05.2018**

(51) International Patent Classification (IPC):
H01H 33/59 *(2006.01)* ***H01H 9/54*** *(2006.01)*
H01H 33/666 *(2006.01)* ***H01H 33/14*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
H01H 9/542; H01H 33/14; H01H 33/596; H01H 33/6661; H01H 2009/543; H01H 2009/544

(86) International application number:
PCT/JP2018/018571

(87) International publication number:
WO 2018/230224 (20.12.2018 Gazette 2018/51)

(54) MECHANICAL SWITCHING DEVICE FOR DIRECT-CURRENT CIRCUIT BREAKER AND DIRECT-CURRENT CIRCUIT BREAKER COMPRISING THE MECHANICAL SWITCHING DEVICE

MECHANISCHE SCHALTVORRICHTUNG FÜR EINEN GLEICHSTROMSCHUTZSCHALTER UND GLEICHSTROMSCHUTZSCHALTER MIT DER MECHANISCHEN SCHALTVORRICHTUNG

DISPOSITIF INTERRUPTEUR MÉCANIQUE POUR DISJONCTEUR À COURANT CONTINU ET DISJONCTEUR À COURANT CONTINU AVEC CE DISPOSITIF INTERRUPTEUR MÉCANIQUE

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **16.06.2017 PCT/JP2017/022322**

(43) Date of publication of application:
22.04.2020 Bulletin 2020/17

(73) Proprietor: **Toshiba Energy Systems & Solutions Corporation**
Kawasaki-shi, Kanagawa 212-0013 (JP)

(72) Inventors:
- **KANAYA Kazuhisa**
  Tokyo 105-8001 (JP)
- **OHDA Yoshiaki**
  Tokyo 105-8001 (JP)
- **ISHIGURO Takahiro**
  Tokyo 105-8001 (JP)

(74) Representative: **AWA Sweden AB**
Junkersgatan 1
582 35 Linköping (SE)

(56) References cited:
EP-A1- 3 125 262
WO-A1-2013/178787
JP-A- S 509 074
JP-A- H07 123 547
JP-A- 2000 166 031
JP-A- 2016 004 699
JP-A- 2016 004 699
JP-A- 2016 162 713
JP-A- 2016 187 275
JP-A- 2016 187 275

Processed by Luminess, 75001 PARIS (FR)

Description

[Technical Field]

[0001] The present invention relates to a mechanical switching device for a direct-current circuit breaker, and a direct-current circuit breaker.

[Background Art]

[0002] Direct-current power transmission has higher power transmission efficiency than alternating-current power transmission. On the other hand, the introduction costs of equipment for direct-current power transmission is higher than that for alternating-current transmission. However, in long-distance power transmission, underwater power transmission, or the like, since the power transmission efficiency of direct-current power transmission is overwhelmingly high, direct-current power transmission generally has lower costs when this is evaluated by adding operating costs to the equipment costs. Therefore, direct-current power transmission is used, for example, for power transmission between two bases across the sea. In recent years, a method in which large-scale power generation is performed at a location far from an urban area that is a major power consumer using offshore wind power generation or solar power generation in a desert area or the like and then long-distance power transmission is performed has been studied to enhance a proportion of power generated using renewable energy in all generated power and to supply a larger amount of power using renewable energy. Accordingly, construction of direct-current power transmission networks which connect a plurality of power supply points with a plurality of demand points is planned.

[0003] When a power transmission network in which three or more bases are connected with each other is constructed, a device capable of rapidly isolating a point at which an accident has occurred from a healthy system is required when an accident occurs in the power transmission network. In general, a mechanical contact type circuit breaker is used in an alternating current system. A mechanical contact type circuit breaker opens contacts at a current zero point generated by an alternating current and interrupts a fault current by blowing an insulating medium with an arc current between the contacts. On the other hand, in a direct-current transmission system, since a current zero point does not occur in a fault current, it is thought that it would be difficult to quickly interrupt a fault current in a conventional mechanical contact type circuit breaker.

[0004] Therefore, a semiconductor circuit breaker using a plurality of semiconductor elements having a self-extinguishing capability, such as insulated gate bipolar transistors (IGBTs), has been proposed as a semiconductor breaker capable of interrupting a direct current alone. However, since all of the power to be transmitted always passes through the plurality of semiconductor elements, a large conduction loss occurs, and thus a decrease in the power transmission efficiency is caused during a normal operation.

[0005] To solve this problem, a hybrid circuit breaker in which another semiconductor circuit breaker is connected in parallel to a circuit in which a mechanical contact type disconnector and an auxiliary semiconductor circuit breaker are connected in series has been proposed. In the hybrid circuit breaker, when power is transmitted normally, the mechanical contact type disconnector and the auxiliary semiconductor circuit breaker are in a conductive state, and the other semiconductor circuit breaker is in an interrupted state. Thus, a transmission current flows through the mechanical contact type disconnector and the auxiliary semiconductor circuit breaker.

[0006] Also, in the event of an accident, an opening command is given to the mechanical contact type disconnector at the same time as the auxiliary semiconductor circuit breaker is put into an interrupted state. In this way, since the auxiliary semiconductor circuit breaker is in an interrupted state, a fault current flowing in a path between the mechanical contact type disconnector and the auxiliary semiconductor circuit breaker is commutated to the above-described other semiconductor circuit breaker. Additionally, after the opening operation of the mechanical contact type disconnector is completed, and withstand voltage performance of a steady current conduction path is secured, the interruption of a fault current is completed by shutting off the other semiconductor circuit breaker.

[0007] In such a hybrid circuit breaker, since the conduction loss at the time of steady energization is only the conduction loss in the auxiliary semiconductor circuit breaker, the conduction loss can be reduced as compared with a constitution in which the steady current conduction path is only in the semiconductor circuit breaker which can interrupt a direct current alone as described above. However, since the conduction loss in the auxiliary semiconductor circuit breaker still occurs, the hybrid circuit breaker has a large conduction loss as compared with a conventional mechanical contact type circuit breaker in which the steady current conduction path includes only the mechanical contacts.

[0008] Therefore, a direct-current circuit breaker in which a mechanical contact type circuit breaker is connected in parallel to a circuit in which a semiconductor circuit breaker and a commutation circuit constituted by a half bridge circuit are connected in series has been proposed. In this direct-current circuit breaker, when power is transmitted normally, the mechanical contact type disconnector is in a conductive state, and the semiconductor circuit breaker and the commutation circuit are in an interrupted state. Therefore, when power is transmitted normally, the transmission current flows only through the mechanical contact type disconnector.

[0009] In the event of an accident, an opening command is given to the mechanical contact type circuit breaker, the semiconductor circuit breaker is brought into a conductive state, and a commutation command is given to the commutation circuit. Then, the commutation circuit generates a zero point in the current of the mechanical contact type circuit breaker by causing a current to flow in a direction opposite to a fault current flowing to the mechanical contact type circuit breaker, and the fault current is commutated from the mechanical contact type circuit breaker to the semiconductor circuit breaker and the commutation circuit by the mechanical contact type circuit breaker opening. After the commutation of the fault current, interruption of the fault current is completed by shutting off the semiconductor circuit breaker.

[0010] In such a direct-current circuit breaker, since the steady current conduction path is formed only by the mechanical contact type circuit breaker, it is possible to significantly reduce the conduction loss.

[0011] A general mechanical contact type circuit breaker includes a fixed contact and a mobile contact which are provided to be brought into contact with or separated from each other, a metal tank which encloses the fixed contact and the mobile contact therein, and an operation mechanism which is driven so that the mobile contact is brought into contact with or separated from the fixed contact. The inside of the metal tank is filled with an insulating medium. The metal tank is grounded and electrically insulated from the fixed contact and the mobile contact. The operation mechanism is grounded and located outside of the metal tank and is connected to the mobile contact in the metal tank via a seal rod which passes through the metal tank and an insulating operation rod which is connected to the seal rod in the metal tank.

[0012] However, it is necessary to improve the withstand voltage performance in the respective parts of the mechanical contact type circuit breaker as a voltage of the direct-current transmission system increases. That is, in the above-described mechanical contact type circuit breaker, it is necessary to increase a distance between the fixed contact and the mobile contact in the high voltage part and the grounded metal tank to electrically insulate them from each other, as the voltage is increased. Further, when desired interrupting performance cannot be obtained with one mechanical contact type circuit breaker as the voltage is increased, a plurality of mechanical contact type circuit breakers may be connected in series to improve the interrupting performance. Also in this case, in all the mechanical contact type circuit breakers connected in series, it is necessary to increase the distance between the fixed contact and the mobile contact of the high voltage part and the grounded metal tank to electrically insulate them from each other. As a result, a size of the mechanical contact type circuit breaker increases. The direct-current circuit breaker is assumed to be operated on a platform built on the sea, and the cost of building the platform may increase due to the increase in the size of the mechanical contact type circuit breaker. Further, as the voltage is increased, an insulating rod which connects the mobile contact of the high voltage part with the grounded operation mechanism is also elongated. As a result, since a mass of a movable part of the operation mechanism increases, an opening speed of the fixed contact and the mobile contact may be reduced, and responsiveness of the interrupting operation may be reduced. EP 3125262 A1 relates to a mechanical switching device for a DC circuit breaker according to the preamble of claim 1.

[Citation List]

[Patent Literature]

[0013]

[Patent Document 1]
Japanese Unexamined Patent Application, First Publication No. 2016-187275
[Patent Document 2]
PCT International Publication No. WO 2011/057675
[Patent Document 3]
PCT International Publication No. WO 2013/131582

[Summary of Invention]

[Technical Problem]

[0014] An object of the present invention is to provide a mechanical switching device for a direct-current circuit breaker capable of easily increasing a voltage, curbing an increase in a size thereof, and ensuring responsiveness of an interrupting operation, and a direct-current circuit breaker comprising that mechanical switching device.

[Solution to Problem]

[0015] The invention is defined by the mechanical switching device according to independent claim 1. Further embodiments are defined in the dependent claims.

[Brief Description of Drawings]

[0016]

FIG. 1 is a perspective view showing a direct-current circuit breaker according to a first embodiment.
FIG. 2 is a perspective view schematically showing the direct-current circuit breaker of the first embodiment.
FIG. 3 is a perspective view showing a mechanical switching part according to the first embodiment.
FIG. 4 is a cross-sectional view showing a high voltage contact.
FIG. 5 is a cross-sectional view showing a current interrupting contact.
FIG. 6 is a perspective view schematically showing

the mechanical switching part according to the first embodiment.

FIG. 7 is a perspective view showing a semiconductor switching part according to the first embodiment.

FIG. 8 is a perspective view schematically showing the semiconductor switching part according to the first embodiment.

FIG. 9 is a perspective view showing a commutation device according to the first embodiment.

FIG. 10 is a circuit diagram showing the commutation circuit.

FIG. 11 is a perspective view schematically showing the commutation device of the first embodiment.

FIG. 12 is a circuit diagram schematically showing the direct-current circuit breaker of the first embodiment.

FIG. 13 is a cross-sectional view showing a modified example of the high voltage contact.

FIG. 14 is a front view schematically showing a mechanical switching part according to a second embodiment.

FIG. 15 is a front view schematically showing a mechanical switching part according to a third embodiment.

FIG. 16 is a front view schematically showing a mechanical switching part according to a fourth embodiment.

FIG. 17 is a front view schematically showing a mechanical switching part according to a fifth embodiment.

[Description of Embodiments]

[0017] Hereinafter, a mechanical switching device for a direct-current circuit breaker, a direct-current circuit breaker comprising the mechanical switching device will be described with reference to the drawings. In the following description, components having the same or similar functions are designated by the same reference numerals. Additionally, duplicate explanation of the components may be omitted.

(First embodiment)

[0018] FIG. 1 is a perspective view showing a direct-current circuit breaker according to the first embodiment. FIG. 2 is a perspective view schematically showing the direct-current circuit breaker according to the first embodiment.

[0019] As shown in FIGS. 1 and 2, the direct-current circuit breaker 1 includes a mechanical switching part 2 (a mechanical switching device), a semiconductor switching part 3 (a semiconductor switching device), and a commutation device 4.

[0020] FIG. 3 is a perspective view showing the mechanical switching part according to the first embodiment.

[0021] As shown in FIGS. 1 and 3, the mechanical switching part 2 includes a plurality of (four in the illustrated example) mechanical switching units 10 and a plurality of (four in the illustrated example) insulating columns 12 which support the mechanical switching units 10. The plurality of mechanical switching units 10 are stacked in multiple stages in the vertical direction with respect to the insulating columns 12.

[0022] Each of the mechanical switching units 10 includes a pair of unitary switching parts 14, a power supply part 30, a control part 31, and a mechanical switching part support plate 33 onto which the pair of unitary switching parts 14 (a first unitary switching part and a second unitary switching part), the power supply part 30 and the control part 31 are fixedly disposed. Each of the unitary switching parts 14 constitutes a high voltage contact 14A or a current interrupting contact 14B. In the embodiment, the mechanical switching unit 10 includes only the high voltage contact 14A or only the current interrupting contact 14B. Specifically, the uppermost mechanical switching unit 10 has a pair of current interrupting contacts 14B. Further, each of the other mechanical switching units 10 has a pair of high voltage contacts 14A. The high voltage contact 14A is preferably a disconnector having a withstand voltage performance higher than or equivalent to that of the current interrupting contact 14B. The current interrupting contact 14B is preferably a circuit breaker having high current interrupting performance as compared to the high voltage contact 14A. The disconnector having high voltage withstand performance is, for example, a gas disconnector having a gas contact. The circuit breaker having high current interrupting performance is, for example, a vacuum circuit breaker having a vacuum interrupter.

[0023] FIG. 4 is a cross-sectional view showing the high voltage contact.

[0024] As shown in FIG. 4, a mechanical contact part 16 of the unitary switching part 14 constituting the high voltage contact 14A is a gas contact. The unitary switching part 14 constituting the high voltage contact 14A includes the mechanical contact part 16 having a fixed contact 17 and a movable contact 18, a sealed container 20 in which the mechanical contact part 16 and an insulating gas are enclosed, a fixed rod 25 connected to the fixed contact 17, an operation rod 26 connected to the movable contact 18, an operation mechanism 27 connected to the operation rod 26, and a capacitor 29 (refer to FIGS. 1 and 3) connected in parallel to the mechanical contact part 16.

[0025] The mechanical contact part 16 is a contact having high withstand voltage performance. The fixed contact 17 and the movable contact 18 are provided to be brought into contact with or separated from each other. The mechanical contact part 16 is opened by separating the fixed contact 17 and the movable contact 18 from each other. A current conduction path which passes through the mechanical contact part 16 is opened by separating the fixed contact 17 and the movable contact 18 from each other. In the following description regarding the high voltage contact 14A, a direction in which the fixed contact 17 and the movable contact 18 are brought into contact with or separated from each other is referred to as a first direction. In the embodiment, the first direction is one horizontal direction.

[0026] The sealed container 20 encloses, for example, sulfur hexafluoride (SF_6) gas or the like as an insulating gas. The sealed container 20 includes a cylindrical insulated cylinder 21, and a first flange 22 and a second flange 23 which close openings at both ends of the insulated cylinder 21. The insulated cylinder 21 extends in the first direction. The insulated cylinder 21 is, for example, a bushing formed of an insulating material. Each of the first flange 22 and the second flange 23 is formed of a metal material.

[0027] The fixing rod 25 is formed of a metal material. The fixing rod 25 extends in the first direction. The fixed rod 25 connects the first flange 22 with the fixed contact 17 in the sealed container 20. The fixed rod 25 may be integrally formed with the fixed contact 17. The fixed rod 25 electrically connects the fixed contact 17 to the first flange 22.

[0028] For example, the entire operation rod 26 is formed of a metal material. The operation rod 26 extends in the first direction. The operation rod 26 is connected to the movable contact 18 in the sealed container 20 and extends outside of the sealed container 20 through a through hole 23a provided in the second flange 23. The operation rod 26 may be integrally formed with the movable contact 18. The operation rod 26 is provided to be slidable with respect to the second flange 23 while keeping the inside of the sealed container 20 airtight. The operation rod 26 electrically connects the movable contact 18 with the second flange 23.

[0029] The operation mechanism 27 is a highly responsive electromagnetic actuator energized by a power source. The electromagnetic actuator may be, for example, an electromagnetic repulsion operation mechanism. The electromagnetic repulsion operation mechanism has a metal plate of a good conductor connected to the operation rod 26, and a coil installed to face the metal plate. When the electromagnetic repulsion operation mechanism is driven, a current is applied to the coil to generate an induced current for the metal plate in a reverse direction, and a repulsive force in the reverse direction to the coil is applied to the metal plate to operate the operation rod 26. The operation mechanism 27 is disposed outside of the sealed container 20 to be parallel to the second flange 23 in the first direction. The operation mechanism 27 is fixed to the second flange 23 via a support portion 28. For example, the entire support portion 28 is formed of a metal material. The operation mechanism 27 reciprocates the operation rod 26 in the first direction. Thus, the operation mechanism 27 displaces the movable contact 18 connected to the operation rod 26 and causes the movable contact 18 to be brought into contact with or separated from the fixed contact 17.

[0030] As shown in FIGS. 1 and 3, the capacitor 29 is disposed outside of the sealed container 20. The capacitor 29 is connected to the first flange 22 and the second flange 23. The capacitor 29 is formed by encapsulating a dielectric in a high-resistance cylinder, and has electrodes at both ends thereof, and has capacitance and resistance. The capacitor 29 adjusts a voltage applied to the mechanical contact part 16 (refer to FIG. 4) at the time of current interruption and in an open state.

[0031] FIG. 5 is a cross-sectional view showing the current interrupting contact.

[0032] As shown in FIG. 5, a mechanical contact part 36 of the unitary switching part 14 constituting the current interrupting contact 14B is a vacuum interrupter. The unitary switching part 14 constituting the current interrupting contact 14B includes the mechanical contact part 36 which is a vacuum interrupter 44 having a fixed contact 37 and a movable contact 38, a sealed container 40 which encloses the mechanical contact part 36, a fixed rod 45 connected to the fixed contact 37, an operation rod 46 connected to the movable contact 38, an operation mechanism 47 connected to the operation rod 46, and a capacitor 49 (refer to FIGS. 1 and 3) connected in parallel to the mechanical contact part 36.

[0033] The mechanical contact part 36 is a contact capable of mechanically interrupting the current at a current zero point. The fixed contact 37 and the movable contact 38 are provided to be brought into contact with and separated from each other. The mechanical contact part 36 is opened by separating the fixed contact 37 and the movable contact 38 from each other. A current conduction path which passes through the mechanical contact part 36 is opened by separating the fixed contact 37 and the movable contact 38. In the following description regarding the current interrupting contact 14B, a direction in which the fixed contact 37 and the movable contact 38 are brought into contact with and separated from each other is referred to as a second direction. In the embodiment, the second direction is one horizontal direction.

[0034] The vacuum interrupter 44 maintains an inside vacuum. The vacuum interrupter 44 includes the fixed contact 37, the movable contact 38, a cylindrical insulated cylinder 44a, a first flange 44b and a second flange 44c which close openings at both ends of the insulated cylinder 44a, and a bellows 44d provided at the inside of the insulated cylinder 44a. The insulated cylinder 44a extends in the second direction. The insulated cylinder 44a is, for example, a bushing formed of an insulating material. Each of the first flange 44b and the second flange 44c is formed of a metal material.

[0035] The fixed contact 37 is connected to the first flange 44b in the vacuum interrupter 44. The fixed contact 37 is electrically connected with the first flange 44b. The movable contact 38 extends to the outside of the vacuum interrupter 44 through a through hole 44e provided in the second flange 44c. The movable contact 38 is provided to be slidable with respect to the second flange 44c. The movable contact 38 is electrically connected to the second flange 44c.

[0036] The bellows 44d is disposed in the inside of the insulated cylinder 44a to surround the movable contact 38. One end portion of the bellows 44d is fixed to the second flange 44c. The other end portion of the bellows 44d is fixed to a peripheral surface of the movable contact 38. The bellows 44d isolates the vacuum in the vacuum interrupter 44 from the outside while causing the movable contact 38 to be displaceable with respect to the insulated cylinder 44a in the second direction.

[0037] The sealed container 40 encloses, for example, sulfur hexafluoride (SF_6) gas or the like as an insulating gas. The sealed container 40 includes a cylindrical insulated cylinder 41, and a first flange 42 and a second flange 43 which close openings at both ends of the insulated cylinder 41. The insulated cylinder 41 extends in the second direction. The insulated cylinder 41 is, for example, a bushing formed of an insulating material. Each of the first flange 42 and the second flange 43 is formed of a metal material.

[0038] The fixing rod 45 is formed of a metal material. The fixing rod 45 extends in the second direction. The fixed rod 45 connects the first flange 42 to the first flange 44b in the sealed container 40. The fixed rod 45 may be integrally formed with the first flange 44b. The fixed rod 45 electrically connects the fixed contact 37 to the first flange 44b and the first flange 42.

[0039] For example, the entire operation rod 46 is formed of a metal material. The operation rod 46 extends in the second direction. The operation rod 46 is connected to the movable contact 38 in the sealed container 40 and extends to the outside of the sealed container 40 through a through hole 43a provided in the second flange 43. The operation rod 46 may be integrally formed with the movable contact 38. The operation rod 46 is provided to be slidable with respect to the second flange 43. The operation rod 46 electrically connects the movable contact 38 with the second flange 43.

[0040] The operation mechanism 47 is a highly responsive electromagnetic actuator energized by a power source. The electromagnetic actuator is, for example, an electromagnetic repulsion operation mechanism. The electromagnetic repulsion operation mechanism has a metal plate of a good conductor connected to the operation rod 46, and a coil installed to face the metal plate. When the electromagnetic repulsion operation mechanism is driven, a current is applied to the coil to generate an induced current to the metal plate in a reverse direction, and a repulsive force in the reverse direction to the coil is applied to the metal plate to operate the operation rod 46. The operation mechanism 47 is disposed outside of the sealed container 40 to be parallel to the second flange 43 in the second direction. The operation mechanism 47 is fixed to the second flange 43 via a support portion 48. For example, the entire support portion 48 is formed of a metal material. The operation mechanism 47 reciprocates the operation rod 46 in the second direction. Thus, the operation mechanism 47 displaces the movable contact 38 connected to the operation rod 46 and causes the movable contact 38 to be brought into contact with or separated from the fixed contact 37.

[0041] As shown in FIGS. 1 and 3, the capacitor 49 is disposed outside of the sealed container 40. The capacitor 49 is connected to the first flange 42 and the second flange 43. The capacitor 49 is formed by encapsulating a dielectric in a high-resistance cylinder, and has electrodes at both ends thereof, and has capacitance and resistance. The capacitor 49 adjusts a voltage applied to the mechanical contact part 36 (refer to FIG. 5) at the time of current interruption and in an open state.

[0042] As shown in FIGS. 1, 3, 4 and 5, in each of the mechanical switching units 10, the pair of unitary switching parts 14 disposed on the mechanical switching part support plate 33 are disposed so that the respective operation rods 26, 46 are operated on the same straight line when the mechanical contact parts 16, 36 are opened by the operation mechanisms 27, 47. Specifically, in each of the mechanical switching units 10, the operation rods 26, 46 of the respective unitary switching parts 14 extend on the same straight line. Furthermore, in each of the mechanical switching units 10, the pair of unitary switching parts 14 disposed on the mechanical switching part support plate 33 are disposed so that operating directions of the operation rods 26, 46 at the time of the opening operation of the mechanical contact parts 16, 36 by the operation mechanisms 27, 47 are opposite to each other. Specifically, the pair of unitary switching parts 14 disposed on the mechanical switching part support plate 33 are disposed so that the respective operation mechanisms 27, 47 face each other and come into contact with each other. Further, the unitary switching part 14 of one mechanical switching unit 10 and the unitary switching part 14 of the other mechanical switching unit 10 are disposed to operate on the same straight line when seen in the vertical direction.

[0043] Further, in each of the mechanical switching units 10, the sealed containers 20, 40 of the pair of unitary switching parts 14 disposed on the mechanical switching part support plate 33 are disposed outside of the mechanical switching part support plate 33 in the horizontal direction. In the illustrated example, although the whole of the sealed containers 20, 40 is disposed outside of the mechanical switching part support plate 33 in the horizontal direction, only a part of the sealed containers 20, 40 may be disposed outside of the mechanical switching part support plate 33 in the horizontal direction. Specifically, portions (for example, the first flanges 22, 42) of the sealed containers 20, 40 having the same potential as that of the fixed contacts 17, 37 may be disposed outside of the mechanical switching part support plate 33 in the horizontal direction.

[0044] Here, the arrangement on the outside of the mechanical switching part support plate 33 in the horizontal direction will be described in another expression with reference to FIG. 1.

[0045] For example, assuming that the above-described first direction is a projection line, it is possible to define two vertical projection planes including two sides, which are in a twisted positional relationship with a projection line, among four sides constituting the mechanical switching part support plate 33. At least a part of the sealed containers 20, 40 may be disposed to protrude from a space (a space on the side on which the operation mechanisms 27, 47 are present) divided by the two vertical projection planes.

[0046] In each of the unitary switching parts 14, the mechanical contact parts 16, 36 are electrically insulated from the ground. Further, in each of the unitary switching parts 14, the operation mechanisms 27, 47 are provided at the same potential as that of the movable contacts 18, 38 of the mechanical contact parts 16, 36 and the mechanical switching part support plate 33. Specifically, the operation mechanisms 27, 47 are provided such that a reference potential is the same potential as that of the movable contacts 18, 38 of the mechanical contact parts 16, 36 and the mechanical switching part support plate 33.

[0047] In each of the unitary switching parts 14, the sealed containers 20, 40 are electrically insulated from the ground. Further, the sealed containers 20, 40 electrically insulate the fixed contacts 17, 37 from the movable contacts 18, 38 when the mechanical contact parts 16, 36 are opened.

[0048] As shown in FIGS. 1 and 3, the power supply part 30 supplies power to the operation mechanisms 27, 47 of the pair of unitary switching parts 14 disposed on the mechanical switching part support plate 33 common to the power supply part 30. The power supply part 30 is provided so that a reference potential is the same as that of the operation mechanisms 27, 47. The power supply part 30 includes, for example, a capacitor which supplies power to the operation mechanisms 27, 47 at an opening operation of the mechanical contact parts 16, 36 (refer to FIGS. 4 and 5), a capacitor which supplies power to the operation mechanisms 27, 47 at the time of a closing operation of the mechanical contact parts 16, 36, a charging device for the respective capacitors, and a switching element which holds each of the capacitors in a charged state and discharges power when the power is supplied (all of which are not shown). For example, a power feeding device capable of supplying power while electrically insulating the power supply part 30 from the ground, such as an insulation transformer, a laser power feeding device, and an electromagnetic induction type wireless power feeding device (all of which are not shown), may be used for power supply from the ground to the charging device.

[0049] The control part 31 monitors a state of the power supply part 30 and the operation mechanisms 27, 47 disposed on the same mechanical switching part support plate 33. Further, the control part 31 controls the power supply from the power supply part 30 disposed on the same mechanical switching part support plate 33 to the operation mechanisms 27, 47.

[0050] As shown in FIGS. 1 and 3, for example, the mechanical switching part support plate 33 is formed of a metal material such as an aluminum alloy. The mechanical switching part support plate 33 is formed in a rectangular shape in a plan view. The mechanical switching part support plates 33 are stacked in multiple stages in the vertical direction with respect to the insulating column 12. The mechanical switching part support plates 33 are installed in parallel in a direction (the first direction) in which the unitary switching parts 14 perform the interrupting operation.

[0051] The insulating column 12 is formed of, for example, an insulator, a polymer, fiber reinforced plastic, or the like. The insulating column 12 stands on the foundation 5. The insulating column 12 extends in the vertical direction. The respective insulating columns 12 supports corner portions of the respective mechanical switching part support plates 33 stacked in multiple stages. The insulating column 12 electrically insulates the plurality of mechanical switching units 10 from each other and mechanically connects each of the mechanical switching units 10 to the foundation 5 while electrically insulating the mechanical switching units 10 from the foundation 5.

[0052] The length of the insulating column 12 is set to insulate mechanical switching units 10 adjacent to each other in the vertical direction when the power is interrupted, and to electrically insulate all of the mechanical switching units 10 from the ground when power is applied. That is, the length of a portion of the insulating column 12 provided between a pair of mechanical switching units 10 adjacent to each other in the vertical direction is set so that the mechanical switching units 10 can be electrically insulated from each other when the power is interrupted. Further, the length of a portion of the insulating column 12 provided between the lowermost mechanical switching unit 10 and the foundation 5 is set so that all of the plurality of mechanical switching units 10 can be electrically insulated from the ground when power is applied.

[0053] In the embodiment, the length of the portion of the insulating column 12 provided between the lowermost mechanical switching unit 10 and the foundation 5 is longer than the length of the portion thereof provided between a pair of mechanical switching units 10 adjacent to each other in the vertical direction. Further, the length of the portion of the insulating column 12 provided between the lowermost mechanical switching unit 10 and the foundation 5 is shorter than the sum of the lengths of the portions provided between a pair of mechanical switching units 10 adjacent to each other in the vertical direction. The respective insulating columns 12 may extend continuously from a lower end to an upper end, or may be divided into a plurality of pieces to sandwich each of the mechanical switching part support plates 33.

[0054] FIG. 6 is a perspective view schematically showing the mechanical switching part according to the first embodiment. In FIG. 6, the pair of unitary switching parts 14 disposed on the mechanical switching part support plate 33 are illustrated as one unitary switching part 14. Moreover, in FIG. 6, illustration of the power supply part 30 and the control part 31 of each of the mechanical switching units 10 is omitted.

[0055] As shown in FIGS. 1, 3 and 6, the pair of unitary switching parts 14 in each of the mechanical switching units 10 are connected in series by an intra-unit bus bar 51 which connects the second flanges 23, 43 to each other. In any pair of mechanical switching units 10 adjacent to each other in the vertical direction, the first flanges 22, 42 of the first unitary switching part 14 of the first mechanical switching unit 10 and the first flanges 22, 42 of the second unitary switching part 14 of the second mechanical switching unit 10 are connected in series by the inter-unit bus bar 52. That is, when the pair of unitary switching parts 14 in each of the mechanical switching units 10 are regarded as one unitary switching part 14, the unitary switching parts 14 are connected in series by the inter-unit bus bars 52 which connects the first flanges 22 to each other and the first flanges 22, 42 to the unitary switching parts 14 of the mechanical switching units 10 adjacent to each other in the vertical direction. Therefore, the plurality of high voltage contacts 14A and the plurality of current interrupting contacts 14B are connected in series by the intra-unit bus bar 51 and the inter-unit bus bar 52 and thus form a mechanical contact module 34. In this constitution, all the high voltage contacts 14A are connected in series with each other. Further, all the current interrupting contacts 14B are connected in series with each other.

[0056] As shown in FIG. 6, a first connection point A1, a second connection point A2, and a third connection point A3 are formed in the mechanical contact module 34. The first connection point A1 is formed at one of both end portions of the mechanical contact module 34 in which the current interrupting contact 14B is provided. The second connection point A2 is formed at one of both end portions of the mechanical contact module 34 on the side opposite to the first connection point A1. The third connection point A3 is an electrical connection point between the high voltage contact 14A and the current interrupting contact 14B. The first connection point A1 and the second connection point A2 are connected to a direct-current transmission system.

[0057] FIG. 7 is a perspective view showing the semiconductor switching part of the first embodiment.

[0058] As shown in FIGS. 1 and 7, the semiconductor switching part 3 is provided on the foundation 5 to be parallel to the mechanical switching part 2. The semiconductor switching part 3 includes a plurality of (three in the illustrated example) semiconductor switching units 60 and a plurality of (four in the illustrated example) insulating columns 62 which support the semiconductor switching units 60. The plurality of semiconductor switching units 60 are stacked in multiple stages in the vertical direction with respect to the insulating column 62.

[0059] Each of the semiconductor switching units 60 includes a pair of semiconductor modules 64, a surge absorber 68, and a semiconductor switching part support plate 70 on which the pair of semiconductor modules 64 and the surge absorber 68 are fixedly disposed.

[0060] The semiconductor module 64 includes a semiconductor stack 65 in which a plurality of semiconductor elements 65a are connected in series, a diode 66 connected in parallel to the semiconductor stack 65, and an attached circuit 67 connected to the semiconductor stack 65. The semiconductor element 65a is, for example, an insulated gate bipolar transistor (IGBT), an injection enhanced gate transistor (IEGT), or the like. The semiconductor stack 65 and the diode 66 are connected in parallel so that forward directions in which the power is applied are opposite to each other. The attached circuit 67 includes a snubber circuit which equalizes voltage distribution of the plurality of semiconductor elements 65a of the semiconductor stack 65, and a gate unit which outputs a switching command to the semiconductor element 65a. In each of the semiconductor switching units 60, the pair of semiconductor modules 64 are connected in series so that the forward directions of the respective semiconductor stacks 65 are opposite to each other.

[0061] FIG. 8 is a perspective view schematically showing the semiconductor switching part of the first embodiment.

[0062] As shown in FIGS. 1, 7 and 8, the surge absorbers 68 are connected in parallel to a pair of semiconductor modules 64 disposed on the same semiconductor switching part support plate 70. A current temporarily flows to the surge absorber 68 in a state in which the pair of semiconductor modules 64 are interrupted. The surge absorber 68 converts the current into thermal energy.

[0063] As shown in FIGS. 1 and 7, for example, the semiconductor switching part support plate 70 is formed of an insulating material such as fiber reinforced plastic or a metal material such as an aluminum alloy. The semiconductor switching part support plate 70 is formed so that both ends of the semiconductor module 64 are insulated, both ends of the surge absorber 68 are insulated and the semiconductor module 64 and the surge absorber 68 can be supported by the insulating column 62. The semiconductor switching part support plate 70 is stacked in multiple stages in the vertical direction with respect to the insulating column 62.

[0064] The insulating column 62 is formed of, for example, an insulator, a polymer, fiber reinforced plastic, or the like. The insulating column 62 stands on the foundation 5. The insulating column 62 extends in the vertical direction. The respective insulating columns 62 supports corner portions of the respective semiconductor switching part support plates 70 stacked in multiple stages. The insulating column 62 electrically insulates the plurality of semiconductor switching units 60 from each other and mechanically connects each of the semiconductor switching units 60 to the foundation 5 while electrically insulating the semiconductor switching units 60 from the foundation 5.

[0065] The length of the insulating column 62 is set to insulate the semiconductor switching units 60 adjacent to each other in the vertical direction when the power is interrupted, and to electrically insulate the whole of the semiconductor switching units 60 from the ground when the power is applied. That is, the length of a portion of the insulating column 62 provided between the pair of semiconductor switching units 60 adjacent to each other in the vertical direction is set so that the semiconductor switching units 60 can be electrically insulated from each other when the power is interrupted. Further, the length of a portion of the insulating column 62 provided between the lowermost semiconductor switching units 60 and the foundation 5 is set so that the whole of the plurality of semiconductor switching units 60 can be electrically insulated from the ground when the power is applied.

[0066] In the embodiment, the length of the portion of the insulating column 62 provided between the lowermost semiconductor switching units 60 and the foundation 5 is longer than the length of the portion thereof provided between the pair of semiconductor switching units 60 adjacent to each other in the vertical direction. Further, the length of the portion of the insulating column 62 provided between the lowermost semiconductor switching units 60 and the foundation 5 is shorter than the sum of the lengths of the portions provided between the pair of semiconductor switching units 60 adjacent to each other in the vertical direction. The respective insulating columns 62 may extend continuously from a lower end to an upper end, or may be divided into a plurality of pieces to sandwich each of the semiconductor switching part support plates 70.

[0067] As shown in FIGS. 1, 7 and 8, when the pair of semiconductor modules 64 in each of the semiconductor switching units 60 are regarded as one semiconductor module 64, the plurality of semiconductor modules 64 are connected in series by a plurality of bus bar 72. Specifically, the semiconductor modules 64 are connected in series by the bus bars 72 to the semiconductor modules 64 of the semiconductor switching units 60 adjacent to each other in the vertical direction. Here, all the semiconductor modules 64 connected in series are referred to as a semiconductor module group. As shown in FIG. 8, the first connection point B 1 and the second connection point B2 are formed in a semiconductor switching unit module group. The first connection point B 1 is formed at one end of the semiconductor switching part module group. The second connection point B2 is formed at the other end of the semiconductor switching module part group.

[0068] FIG. 9 is a perspective view showing the commutation device of the first embodiment.

[0069] As shown in FIGS. 1 and 9, the commutation device 4 includes a commutation circuit 80, a commutation reactor 86, a commutation device support plate 88 on which the commutation circuit 80 and the commutation reactor 86 are fixedly disposed, and an insulating column 90 which supports the commutation device support plate 88.

[0070] FIG. 10 is a circuit diagram showing the commutation circuit.

[0071] As shown in FIGS. 1, 9 and 10, the commutation circuit 80 is a half bridge circuit constituted by connecting a pair of legs 82 formed by connecting a pair of semiconductor elements 82a in series, with a capacitor 84 in parallel. The semiconductor element 82a is, for example, an IGBT, an IEGT, or the like. A diodes 82b is connected in parallel to each of the semiconductor elements 82a so that forward directions in which the power is applied are opposite to each other. An attached circuit (not shown) including a snubber circuit which equalizes voltage distribution of the semiconductor elements 82a and a gate unit which outputs a switching command to the semiconductor element 82a is connected to the pair of legs 82. One commutation circuit 80 may be provided, or a plurality of commutation circuits may be connected in series. In the example shown in FIG. 1, one commutation circuit 80 is provided.

[0072] FIG. 11 is a perspective view schematically showing the commutation device of the first embodiment.

[0073] As shown in FIGS. 1, 9 and 11, the commutation reactor 86 is connected in series to the commutation circuit 80 via a bus bar 92. The commutation reactor 86 adjusts a discharge time of the capacitor 84 of the commutation circuit 80.

[0074] As shown in FIG. 11, a first connection point C1, a second connection point C2, and a third connection point C3 are formed in a series of circuits formed by the commutation circuit 80 and the commutation reactor 86. The first connection point C1 is an electrical connection point between the commutation circuit 80 and the commutation reactor 86. The second connection point C2 is formed at one of both end portions of the commutation reactor 86 on the side opposite to the first connection point C1. The third connection point C3 is formed at one of both end portions of the commutation circuit 80 on the side opposite to the first connection point C1.

[0075] As shown in FIGS. 1 and 9, for example, the commutation device support plate 88 is formed of an insulating material such as fiber reinforced plastic or a metal material such as an aluminum alloy. The commutation device support plate 88 is formed so that both ends of the commutation circuit 80 are insulated, the commutation circuit 80 is insulated from the commutation reactor 86 by the other than the bus bar 92, and the commutation circuit 80 and the commutation reactor 86 can be supported by the insulating column 90.

[0076] The insulating column 90 is formed of, for example, an insulator, a polymer, or fiber reinforced plastic. The insulating column 90 stands on the foundation 5. The insulating column 90 extends in the vertical direction. The respective insulating columns 90 support corner portions of the commutation device support plate 88. The insulating column 90 mechanically connects the commutation device support plate 88 to the foundation 5 while electrically insulating the commutation device support plate 88 from the foundation 5. The length of the insulating column 90 is set so that the commutation circuit 80 and the commutation reactor 86 can be electrically insulated from the ground when the power is applied.

[0077] The commutation device support plate 88 is disposed above the semiconductor switching part 3. Also, the insulating column 90 of the commutation device 4 is shared with the insulating column 62 of the semiconductor switching part 3. As a result, the commutation device 4 is stacked on an upper portion of the semiconductor switching part 3. In this case, the insulating column 90 electrically insulates the commutation circuit 80 and the commutation reactor 86 from the semiconductor switching unit 60. The length of a portion of the insulating column 90 provided between the commutation device support plate 88 and the semiconductor switching unit 60 disposed immediately below the commutation device support plate 88 is set so that the commutation circuit 80 and the commutation reactor 86 can be electrically insulated from the semiconductor switching unit 60 when the power is interrupted.

[0078] FIG. 12 is a circuit diagram schematically showing the direct-current circuit breaker of the first embodiment. In FIG. 12, a plurality of high voltage contacts 14A connected in series with each other are illustrated as one high voltage contact 14A. Further, in FIG. 12, the pair of current interrupting contacts 14B connected in series with each other are illustrated as one current interrupting contact 14B. Also, FIG. 12 shows only a pair of semiconductor modules 64 connected in series among the plurality of semiconductor modules 64 connected in series.

[0079] As shown in FIGS. 2 and 12, a series of circuits formed by the commutation circuit 80 and the commutation reactor 86 are connected in parallel to the current interrupting contact 14B. The commutation circuit 80 is connected to the high voltage contact 14A side from the commutation reactor 86. Specifically, the second connection point C2 of the commutation device 4 and the first connection point A1 of the mechanical contact module 34 are electrically connected by a bus bar 94. Further, the third connection point C3 of the commutation device 4 and the third connection point A3 of the mechanical contact module 34 are electrically connected by a bus bar 95.

[0080] The semiconductor module 64 is connected in parallel to a series of circuits formed by the high voltage contact 14A and the commutation circuit 80. Specifically, the first connection point B 1 of the semiconductor switching part 3 and the second connection point A2 of the mechanical contact module 34 are electrically connected by a bus bar 96. In addition, the second connection point B2 of the semiconductor switching part 3 and the first connection point C1 of the commutation device 4 are electrically connected by a bus bar 97.

[0081] Subsequently, an operation of the direct-current circuit breaker 1 will be described with reference to FIGS. 1 to 12.

[0082] When the power is normally transmitted in the direct-current transmission system, a transmission current flows to the mechanical contact module 34. In this state, no current flows to the semiconductor module 64, the commutation circuit 80, and the commutation reactor 86. Further, the capacitor 84 of the commutation circuit 80 is charged in advance by a power feeding device (not shown) capable of supplying power while electrically insulating the ground and the commutation circuit 80 from each other.

[0083] When a fault current is generated in the direct-current transmission system, the fault current is detected by the control device (not shown), an accident interruption command is given to the direct-current circuit breaker 1, and the mechanical contact parts 16, 36 in the high voltage contact 14A and the current interrupting contact 14B of the mechanical contact module 34 are opened. Specifically, an opening operation command is given to the control part 31 by the control device (not shown), the power is supplied from the power supply part 30, and the operation mechanisms 27, 47 of the unitary switching parts 14 are driven, and thus each of the unitary switching parts 14 are opened. At this time, in each of the mechanical switching units 10, since the pair of operation rods 26, 46 operate in opposite directions on the same straight line, an impact force and a reaction which occur in the operation mechanisms 27, 47 are offset.

[0084] In addition, when the unitary switching parts 14 are opened, the semiconductor element 82a of the commutation circuit 80 is turned on (a power applied state), and an electric charge of the capacitor 84 is discharged. When the electric charge of the capacitor 84 is discharged, a current of the current interrupting contact 14B connected in parallel to the commutation circuit 80 decreases, and a current zero point is generated at the current interrupting contact 14B. Therefore, an arc is extinguished at the current interrupting contact 14B, and the commutation is completed. In this state, the fault current flows through the high voltage contact 14A, the commutation circuit 80 and the commutation reactor 86.

[0085] Next, the semiconductor element 65a of the semiconductor module 64 is turned on, and the semiconductor element 82a of the commutation circuit 80 is switched off. Thus, the fault current is commutated to the semiconductor module 64 connected in parallel to the commutation circuit 80. In this state, the fault current flows through the semiconductor module 64 and the commutation reactor 86.

[0086] Next, after insulation recovery of the high voltage contact 14A is awaited, the semiconductor element 65a of the semiconductor module 64 is switched off. When the semiconductor element 65a of the semiconductor module 64 is switched off, the fault current is commutated to the surge absorber 68 connected in parallel to the semiconductor element 65a. Thus, the fault current is absorbed in the surge absorber 68, and the interruption of the fault current in the direct-current transmission system is completed.

[0087] In the embodiment, a constitution in which the mechanical switching part 2 has the unitary switching part 14 including the mechanical contact parts 16, 36 which have the fixed contacts 17, 37 and the movable contacts 18, 38 and are electrically insulated from the ground, the sealed containers 20, 40 which enclose the mechanical contact parts 16, 36 and an insulating gas and are electrically insulated from the ground, the operation rods 26, 46 connected to the movable contacts 18, 38, and the operation mechanisms 27, 47 connected to the operation rods 26, 46 and provided at the same potential as the movable contacts 18, 38 of the mechanical contact parts 16, 36 is adopted.

[0088] With such a constitution, since the sealed containers 20, 40 are not grounded to the ground, the insulation between the sealed containers 20, 40 and the mechanical contact parts 16, 36 can be omitted. Therefore, the sealed containers 20, 40 can be downsized, and an increase in size of the unitary switching part 14 can be curbed as compared with a case in which the sealed container is electrically insulated from the mechanical contact part by being grounded to the ground, or the like. Further, even when the plurality of unitary switching parts 14 are connected in series to improve the interrupting performance as the voltage is increased, the increase in size of all the unitary switching parts 14 connected in series can be curbed. Accordingly, it is possible to provide the direct-current circuit breaker 1 which is easy to increase the voltage and can curb the increase in size.

[0089] Further, with such a constitution, since the sealed containers 20, 40 and the operation mechanisms 27, 47 are not grounded to the ground, the insulation of the operation rods 26, 46 interposed between the mechanical contact parts 16, 36 and the operation mechanisms 27, 47 can be omitted, and an increase in length of the operation rods 26, 46 can be curbed as compared with a case in which the operation mechanism is electrically insulated from the mechanical contact part by being grounded to the ground, or the like. Thus, an increase in mass of the mobile parts of the operation mechanisms 27, 47 is curbed, and a decrease in the opening speed of the mechanical contact parts 16, 36 can be curbed. Therefore, it is possible to provide the direct-current circuit breaker 1 capable of securing responsiveness of the interrupting operation.

[0090] Further, the pair of unitary switching parts 14 in each of the mechanical switching units 10 are disposed so that the respective operation rods 26, 46 operate on the same straight line by the operation mechanisms 27, 47, and the operating directions of the operation rods 26, 46 by the operation mechanisms 27, 47 are opposite to each other.

[0091] With such a constitution, when the operation rods 26, 46 are operated on the mechanical switching part support plate 33 of each of the mechanical switching units 10, the impact force and the reaction generated on the operation mechanisms 27, 47 can be offset. Thus, it is possible to curb occurrence of a bending moment in the insulating columns 12 which support the mechanical switching units 10 when the operation mechanisms 27, 47 are operated. Therefore, vibration of the mechanical switching part 2 can be curbed, and the excessive increase in size of the insulating column 12, the increase in the number of supporting structures, and the increase in weight thereof can be curbed.

[0092] Further, the pair of unitary switching parts 14 disposed on the mechanical switching part support plate 33 are disposed so that the respective operation mechanisms 27, 47 face each other and come into contact with each other.

[0093] As compared with the constitution in which the respective sealed containers 20 face each other and come into contact with each other, according to the above a constitution, in a situation in which the impact force and the reaction which occur in the operation mechanisms 27, 47 when the operation rods 26, 46 are operated are offset, the impact force and the reaction are not offset via the sealed container 20 that has a relatively low strength and is formed of the bushing but can be offset directly between the operation mechanisms 27, 47 that have a relatively high strength and are formed of a metal material. Thus, application of a large force to the sealed container 20 can be prevented. Accordingly, damage to the unitary switching parts 14 can be curbed, and reliability of the mechanical switching unit 10 can be improved.

[0094] Further, at least a part of the sealed containers 20, 40 of the pair of unitary switching parts 14 disposed on the mechanical switching part support plate 33 is disposed outside of the mechanical switching part support plate 33 in the horizontal direction. The mechanical switching part support plate 33 is formed of a metal material. The movable contacts 18, 38 of the mechanical contact parts 16, 36, the operation mechanisms 27, 47, and the mechanical switching part support plate 33 are provided at the same potential.

[0095] With such a constitution, While the operation mechanisms 27, 47 are brought close to the mechanical switching part support plate 33, portions (the first flanges 22, 42) of the sealed containers 20, 40 at the same potential as that of the fixed contacts 17, 37 can be moved away from the mechanical switching part support plate 33. Therefore, as compared with a case in which the whole of the sealed containers 20, 40 is disposed at the position in which the sealed containers 20, 40 overlap the mechanical switching part support plate 33 in the horizontal direction, the unitary switching parts 14 and the mechanical switching part support plate 33 can be brought close to each other in the vertical direction while the mechanical switching part support plate 33 and the portion of the sealed containers 20, 40 having the same potential as that of the fixed contacts 17, 37 are insulated. Therefore, an increase in the size of the mechanical switching part 2 in the vertical direction can be curbed, and the bending moment generated in the insulating column 12 which supports the mechanical switching unit 10 can be curbed.

[0096] Further, since the plurality of mechanical switching units 10 are stacked in multiple stages with respect to the insulating column 12, an installation area of the direct-current circuit breaker 1 can be reduced as compared with the case in which the mechanical switching units are disposed side by side. The same operation and effect can be obtained also in that the plurality of semiconductor switching units 60 are stacked in multiple stages with respect to the insulating column 62. Further, the same operation and effect can be obtained also in that the commutation device 4 is stacked on the upper portion of the semiconductor switching part 3.

[0097] Further, in each of the plurality of mechanical switching units 10, at least a part of the sealed containers 20, 40 of each of the pair of unitary switching parts 14 are disposed outside of the mechanical switching part support plate 33 in the horizontal direction.

[0098] With such a constitution, in the mechanical switching part 2, since all the unitary switching parts 14 are connected in series with each other simply by stacking the mechanical switching units 10 in multiple stages in the vertical direction and connecting the first flanges 22, 42 of the sealed containers 20, 40 adjacent to each other in the vertical direction with the inter-unit bus bar 52, the voltage can be easily increased.

[0099] Further, according to the constitution of the embodiment, the bus bar 52 may also be installed with a sufficient insulation distance from the mechanical switching part support plate 33.

[0100] Further, the operation mechanisms 27, 47 of the pair of unitary switching parts 14 disposed on the mechanical switching part support plate 33 are disposed to be opposed to and in contact with each other. Therefore, when the operation rods 26, 46 are operated, the impact force and the reaction generated in the operation mechanisms 27, 47 can be offset more effectively.

[0101] Further, both of the pair of unitary switching parts 14 disposed on the mechanical switching part support plate 33 constitute only one of the high voltage contact 14A and the current interrupting contact 14B. Therefore, when the operation rods 26, 46 in the pair of unitary switching parts 14 are operated, the impact force and the reaction generated in the operation mechanisms 27, 47 can be made equal to each other. Thus, the impact force and the reaction can be offset more effectively.

[0102] Further, the operation mechanisms 27, 47 are disposed outside of the sealed containers 20, 40. Therefore, maintainability of the operation mechanisms 27, 47 can be improved as compared with a case in which the operation mechanism is disposed in the inside of the sealed container.

[0103] Further, in the above-described first embodiment, although the mechanical contact part 16 of the unitary switching part 14 constituting the high voltage contact 14A is a gas contact, the present invention is not limited thereto. For example, as shown in FIG. 13, the mechanical contact part 36 of the unitary switching part 14 constituting the high voltage contact 14A may be a vacuum interrupter having a withstand voltage performance equivalent to that of the mechanical contact part 16 in the first embodiment.

[0104] Further, in the above-described first embodiment, although the pair of current interrupting contacts 14B are provided in the mechanical switching part 2, the present invention is not limited thereto. At least one current interrupting contact 14B may be provided in the mechanical switching part 2. As an example of the constitution in which one current interrupting contact 14B is provided in the mechanical switching part, the uppermost mechanical switching unit 10 may include both the high voltage contact 14A and the current interrupting contact 14B. Also, in this case, the pair of unitary switching parts 14 are preferably disposed so that the respective operation rods 26, 46 operate on the same straight line by the operation mechanisms 27, 47 and the operating directions of the operation rods 26, 46 by the operation mechanisms 27, 47 are opposite to each other. Thus, as described above, the vibration of the mechanical switching part can be curbed, and the excessive increase in size of the insulating column 12, the increase of the number of supporting structures, and the increase in weight thereof can be curbed.

[0105] Further, in the above-described first embodiment, although six high voltage contacts 14A are provided in the mechanical switching part 2, the invention is not limited thereto. At least one high voltage contact 14A may be provided in the mechanical switching part 2.

(Second embodiment)

[0106] FIG. 14 is a front view schematically showing a mechanical switching part according to a second embodiment. In FIG. 14, illustration of the power supply part 30 and the control part 31 (refer to FIGS. 1 and 3) of each of the mechanical switching unit 10 is omitted.

[0107] The second embodiment shown in FIG. 14 is different from the first embodiment in that the current interrupting contact 14B is disposed so that the operating direction of the operation rod 46 by the operation mechanism 47 follows an extending direction (that is, the vertical direction) of the insulating column 12.

[0108] As shown in FIG. 14, the uppermost mechanical switching unit 10 includes one current interrupting contact 14B, the power supply part and the control part which are not shown, and the mechanical switching part support plate 33 on which the current interrupting contact 14B (the unitary switching part 14), the power supply part and control part are fixedly disposed. The current interrupting contact 14B is placed longitudinally. That is, the current interrupting contact 14B is disposed so that the above-described second direction follows the vertical direction. The operation rod 46 is disposed to extend in the vertical direction. The operation mechanism 47 is located between the sealed container 40 and the mechanical switching part support plate 33 and is fixed to the mechanical switching part support plate 33.

[0109] With such a constitution, since the operating direction of the operation rod 46 follows the extending direction of the insulating column 12, it is possible to curb the occurrence of the bending moment in the insulating column 12 due to the impact force and the reaction generated in the operation mechanism 47 at the time of the opening operation of the current interrupting contact 14B. Therefore, the vibration of the mechanical switching part 2 can be curbed, and the excessive increase in size of the insulating column 12, the increase in the number of supporting structures, and the increase in weight thereof can be curbed.

[0110] In the second embodiment shown in FIG. 14, although the mechanical switching units 10 are stacked in two stages, the present invention is not limited thereto, and the mechanical switching units 10 may be stacked in three or more stages.

[0111] Further, in the second embodiment, although the constitution in which the current interrupting contact 14B is longitudinally disposed has been described, the present invention is not limited thereto, and the high voltage contact 14A may be disposed longitudinally.

(Third embodiment)

[0112] FIG. 15 is a front view schematically showing a mechanical switching part according to a third embodiment. In FIG. 15, illustration of the power supply part 30 and the control part 31 (refer to FIGS. 1 and 3) of a mechanical switching unit 110 is omitted.

[0113] The third embodiment as shown in FIG. 15 is different from the above-described embodiments in that the pair of unitary switching parts 14 are directly supported by the insulating column 12.

[0114] As shown in FIG. 15, the mechanical switching unit 110 includes the pair of unitary switching parts 14, the power supply part and the control unit which are not shown, and a connection member 53 which connects the high voltage contact 14A with the current interrupting contact 14B. The first unitary switching part 14 constitutes the high voltage contact 14A. The second unitary switching part 14 constitutes the current interrupting contact 14B. The high voltage contact 14A and the current interrupting contact 14B are longitudinally disposed on the insulating column 12. The high voltage contact 14A is fixedly disposed on the insulating column 12 so that the above-described first direction follows the vertical direction. The operation rod 26 is disposed to extend in the vertical direction. The operation mechanism 27 is located between the sealed container 20 and an upper end portion of the insulating column 12 and is fixed to the insulating column 12. Further, the current interrupting contact 14B is fixedly disposed on the insulating column 12 so that the above-described second direction follows the vertical direction. The operation rod 46 is disposed to extend in the vertical direction. The operation mechanism 47 is located between the sealed container 40 and the upper end portion of the insulating column 12 and is fixed to the insulating column 12.

[0115] The connection member 53 is formed of a conductive metal material or the like. The connection member 53 is disposed between the high voltage contact 14A and the current interrupting contact 14B. The connection member 53 mechanically and electrically connects the second flange 23 of the unitary switching part 14 constituting the high voltage contact 14A with the second flange 43 of the unitary switching part 14 constituting the current interrupting contact 14B. Thus, the pair of unitary switching parts 14 are electrically connected in series to each other and mechanically fixed to each other.

[0116] With such a constitution, since the unitary switching part 14 is directly supported by the insulating column 12, the constitution of the mechanical switching part having the mechanical switching unit 110 can be simplified.

[0117] Further, in the unitary switching part 14, since the operating direction of the operation rod 46 follows the extending direction of the insulating column 12, it is possible to curb the occurrence of the bending moment in the insulating column 12 due to the impact force and the reaction generated in the operation mechanisms 27, 47 at the time of the opening operation of the unitary switching part 14, as in the above-described second embodiment. Thus, the vibration of the mechanical switching part having the mechanical switching unit 110 can be curbed, and the excessive increase in size of the insulating column 12, the increase of the number of supporting structures, and the increase in weight thereof can be curbed.

[0118] Furthermore, since the pair of unitary switching parts 14 are mechanically fixed to each other by the connection member 53, the vibration of the mechanical switching part having the mechanical switching unit 110 can be curbed more reliably.

[0119] Also, in the above-described third embodiment, although the case in which the high voltage contact 14A and the current interrupting contact 14B are constituted by the pair of unitary switching parts 14 directly supported by the insulating column 12 has been described as an example, the present invention is not limited thereto. Both of the pair of unitary switching parts 14 directly supported by the insulating column 12 may constitute the high voltage contact 14A, and both of the pair of unitary switching parts 14 may constitute the current interrupting contact 14B.

(Fourth embodiment)

[0120] FIG. 16 is a front view schematically showing a mechanical switching part according to a fourth embodiment. In FIG. 16, illustration of the power supply part 30 and the control part 31 (refer to FIGS. 1 and 3) of the mechanical switching unit 10 is omitted.

[0121] The fourth embodiment as shown in FIG. 16 is different from the above-described embodiments in that the insulating column 12 has a damping member 54 which absorbs vibration.

[0122] As shown in FIG. 16, the damping member 54 is disposed at the insulating column 12 between the mechanical switching part support plates 33 of the mechanical switching units 10 adjacent to each other in the vertical direction and at the insulating column 12 between the mechanical switching part support plate 33 of the lowermost mechanical switching unit 10 and the foundation 5. Specifically, the damping members 54 are respectively disposed at a connecting portion between the foundation 5 and the insulating column 12 and a connecting portion between an upper surface of each of the mechanical switching part support plates 33 and the insulating column 12. The damping member 54 absorbs the vibration transmitted through the insulating column 12. The damping member 54 is, for example, an air damper (an air spring) in which a bellows-shaped rubber member containing air is sandwiched between metal plates, an anti-vibration rubber, or the like.

[0123] With such a constitution, the vibration generated by the mechanical switching unit 10 is absorbed by the damping member 54. Thus, it is possible to curb transmission of the vibration generated in the mechanical switching unit 10 to the other mechanical switching unit 10 along the insulating column 12. Further, since a force in a bending direction of the insulating column 12 can be absorbed by the damping member 54, the generation of the bending moment in the insulating column 12 can be curbed. Therefore, the vibration of the mechanical switching part 2 can be curbed, and the excessive increase in size of the insulating column 12, the increase in the number of supporting structures, and the increase in weight thereof can be curbed.

[0124] In the example shown in FIG. 16, although the damping members 54 are respectively disposed at the connecting portion between the foundation 5 and the insulating column 12 and the connecting portion between the upper surface of each of the mechanical switching part support plates 33 and the insulating column 12, the present invention is limited thereto. For example, the damping members may be disposed at a connection portion between a lower surface of each of the mechanical switching part support plates 33 and the insulating column 12.

(Fifth embodiment)

[0125] FIG. 17 is a front view schematically showing a mechanical switching part according to a fifth embodiment. In FIG. 17, illustration of the power supply part 30 and the control part 31 (refer to FIGS. 1 and 3) of the mechanical switching unit 10 is omitted.

[0126] The fifth embodiment as shown in FIG. 17 is different from the above-described embodiments in that the insulating column 12 is hung on the ceiling of a building 6.

[0127] As shown in FIG. 17, the direct-current circuit breaker 1 is installed in the building 6 in consideration of the maintainability, an influence of contamination, or the like. The respective wall portions which constitutes the building 6 is provided at a position which maintains an insulation distance with respect to a high voltage part of the direct-current circuit breaker 1.

[0128] The insulating column 12 is hung on the ceiling of the building 6. The insulating column 12 has a joint 56 and supports the mechanical switching unit 10 in a rockable manner with respect to the building 6. The joint 56 is provided in a connecting portion between the insulating column 12 and the ceiling of the building 6 and a connecting portion between the insulating column 12 and the upper and lower surfaces of the mechanical switching part support plate 33.

[0129] The length of the insulating column 12 is set to be able to electrically insulate the mechanical switching units 10 adjacent to each other in the vertical direction when the power is interrupted and also to electrically insulate the whole of the mechanical switching unit 10 from the ground and the building 6 when the power is applied. That is, the length of a portion of the insulating column 12 provided between the mechanical switching unit 10 located uppermost and the ceiling of the building 6 is set to electrically insulate the whole of the mechanical switching unit 10 from the building 6 when the power is applied. Further, the entire length of the insulating column 12 is set to electrically insulate the entire mechanical switching unit 10 from the foundation 5 when the power is applied.

[0130] With such a constitution, since the insulating column 12 supports each of the mechanical switching units 10 from the upper side, even when a force in the bending direction of the mechanical switching unit 10 acts on the insulating column 12 from the mechanical switching unit 10, the force in the bending direction can be offset by the gravity of the mechanical switching unit 10. Therefore, as compared to the constitution in which each of the insulating column 12 is supported from the lower side, the occurrence of the bending moment in the insulating column 12 can be curbed more reliably. Thus, the vibration of the mechanical switching part 2 can be curbed, and the excessive increase in size of the insulating column 12, the increase in the number of supporting structures, and the increase in weight thereof can be curbed.

[0131] Moreover, since the insulating column 12 supports the mechanical switching units 10 in a rockable manner with respect to the building 6, even when the building 6 is vibrated due to an earthquake or the like, the transmission of the vibration of the building 6 to the mechanical switching units 10 can be reduced by rocking the mechanical switching units 10 with respect to the building 6. Accordingly, the vibration of the mechanical switching part 2 can be curbed, and the excessive increase in size of the insulating column 12, the increase in the number of supporting structures, and the increase in weight thereof can be curbed.

[0132] In the fifth embodiment, although the constitution in which the insulating column 12 of the mechanical switching part 2 is hung on the ceiling of the building 6 has been described, the insulating column 62 of the semiconductor switching part 3 and the insulating column 90 of the commutation device 4 may also be hung on the ceiling of the building 6. Accordingly, the same operation and effect as those in the case in which the insulating column 12 of the mechanical switching part 2 is hung on the ceiling of the building 6 can be achieved.

[0133] In each of the above-described embodiments, although all of the mechanical switching units 10 are stacked in the vertical direction, the present invention is not limited thereto. For example, the plurality of mechanical switching units 10 may be disposed in parallel in the horizontal direction while being supported by the insulating columns 12.

[0134] Also, in each of the above-described embodiments, although the mechanical switching part support plate 33, the semiconductor switching part support plate 70, and the commutation device support plate 88 are formed separately from each other, the present invention is not limited thereto and may be constituted to share each other. That is, the mechanical switching part support plate 33 may be integrated with at least one of the semiconductor switching part support plate 70 and the commutation device support plate 88. In this case, since the vibration of the mechanical switching part 2 is curbed as described above, the vibration of the semiconductor switching part 3 and the commutation device 4 due to the opening operation of the mechanical switching part 2 is curbed.

[0135] Also, in each of the above-described embodiments, although the mechanical switching part 2 is disposed in parallel to the semiconductor switching part 3 and the commutation device 4, the present invention is not limited thereto. For example, the mechanical switching unit 10 may be stacked on the semiconductor switching unit 60 by sharing the insulating column 12 of the mechanical switching part 2 and the insulating column 62 of the semiconductor switching part 3. Thus, a ground area of the direct-current circuit breaker can be reduced. In this case, as described above, since the vibration of the mechanical switching part 2 is curbed, the vibration of the semiconductor switching part 3 and the commutation device 4 due to the opening operation of the mechanical switching part 2 is curbed.

[0136] Also, in each of the above-described embodiments, although the operation rods 26, 46 and the support portions 28, 48 are entirely formed of a metal material, the invention is not limited thereto.

[0137] For example, to reduce the power application from the movable contacts 18, 38 to the operation mechanisms 27, 47 through the operation rods and the support portions, some of the operation rods and the support portions may be formed of an insulating material or a high resistance material. Also, in this case, since a potential difference between the movable contacts 18, 38 and the operation mechanisms 27, 47 is small, the insulating portion can be made small, and the increase in length of the operation rod can be curbed as compared with a case in which the operation mechanism is electrically insulated from the mechanical contact part by being grounded on the ground, or the like.

[0138] Furthermore, an insulating material may be interposed between the operation mechanisms 27, 47 disposed on the same mechanical switching part support plate 33 and between the operation mechanisms 27, 47 and other members to electrically insulate them from each other. In this case, since the current conduction paths from the operation mechanisms 27, 47 to other members other than the movable contacts 18, 38 are eliminated, the power application from the movable contacts 18, 38 to the operation mechanisms 27, 47 can be curbed.

[0139] Furthermore, a shield which alleviates concentration of an electric field may be appropriately installed in the mechanical switching part 2, the semiconductor switching part 3 and the commutation device 4 in each of the above-described embodiments. For example, the shield may be installed at an end portion of the unitary switching part 14 or end portions of the mechanical switching part support plate 33, the semiconductor switching part support plate 70, and the commutation device support plate 88 which are likely to cause the concentration of the electric field. Thus, a distance required to electrically insulate the respective portions of the mechanical switching part 2, the semiconductor switching part 3, and the commutation device 4 can be shortened, and the increase in size of the direct-current circuit breaker 1 can be curbed. Accordingly, it is possible to provide a direct-current circuit breaker capable of increasing the voltage and curbing the increase in size.

[0140] Also, in each of the above-described embodiments, although the mechanical switching part support plate 33 is formed of a metal material, the present invention is not limited thereto. The mechanical switching part support plate may be formed of an insulating material such as fiber reinforced plastic.

[0141] According to at least one of the above-described embodiments, a mechanical switching part includes a mechanical switching unit having one pair of unitary switching parts including a mechanical contact part having a fixed contact and a movable contact and electrically insulated from the ground, a sealed container which encloses the mechanical contact part and an insulating gas and is electrically insulated from the ground, an operation rod connected to the movable contact, and an operation mechanism connected to the operation rod and provided at the same potential as that of the movable contact of the mechanical contact part; and an insulating column which supports the mechanical switching unit. The mechanical switching unit further includes a mechanical switching part support plate on which the pair of unitary switching parts are disposed and which is supported by the insulating column. The pair of unitary switching parts are disposed so that each of the operation rods is operated on the same straight line by the operation mechanism, operating directions of the operation rods by the operation mechanism are opposite to each other, and each of the operation mechanisms is disposed to face each other. With such a constitution, it is possible to provide a direct-current circuit breaker capable of easily increasing a voltage, curbing an increase in size and ensuring responsiveness of an interrupting operation.

[0142] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the invention defined by the appended claims.

Claims

1. A mechanical switching device (2) for a direct-current circuit breaker (1), the mechanical switching device (2) comprising:

at least one mechanical switching unit (10) having at least one unitary switching part (14) including

a mechanical contact part (16, 36) which has a fixed contact (17, 37) and a movable contact (18, 38) and is electrically insulated from the ground,
a sealed container (20, 40) which encloses the mechanical contact part (16, 36) and an insulating gas and is electrically insulated from the ground,
an operation rod (26, 46) which is connected to the movable contact (18, 38) and extends from an inside of the sealed container (20, 40) to outside thereof, and
an operation mechanism (27, 47) which is connected to the operation rod (26, 46), causes the movable contact (18, 38) to be brought into contact with or separated from the fixed contact (17, 37) and is provided at the same potential as that of the movable contact (18, 38);

an insulating column (12) which supports the at least one mechanical switching unit (10); and
a current interrupting contact (14B), and a high voltage contact (14A) having a withstand voltage performance higher than or equivalent to that of the current interrupting contact (14B),
wherein the at least one mechanical switching unit (10) further includes a mechanical switching part support plate (33) on which the at least one unitary switching part (14) is disposed and which is supported by the insulating column (12),
the at least one unitary switching part (14) includes a first unitary switching part (14) and a second unitary switching part (14),
the first unitary switching part (14) constitutes one of the current interrupting contact (14B) and the high voltage contact (14A),
the second unitary switching part (14) constitutes one of the current interrupting contact (14B) and the high voltage contact (14A),
the first unitary switching part (14) and the second unitary switching part (14) are disposed so that the respective operation rods (26, 46) are operated on the same straight line by the operation mechanism (27, 47), operating directions of the operation rods (26, 46) using the operation mechanism (27, 47) are opposite to each other, and the respective operation mechanisms (27, 47) face each other,
at least a part of the sealed container (20, 40) of the first unitary switching part (14) is disposed outside of the mechanical switching part support plate (33) in a horizontal direction,
at least a part of the sealed container (20, 40) of the second unitary switching part (14) is disposed outside of the mechanical switching part support plate (33) in a horizontal direction, and
the current interrupting contact (14B) and the high voltage contact (14A) are connected in series to form a mechanical contact module (34), both ends of the mechanical contact module (34) are configured to connect to a direct-current transmission system,
characterized in that
the at least one mechanical switching unit (10) includes a plurality of mechanical switching units (10) stacked in multiple stages in a vertical direction with respect to the insulating column (12),
the sealed container (20, 40) of the first unitary switching part (14) and the sealed container (20, 40) of the second unitary switching part (14) in each of the plurality of mechanical switching units (10) are connected in series to each other by an intra-unit bus bar (51),
the plurality of mechanical switching units (10) includes a first mechanical switching unit (10) and a second mechanical switching unit (10) adjacent to each other in the vertical direction, and a portion of the sealed container (20, 40) of the first unitary switching part (14) of the first mechanical switching unit (10) which is disposed outside of the mechanical switching unit support plate (33) in a horizontal direction and a portion of the sealed container (20,40) of the second unitary switching part (14) of the second mechanical switching unit (10) which is disposed outside of the mechanical switching unit support plate (33) in the horizontal direction are connected in series to each other by an inter-unit bus bar (52).

2. The mechanical switching device (2) for a direct-current circuit breaker (1) according to claim 1, wherein the mechanical switching part support plate (33) provided in the at least one mechanical switching unit (10) is formed of a metal material and is provided at the same potential as that of the operation mechanism (27, 47).

3. The mechanical switching device (2) for a direct-current circuit breaker (1) according to claim 1 or 2, wherein the operation mechanism (27, 47) of the first unitary switching part (14) and the operation mechanism (27, 47) of the second unitary switching part (14) are in contact with each other.

4. The mechanical switching device (2) for a direct-current circuit breaker (1) according to any one of claims 1 to 3, wherein both the first unitary switching part (14) and the second unitary switching part (14) constitute one of the high voltage contact (14A) and the current interrupting contact (14B).

5. The mechanical switching device (2) for a direct-current circuit breaker (1) according to any one of claims 1 to 4, wherein the insulating column (12) includes a damping member (54) which absorbs vibration.

6. The mechanical switching device (2) for a direct-current circuit breaker (1) according to any one of claims 1 to 5, wherein:

   the mechanical switching device (2) is installed in a building (6), and
   the insulating column (12) is hung on a ceiling of the building (6).

7. A direct-current circuit breaker (1) comprising the mechanical switching device (2) according to any one of claims 1 to 6, a semiconductor switching part (3), and a commutation device (4),

   wherein the semiconductor switching part (3) includes a semiconductor module (64) including a semiconductor stack (65) in which a plurality of semiconductor elements (65a) are connected in series, and a surge absorber (68) connected in parallel to the semiconductor module (64),
   the commutation device (4) includes a commutation circuit (80) constituted by connecting in parallel a pair of legs (82) formed by connecting one pair of semiconductor elements (82a) in series with a capacitor (84), and a commutation reactor (86) connected in series to the commutation circuit (80),
   the commutation circuit (80) and the commutation reactor (86) are connected in parallel to the current interrupting contact (14B),
   the commutation circuit (80) is connected to the high voltage contact (14A) side from the commutation reactor (86), and
   the semiconductor module (64) is connected in parallel to the high voltage contact (14A) and the commutation circuit (80).

8. The direct-current circuit breaker (1) according to claim 7, wherein:

   the semiconductor switching part (3) includes a semiconductor switching part support plate (70) on which at least one of the semiconductor module (64) and the surge absorber (68) is disposed,
   the commutation device (4) includes a commutation device support plate (88) on which at least one of the commutation circuit (80) and the commutation reactor (86) is disposed, and
   the mechanical switching part support plate (33) is integrated with at least one of the semiconductor switching part support plate (70) and the commutation device support plate (88).

Patentansprüche

1. Mechanische Schaltvorrichtung (2) für einen Gleichstromschutzschalter (1), wobei die mechanische Schaltvorrichtung (2) umfasst:

   mindestens eine mechanische Schalteinheit (10) mit mindestens einem einheitlichen Schaltteil (14), aufweisend

      ein mechanisches Kontaktteil (16, 36), das einen festen Kontakt (17, 37) und einen beweglichen Kontakt (18, 38) aufweist und gegenüber der Erde elektrisch isoliert ist,
      einen abgedichteten Behälter (20, 40), der das mechanische Kontaktteil (16, 36) und ein Isoliergas umschließt und gegenüber der Erde elektrisch isoliert ist,
      eine Betätigungsstange (26, 46), die mit dem beweglichen Kontakt (18, 38) verbunden ist und sich von der Innenseite des abgedichteten Behälters (20, 40) zur Außenseite davon erstreckt, und
      einen mit der Betätigungsstange (26, 46) verbunden Betätigungsmechanismus (27, 47), der bewirkt, dass der bewegliche Kontakt (18, 38) mit dem festen Kontakt (17, 37) in Kontakt gebracht oder von diesem getrennt wird und der auf dem gleichen Potential wie der bewegliche Kontakt (18, 38) vorgesehen ist;

   eine Isoliersäule (12), die die mindestens eine mechanische Schalteinheit (10) trägt; und
   einen Stromunterbrechungskontakt (14B) und

einen Hochspannungskontakt (14A) mit einer Spannungsfestigkeit, die höher oder gleich der des Stromunterbrechungskontakts (14B) ist,
wobei die mindestens eine mechanische Schalteinheit (10) ferner eine Trägerplatte (33) des mechanischen Schaltteils aufweist, auf der das mindestens eine einheitliche Schaltteil (14) angeordnet ist und die von der Isoliersäule (12) getragen wird,
das mindestens eine einheitliche Schaltteil (14) ein erstes einheitliches Schaltteil (14) und ein zweites einheitliches Schaltteil (14) aufweist,
das erste einheitliche Schaltteil (14) den Stromunterbrechungskontakt (14B) oder den Hochspannungskontakt (14A) bildet,
das zweite einheitliche Schaltteil (14) einen von dem Stromunterbrechungskontakt (14B) oder dem Hochspannungskontakt (14A) bildet,
das erste einheitliche Schaltteil (14) und das zweite einheitliche Schaltteil (14) so angeordnet sind, dass die jeweiligen Betätigungsstangen (26, 46) durch den Betätigungsmechanismus (27, 47) auf derselben geraden Linie betätigt werden, wobei Betätigungsrichtungen der Betätigungsstangen (26, 46), die den Betätigungsmechanismus (27, 47) verwenden, einander gegenüberliegen, und die jeweiligen Betätigungsmechanismen (27, 47) einander gegenüberliegen,
mindestens ein Teil des abgedichteten Behälters (20, 40) des ersten einheitlichen Schaltteils (14) in horizontaler Richtung außerhalb der Trägerplatte (33) des mechanischen Schaltteils angeordnet ist,
mindestens ein Teil des abgedichteten Behälters (20, 40) des zweiten einheitlichen Schaltteils (14) in horizontaler Richtung außerhalb der Trägerplatte (33) des mechanischen Schaltteils angeordnet ist, und
der Stromunterbrechungskontakt (14B) und der Hochspannungskontakt (14A) in Reihe geschaltet sind, um ein mechanisches Kontaktmodul (34) zu bilden,
beide Enden des mechanischen Kontaktmoduls (34) für den Anschluss an ein Gleichstromübertragungssystem ausgebildet sind,
dadurch gekennzeichnet, dass
die mindestens eine mechanische Schalteinheit (10) eine Vielzahl von mechanischen Schalteinheiten (10) aufweist, die in mehreren Stufen in vertikaler Richtung in Bezug auf die Isoliersäule (12) gestapelt sind,
der abgedichtete Behälter (20, 40) des ersten einheitlichen Schaltteils (14) und der abgedichtete Behälter (20, 40) des zweiten einheitlichen Schaltteils (14) in jeder der Vielzahl von mechanischen Schalteinheiten (10) durch eine geräteinterne Sammelschiene (51) in Reihe miteinander verbunden sind,
die Vielzahl von mechanischen Schalteinheiten (10) eine erste mechanische Schalteinheit (10) und eine zweite mechanische Schalteinheit (10) aufweisen, die in vertikaler Richtung nebeneinander liegen, und
ein Abschnitt des abgedichteten Behälters (20, 40) des ersten einheitlichen Schaltteils (14) der ersten mechanischen Schalteinheit (10), der außerhalb der Trägerplatte (33) der mechanischen Schalteinheit in horizontaler Richtung angeordnet ist, und ein Abschnitt des abgedichteten Behälters (20,40) des zweiten einheitlichen Schaltteils (14) der zweiten mechanischen Schalteinheit (10), der außerhalb der Trägerplatte (33) der mechanischen Schalteinheit in horizontaler Richtung angeordnet ist, durch eine Sammelschiene (52) zwischen den Einheiten miteinander in Reihe geschaltet sind.

2. Mechanische Schaltvorrichtung (2) für einen Gleichstromschutzschalter (1) nach Anspruch 1, wobei die in der mindestens einen mechanischen Schalteinheit (10) vorgesehene Trägerplatte (33) des mechanischen Schaltteils aus einem Metallmaterial gebildet ist und auf dem gleichen Potential wie der Betätigungsmechanismus (27, 47) liegt.

3. Mechanische Schaltvorrichtung (2) für einen Gleichstromschutzschalter (1) nach Anspruch 1 oder 2, wobei der Betätigungsmechanismus (27, 47) des ersten einheitlichen Schaltteils (14) und der Betätigungsmechanismus (27, 47) des zweiten einheitlichen Schaltteils (14) miteinander in Kontakt stehen.

4. Mechanische Schaltvorrichtung (2) für einen Gleichstromschutzschalter (1) nach einem der Ansprüche 1 bis 3, wobei sowohl das erste einheitliche Schaltteil (14) als auch das zweite einheitliche Schaltteil (14) einen von dem Hochspannungskontakt (14A) und dem Stromunterbrechungskontakt (14B) bilden.

5. Mechanische Schaltvorrichtung (2) für einen Gleichstromschutzschalter (1) nach einem der Ansprüche 1 bis 4, wobei die Isoliersäule (12) ein Dämpfungselement (54) aufweist, das Vibrationen absorbiert.

6. Mechanische Schaltvorrichtung (2) für einen Gleichstromschutzschalter (1) nach einem der Ansprüche 1 bis 5, wobei:

die mechanische Schaltvorrichtung (2) in einem Gebäude (6) installiert ist, und
die Isoliersäule (12) an einer Decke des Gebäudes (6) aufgehängt ist.

7. Gleichstromschutzschalter (1) mit der mechanische Schaltvorrichtung (2) nach einem der Ansprüche 1 bis 6, einem Halbleiterschaltteil (3), und einer Kommutierungsvorrichtung (4),

wobei der Halbleiterschaltteil (3) ein Halbleitermodul (64) aufweist, das einen Halbleiterstapel (65), in dem eine Vielzahl von Halbleiterelementen (65a) in Reihe geschaltet sind, und einen parallel zu dem Halbleitermodul (64) geschalteten Überspannungsableiter (68) aufweist,
die Kommutierungsvorrichtung (4) eine Kommutierungsschaltung (80) aufweist, die ausgebildet wird durch Parallelschaltung eines Paars von Zweigen (82), die gebildet werden durch Reihenschaltung eines Paars von Halbleiterelementen (82a) mit einem Kondensator (84), und eine Kommutierungsdrossel (86) in Reihenschaltung mit der Kommutierungsschaltung (80),
die Kommutierungsschaltung (80) und die Kommutierungsdrossel (86) parallel zu dem Stromunterbrechungskontakt (14B) geschaltet sind,
die Kommutierungsschaltung (80) mit der Hochspannungskontakt-(14A) Seite von der Kommutierungsdrossel (86) verbunden ist, und
das Halbleitermodul (64) parallel zu dem Hochspannungskontakt (14A) und der Kommutierungsschaltung (80) geschaltet ist.

8. Gleichstromschutzschalter (1) nach Anspruch 7, wobei:

der Halbleiterschaltteil (3) ein Trägerplatte (70) des Halbleiterschaltteils aufweist, auf der mindestens eines von dem Halbleitermodul (64) und dem Überspannungsableiter (68) angeordnet ist,
die Kommutierungsvorrichtung (4) eine Trägerplatte (88) der Kommutierungsvorrichtung aufweist, auf der zumindest eine von der Kommutierungsschaltung (80) und der Kommutierungsdrossel (86) angeordnet ist, und
die Trägerplatte (33) des mechanischen Schaltteils mit mindestens einer von der Trägerplatte (70) des Halbleiterschaltteils und der Trägerplatte (88) der Kommutierungsvorrichtung integriert ist.

Revendications

1. Dispositif de commutation mécanique (2) pour un disjoncteur à courant
continu (1), le dispositif de commutation mécanique (2) comprenant :

au moins une unité de commutation mécanique (10) comportant au moins
une partie de commutation unitaire (14) comprenant une partie de contact mécanique (16, 36) qui possède un contact fixe (17, 37)
et un contact mobile (18, 38) et est isolé électriquement du sol,

un conteneur étanche (20, 40) qui renferme la partie de contact mécanique (16, 36) et un gaz isolant et est électriquement isolé du sol,
une tige de commande (26, 46) qui est raccordée au contact mobile (18, 38) et s'étend depuis l'intérieur du récipient étanche (20, 40) jusqu'à l'extérieur de celui-ci, et
un mécanisme de commande (27, 47) qui est raccordé à la tige de commande (26, 46), amène le contact mobile (18, 38)) à être mis en contact ou séparé du contact fixe (17, 37) et est prévu au même potentiel que celui du contact mobile (18, 38) ;
une colonne isolante (12) qui supporte la ou les unités de commutation mécanique (10) ; et
un contact d'interruption de courant (14B), et un contact haute tension (14A) ayant une performance de tension de tenue supérieure ou équivalente à celle du contact d'interruption de courant (14B),
dans lequel la au moins une unité de commutation mécanique (10) comprend en outre une plaque de support de partie de commutation mécanique (33) sur laquelle la au moins une partie de commutation unitaire (14) est disposée et qui est supportée par la colonne isolante (12),
la au moins une partie de commutation unitaire (14) comprend une première partie de commutation unitaire (14) et une deuxième partie de commutation unitaire (14),
la première partie de commutation unitaire (14) constitue l'un du contact d'interruption de courant (14B) et du contact haute tension (14A),
la deuxième partie de commutation unitaire (14) constitue un du contact d'interruption de courant (14B) et du contact haute tension (14A),
la première partie de commutation unitaire (14) et la deuxième partie de commutation unitaire (14) sont disposées de telle sorte que les tiges de commande respectives (26, 46) soient actionnées sur la même ligne droite par le mécanisme de commande (27, 47) , les directions de fonctionnement des tiges de commande (26, 46) utilisant le mécanisme de commande (27, 47) sont opposées l'une à l'autre et les mécanismes de commande respectifs (27, 47) se font face,
au moins une partie du récipient étanche (20, 40) de la première partie de commutation unitaire (14) est disposée à l'extérieur de la plaque de support de partie de commutation mécanique (33) dans une direction horizontale,

au moins une partie du récipient étanche (20, 40) de la deuxième partie de commutation unitaire (14) est disposé à l'extérieur de la plaque de support de partie de commutation mécanique (33) dans une direction horizontale et
le contact d'interruption de courant (14B) et le contact haute tension (14A) sont connectés en série pour former un module de contact mécanique (34),
les deux extrémités du module de contact mécanique (34) sont configurées pour se connecter à un système de transmission à courant continu,
caractérisé en ce que
la ou les unités de commutation mécanique (10) comprennent une pluralité d'unités de commutation mécanique (10) empilées en plusieurs étages dans une direction verticale par rapport à la colonne isolante (12),
le conteneur étanche (20, 40) de la première partie de commutation unitaire (14) et le conteneur étanche (20, 40) de la deuxième partie de commutation unitaire (14) dans chacune de la pluralité d'unités de commutation mécanique (10) est connecté en série les unes aux autres par une barre omnibus intra-unité (51),
la pluralité d'unités de commutation mécanique les unités de commutation (10) comprennent une première unité de commutation mécanique (10) et une deuxième unité de commutation mécanique (10) adjacentes l'une à l'autre dans la direction verticale et
une partie du conteneur étanche (20, 40) de la première partie de commutation unitaire (14) de la première unité de commutation mécanique (10) qui est disposée à l'extérieur de la plaque de support d'unité de commutation mécanique (33) dans une direction horizontale et une partie du conteneur étanche (20, 40) de la deuxième partie de commutation unitaire (14) de la deuxième unité de commutation mécanique (10) qui est disposée à l'extérieur de la plaque de support d'unité de commutation mécanique (33) dans la direction horizontale sont connectées en série les unes aux autres par une barre omnibus inter-unités (52).

2. Dispositif de commutation mécanique (2) pour disjoncteur à courant continu (1) selon la revendication 1, dans lequel la plaque de support (33) de la partie de commutation mécanique prévue dans au moins une unité de commutation mécanique (10) est formée d'un matériau métallique et est prévue au même potentiel que celui du mécanisme de commande (27, 47).

3. Dispositif de commutation mécanique (2) pour disjoncteur à courant continu (1) selon la revendication 1 ou 2, dans lequel le mécanisme de commande (27, 47) de la première partie de commutation unitaire (14) et le mécanisme de commande (27, 47) de la deuxième partie de commutation unitaire (14) sont en contact l'un avec l'autre.

4. Dispositif de commutation mécanique (2) pour disjoncteur à courant continu (1) selon une quelconque des revendications 1 à 3, dans lequel à la fois la première partie de commutation unitaire (14) et la deuxième partie de commutation unitaire (14) constituent un du contact haute tension (14A) et du contact de coupure de courant (14B).

5. Dispositif de commutation mécanique (2) pour disjoncteur à courant continu (1) selon une quelconque des revendications 1 à 4, dans lequel la colonne isolante (12) comprend un organe amortisseur (54) qui absorbe les vibrations.

6. Dispositif de commutation mécanique (2) pour disjoncteur continu (1)
selon une quelconque des revendications 1 à 5, dans lequel :

 le dispositif de commutation mécanique (2) est installé dans un bâtiment (6),
 et
 la colonne isolante (12) est suspendue au plafond du bâtiment (6).

7. Disjoncteur à courant continu (1) comprenant le dispositif de commutation mécanique (2) selon une quelconque des revendications 1 à 6, une partie de commutation à semi-conducteur (3) et un dispositif de commutation (4),

 dans lequel la partie de commutation à semi-conducteur (3) comprend un module à semi-conducteur (64) comprenant un empilement semi-conducteur (65) dans lequel une pluralité d'éléments semi-conducteurs (65a) sont connectés en série, et un absorbeur de surtension (68) connecté en parallèle au module semi-conducteur (64),
 le dispositif de commutation (4) comprend un circuit de commutation (80) constitué en connectant en parallèle une paire de pattes (82) formée en connectant une paire d'éléments semi-conducteurs (82a) en série avec un condensateur (84), et un réacteur de commutation (86) connecté en série au circuit de commutation (80),
 le circuit de commutation (80) et le réacteur de commutation (86) sont connectés en parallèle au contact de coupure de courant (14B),
 le circuit de commutation (80) est connecté du côté du contact haute tension (14A) du réacteur de commutation (86) et

le module semi-conducteur (64) est connecté en parallèle au contact haute tension (14A) et au circuit de commutation (80).

8. Disjoncteur à courant continu (1) selon la revendication 7, dans lequel :

la partie de commutation à semi-conducteur (3) comprend une plaque de support de partie de commutation à semi-conducteur (70) sur laquelle est disposé au moins un parmi le module semi-conducteur (64) et l'absorbeur de surtension (68),
le dispositif de commutation (4) comprend une plaque de support de dispositif de commutation (88) sur laquelle est disposé au moins un parmi le circuit de commutation (80) et le réacteur de commutation (86), et
la plaque de support de partie de commutation mécanique (33) est intégrée à au moins une des plaques de support de partie de commutation à semi-conducteur (70) et la plaque de support de dispositif de commutation (88).

FIG. 1

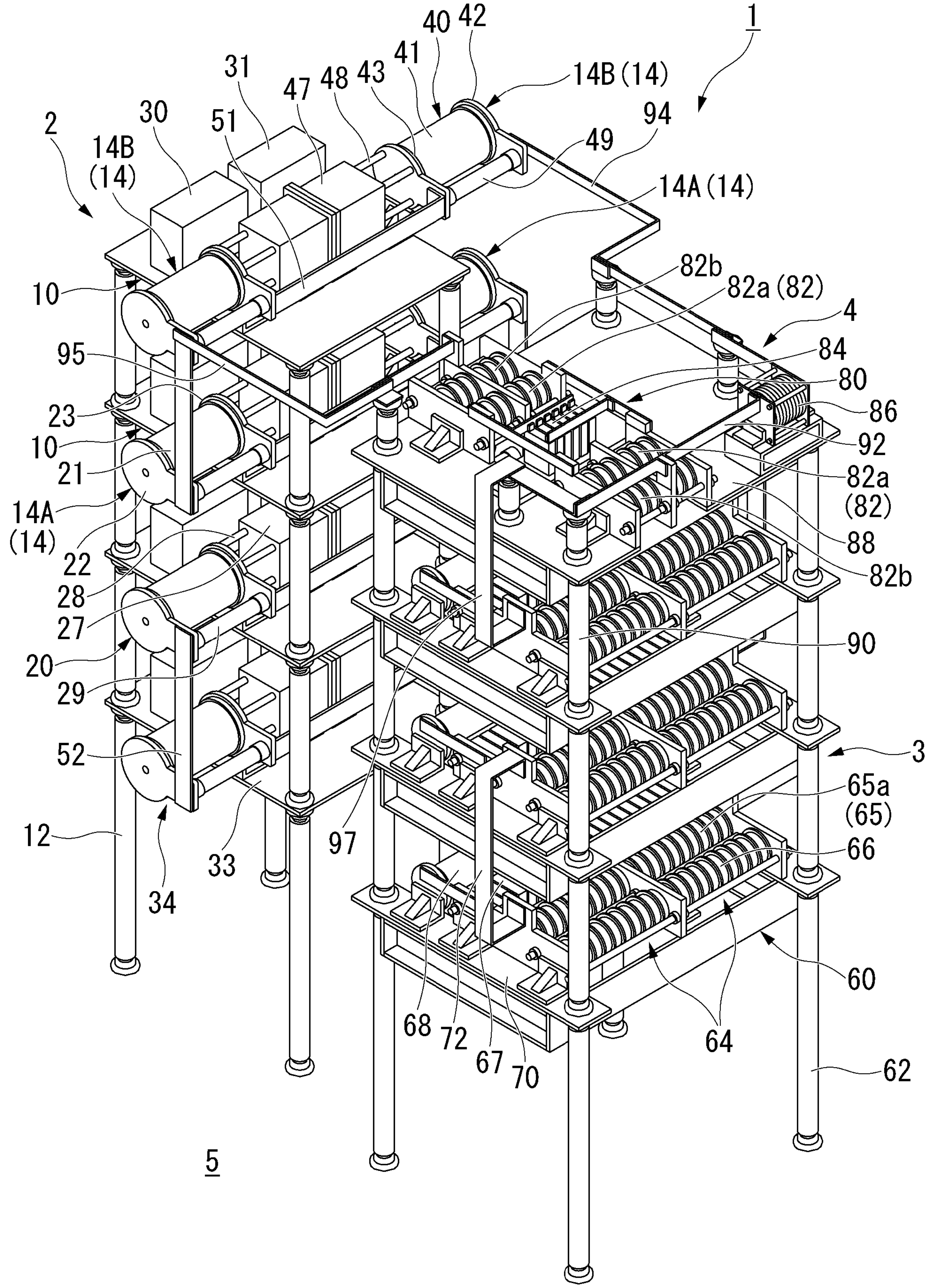

1
2
30
31
47
48
43
41
40
42
14B (14)
94
49
14A (14)
14B
(14)
51
10
95
23
10
21
14A
(14)
22
28
27
20
29
52
12
34
33
97
82b
82a (82)
4
84
80
86
92
82a
(82)
88
82b
90
3
65a
(65)
66
60
64
62
68
72
67
70
5

FIG. 2

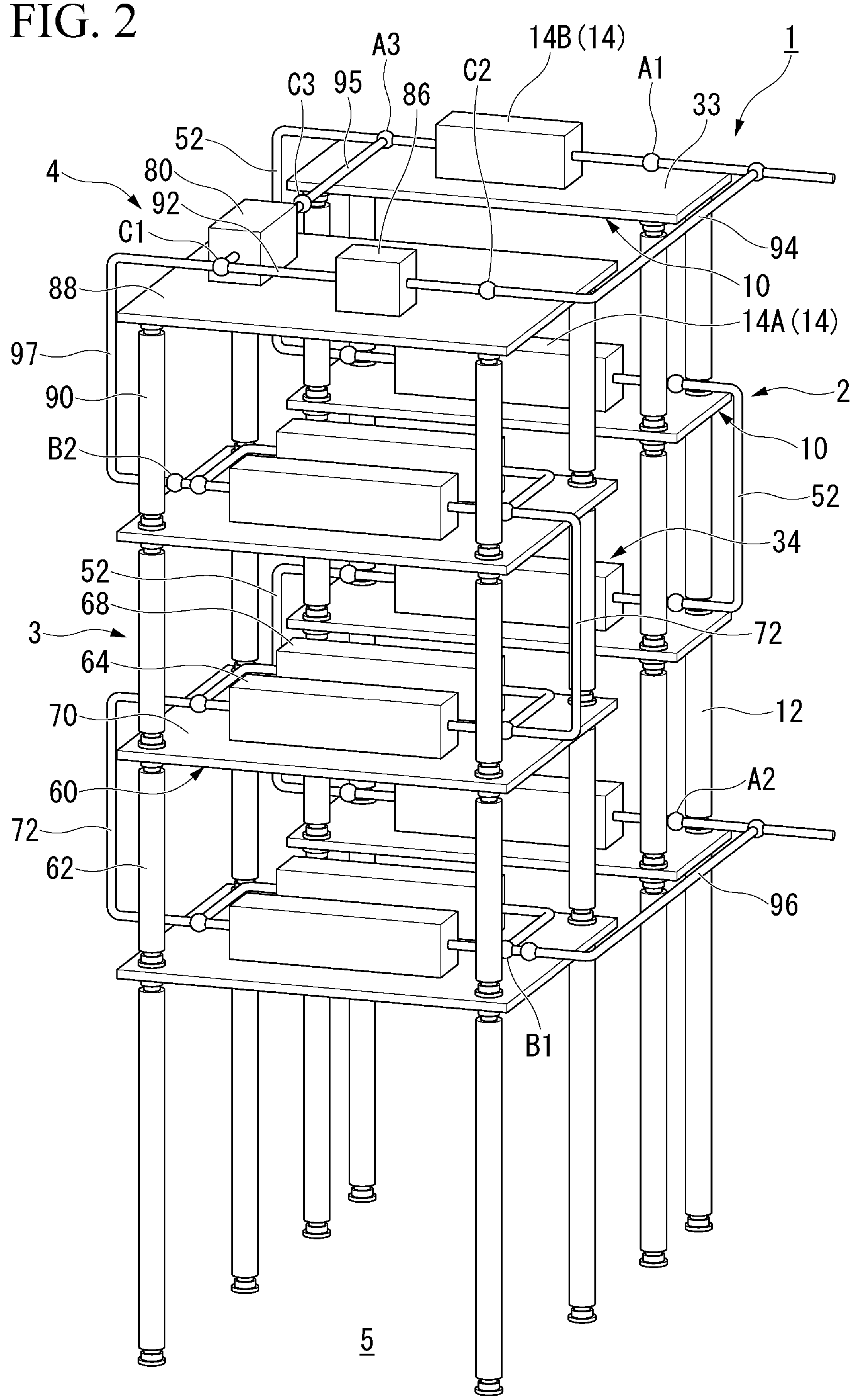

1
14B (14)
A3
A1
C2
C3
95
86
33
52
80
4
92
C1
94
10
88
14A (14)
97
2
90
10
B2
52
34
52
68
72
3
64
12
70
60
A2
72
62
96
B1
5

FIG. 3

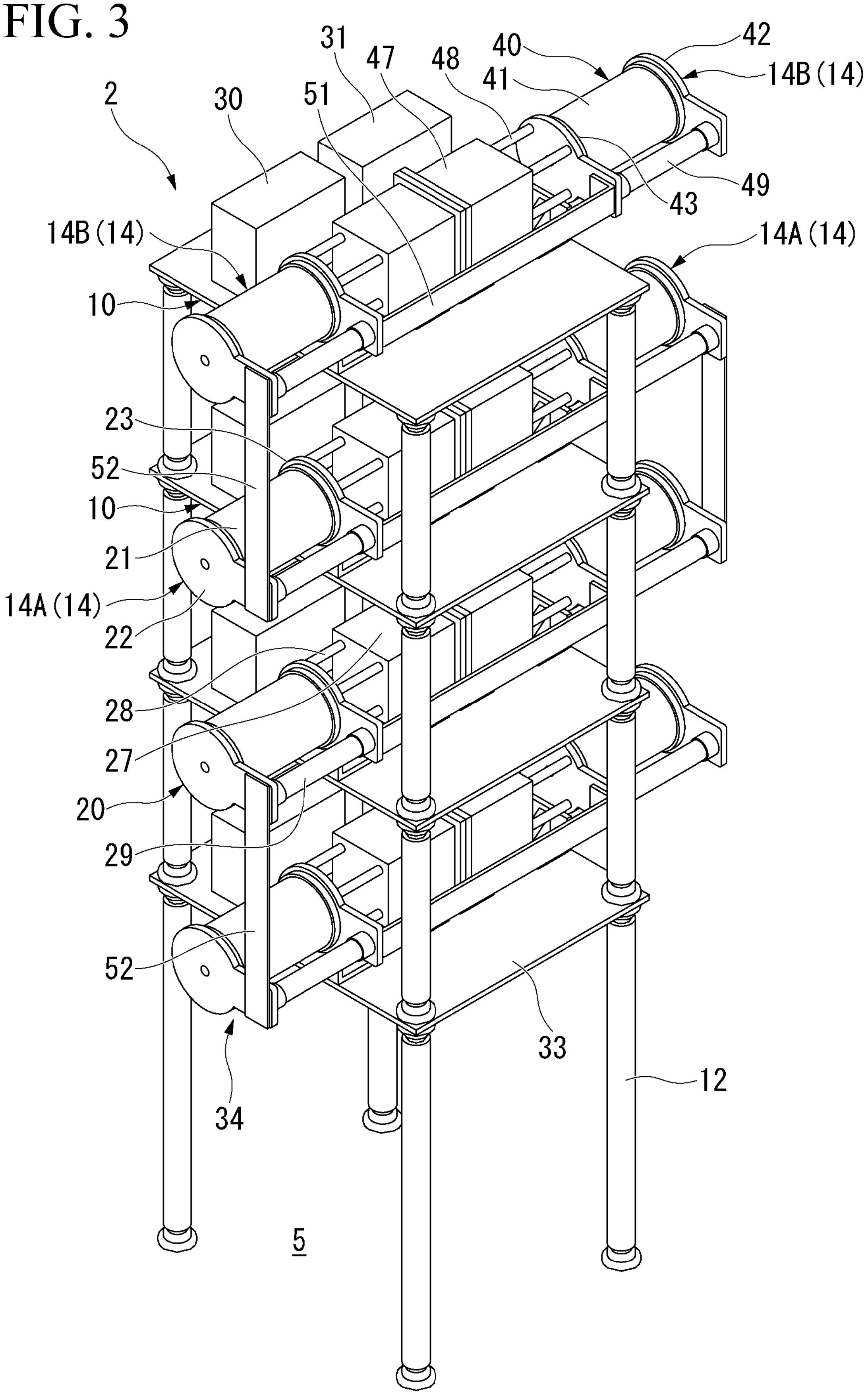

2
30
31
47
48
51
40
41
42
14B (14)
49
43
14B (14)
14A (14)
10
23
52
10
21
14A (14)
22
28
27
20
29
52
34
33
12
5

FIG. 4

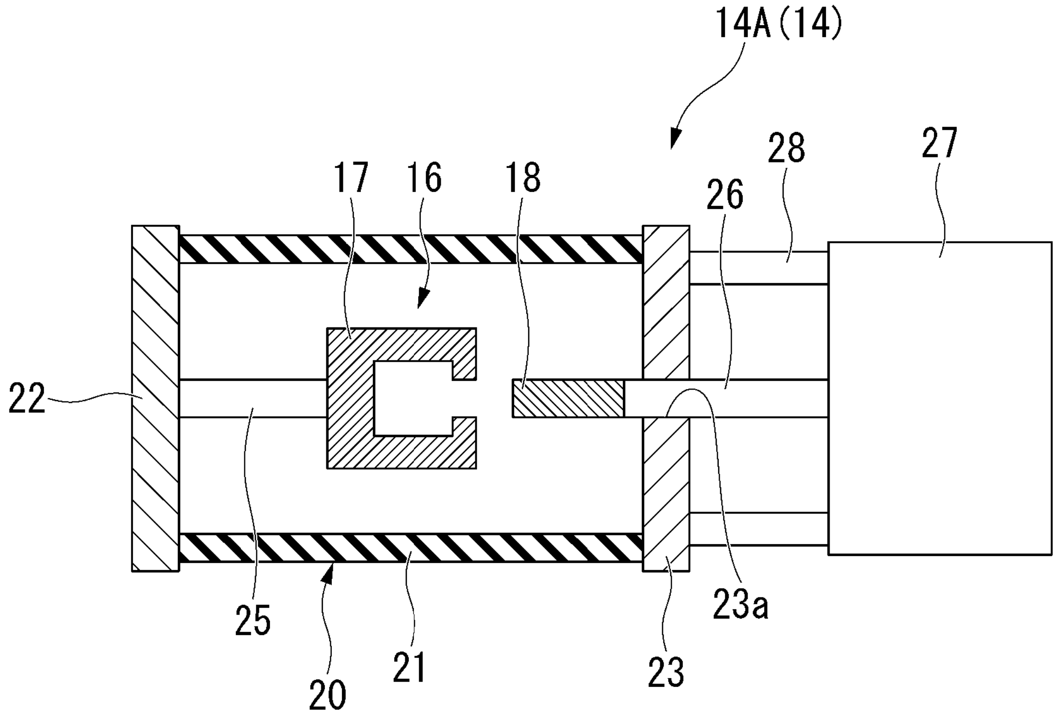

14A (14)
28
27
17
16
18
26
22
25
20
21
23
23a

FIG. 5

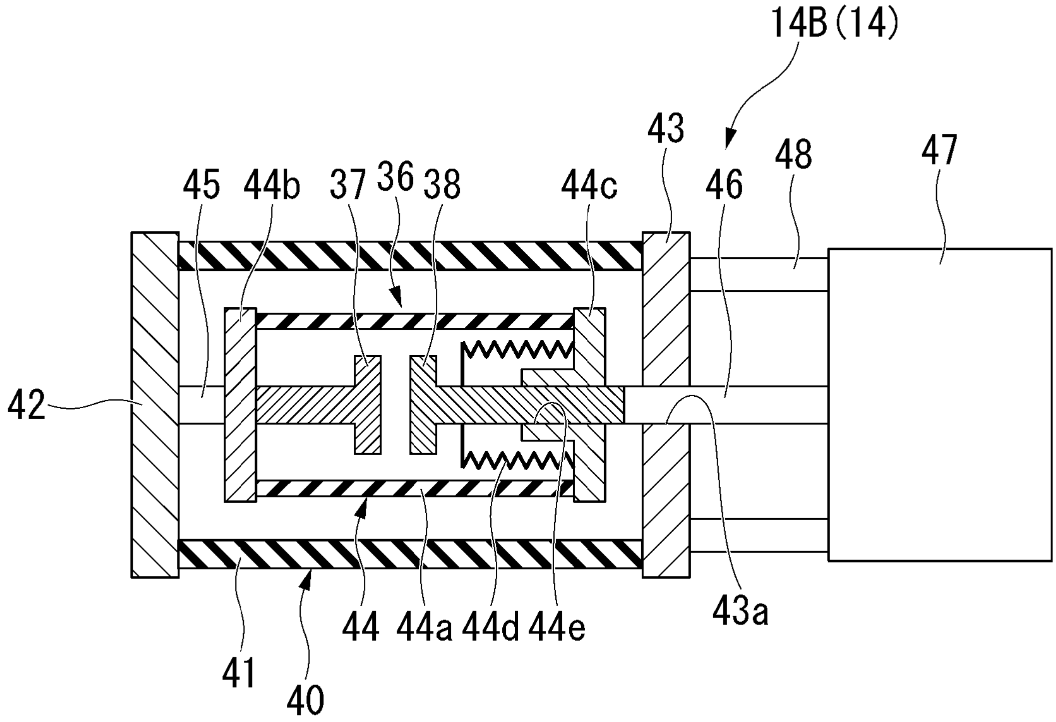

14B (14)
43
48
47
45
44b
37
36
38
44c
46
42
41
40
44
44a
44d
44e
43a

FIG. 6

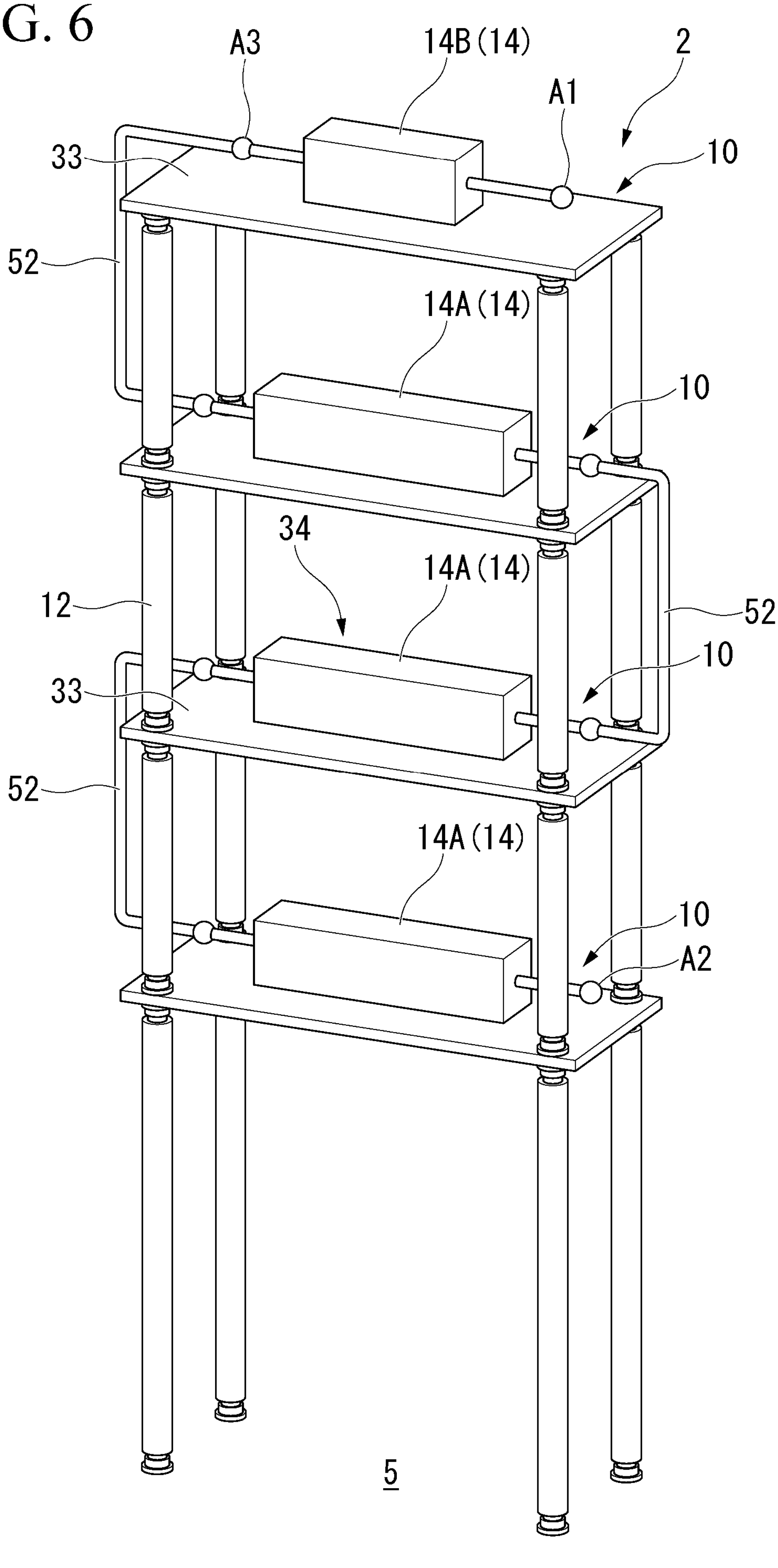

A3
14B(14)
2
A1
33
10
52
14A(14)
10
34
14A(14)
12
52
10
33
52
14A(14)
10
A2
5

FIG. 7

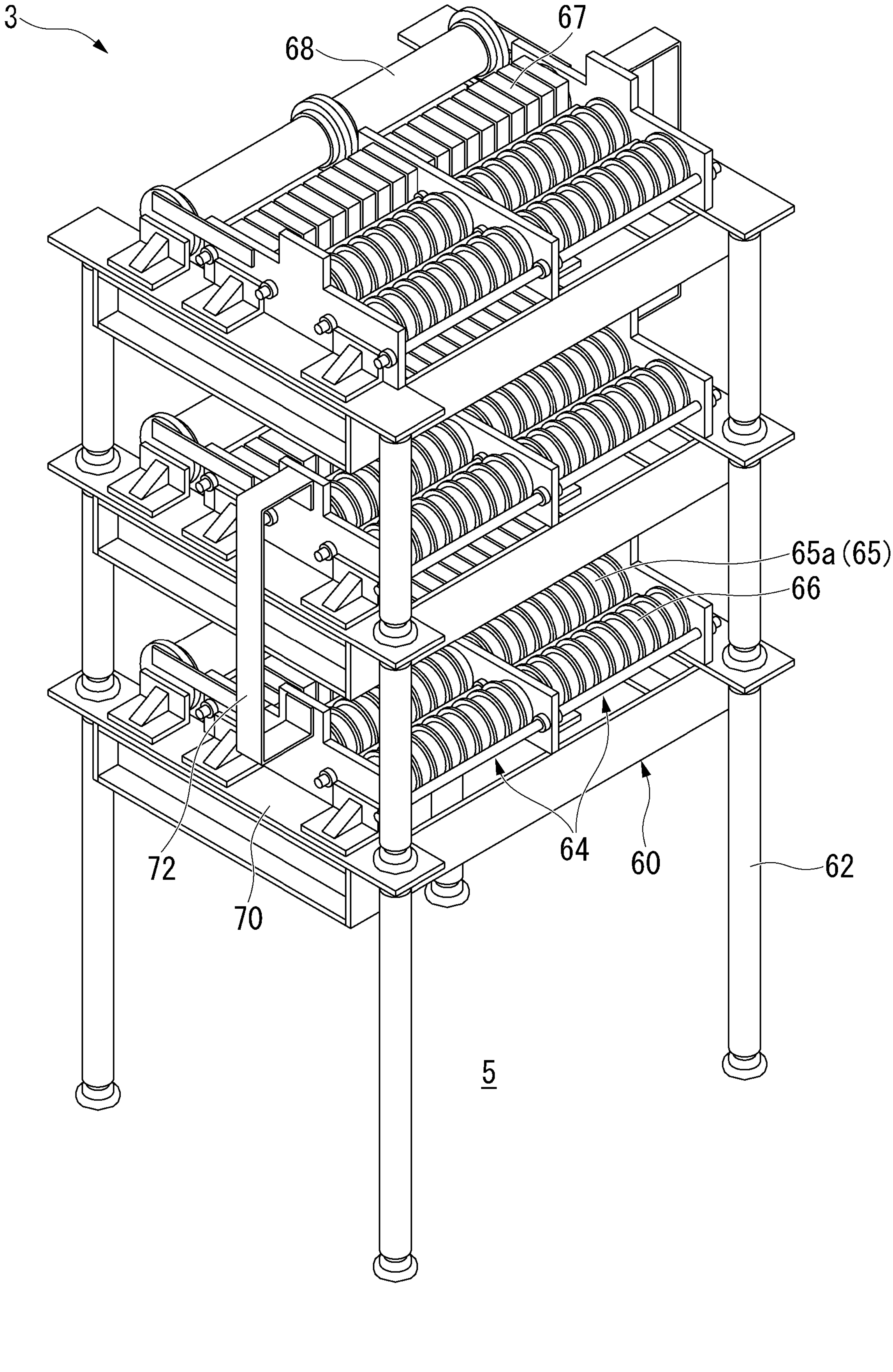


FIG. 8

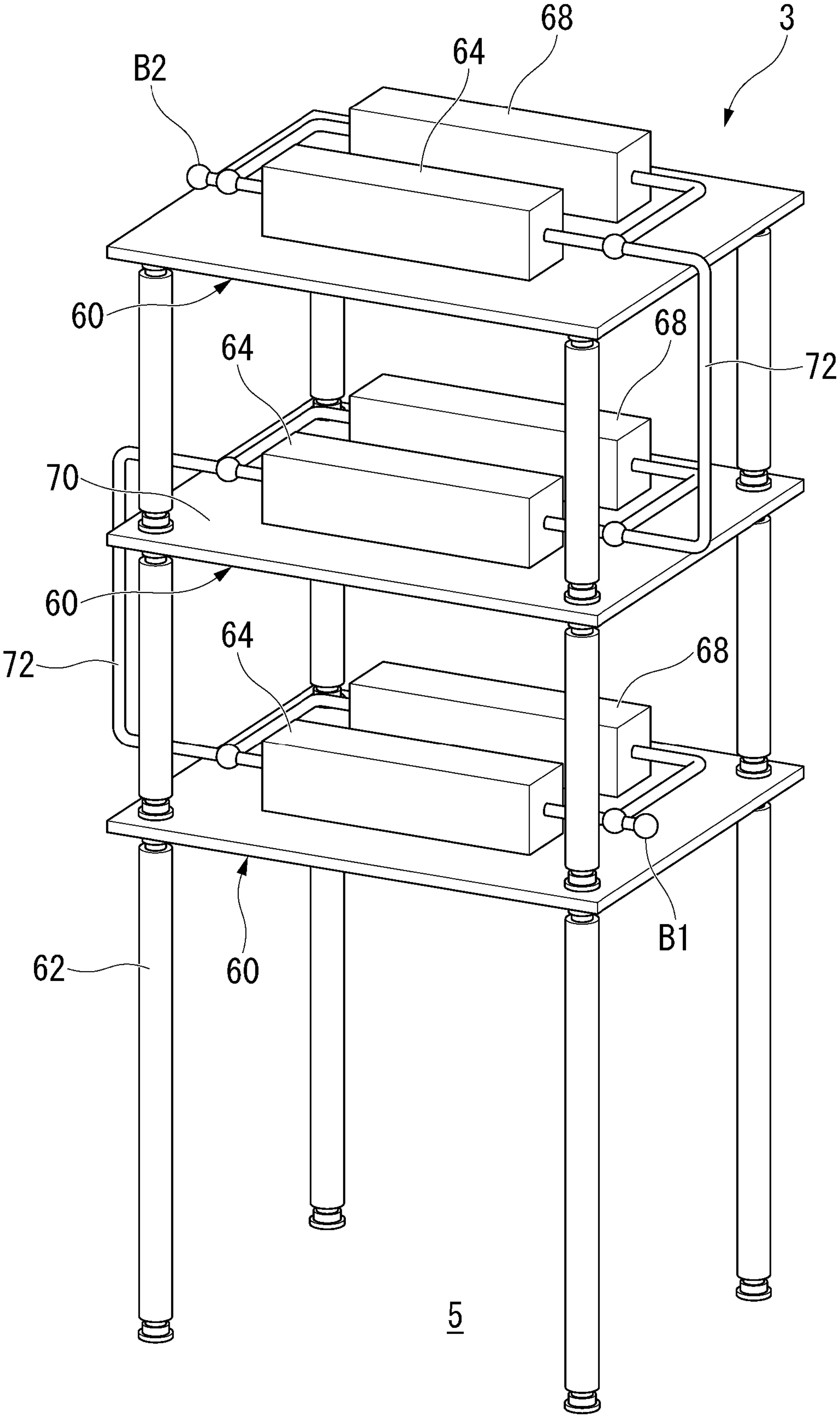


FIG. 9

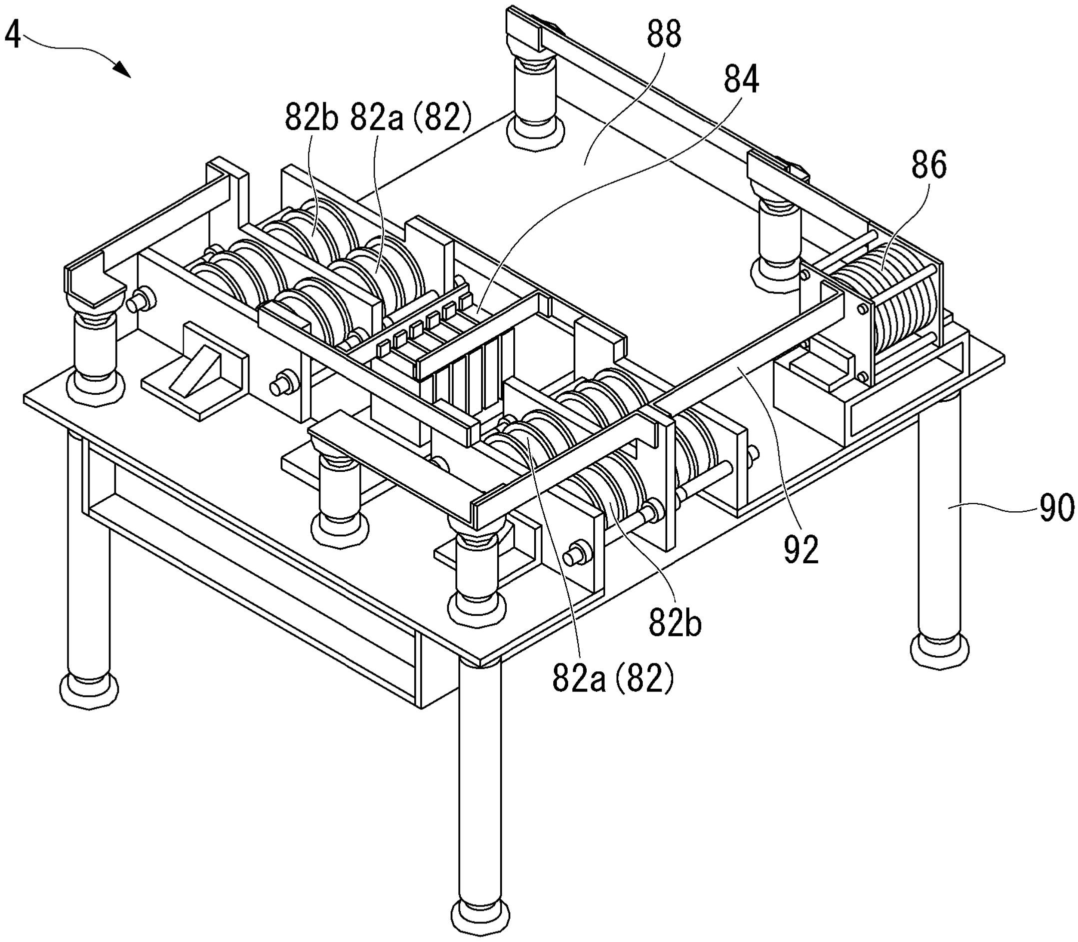

4
88
84
82b 82a (82)
86
90
92
82b
82a (82)

FIG. 10

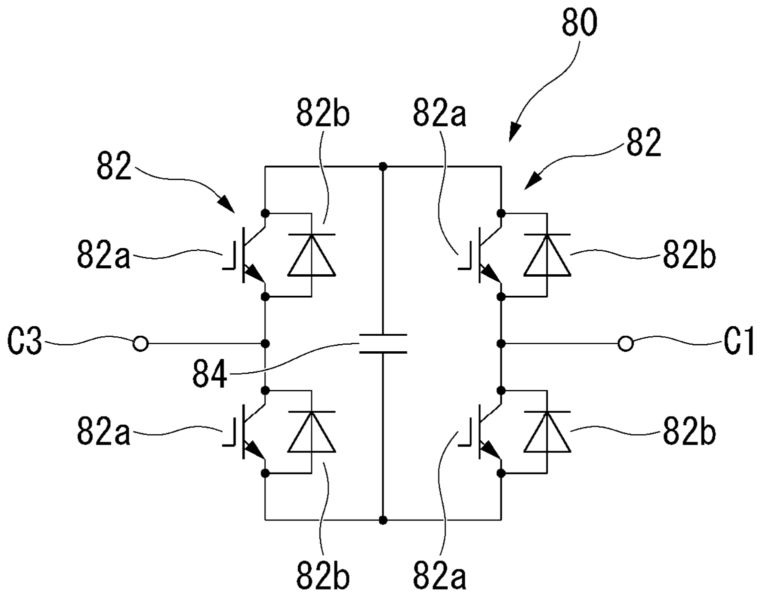

80
82b
82a
82
82
82a
82b
C3
C1
84
82a
82b
82b
82a

FIG. 11

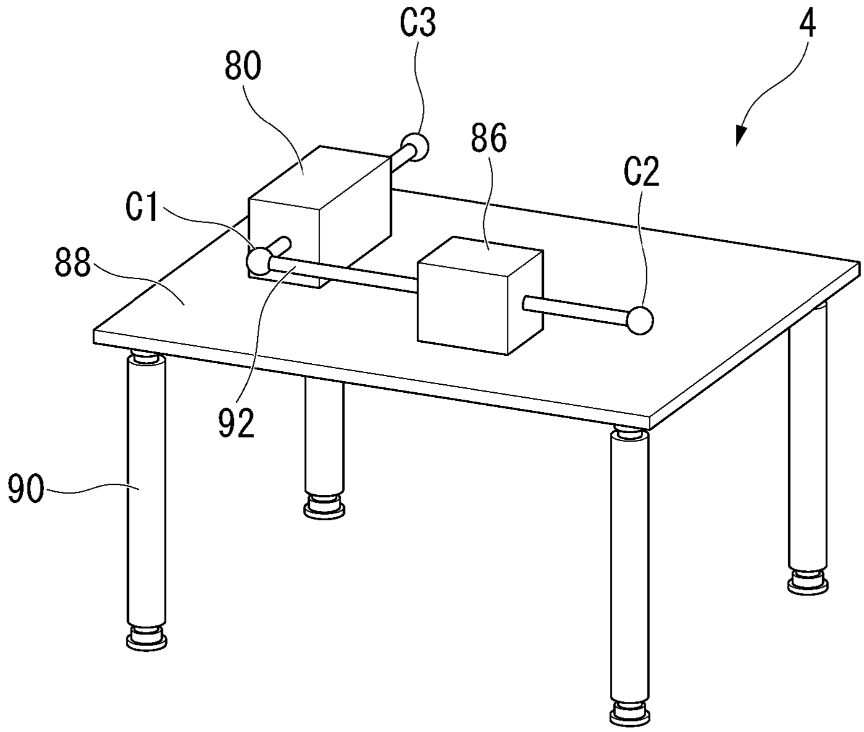


FIG. 12

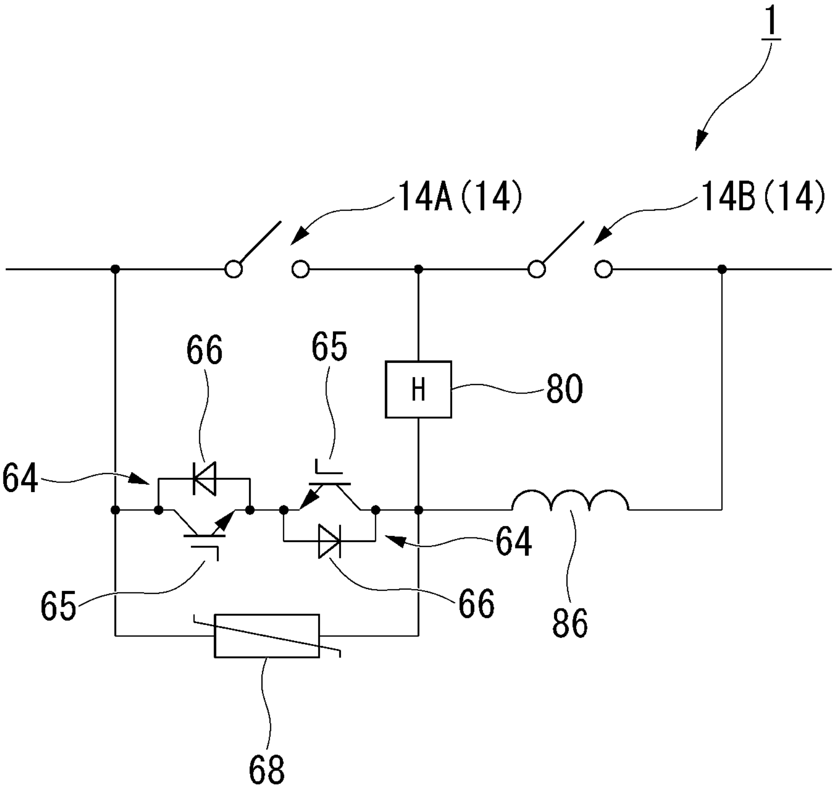


FIG. 13

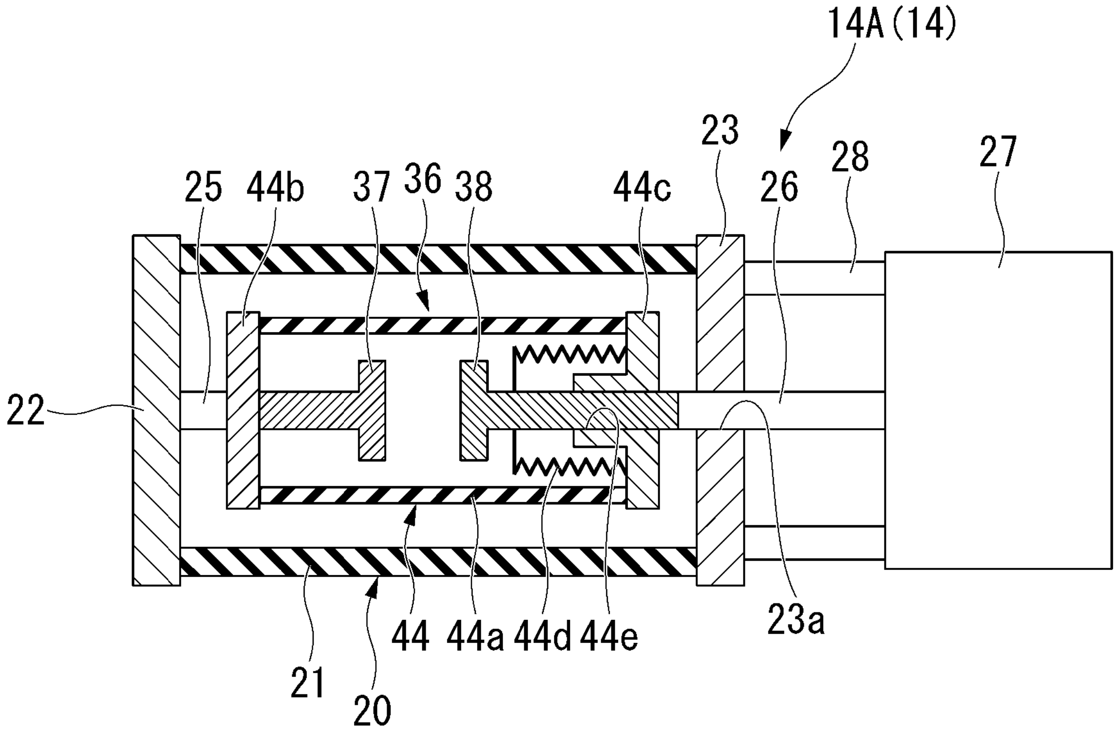


FIG. 14

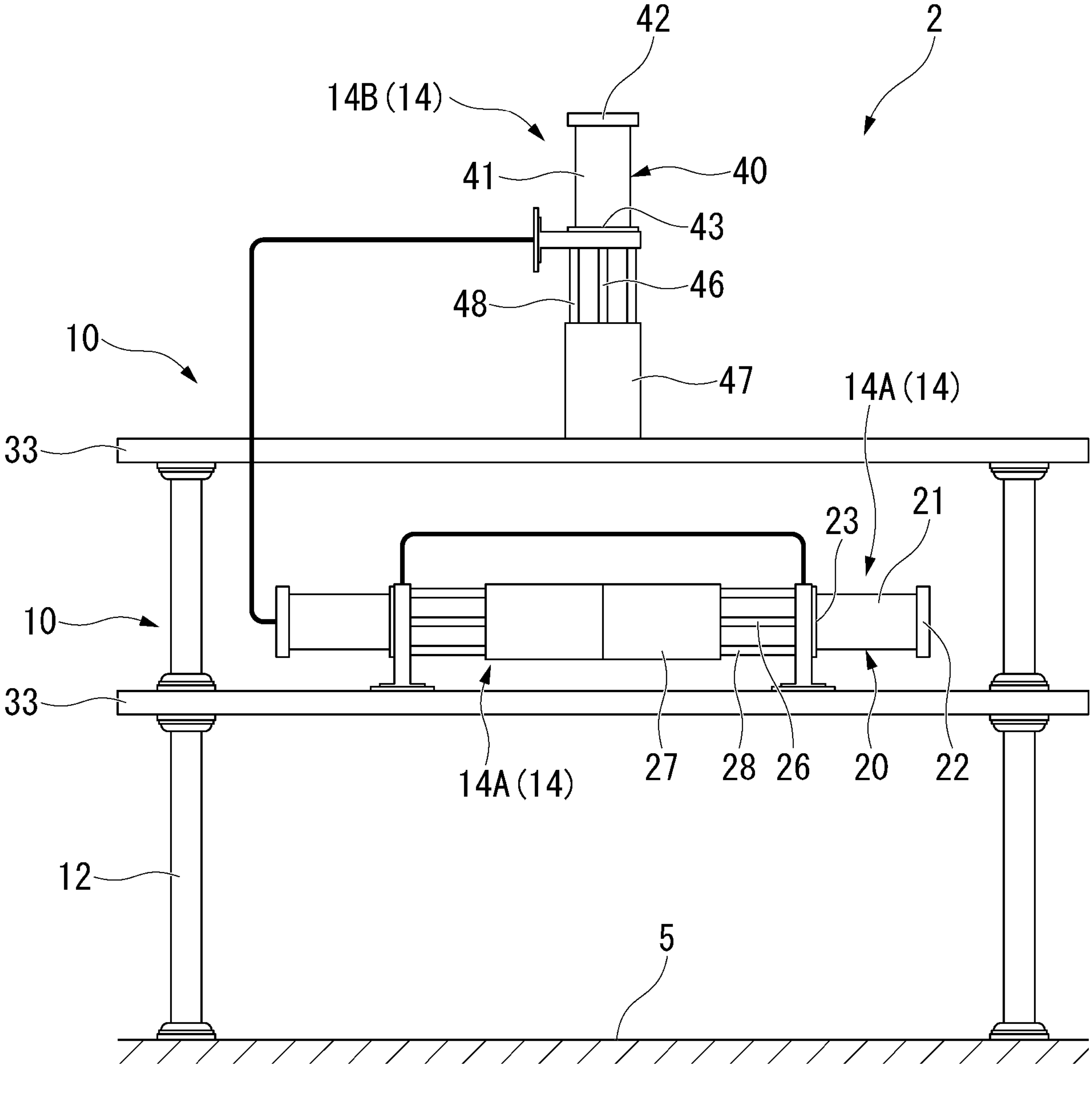

42
2
14B(14)
41
40
43
46
48
10
47
14A(14)
33
23
21
10
33
14A(14)
27
28
26
20
22
12
5

FIG. 15

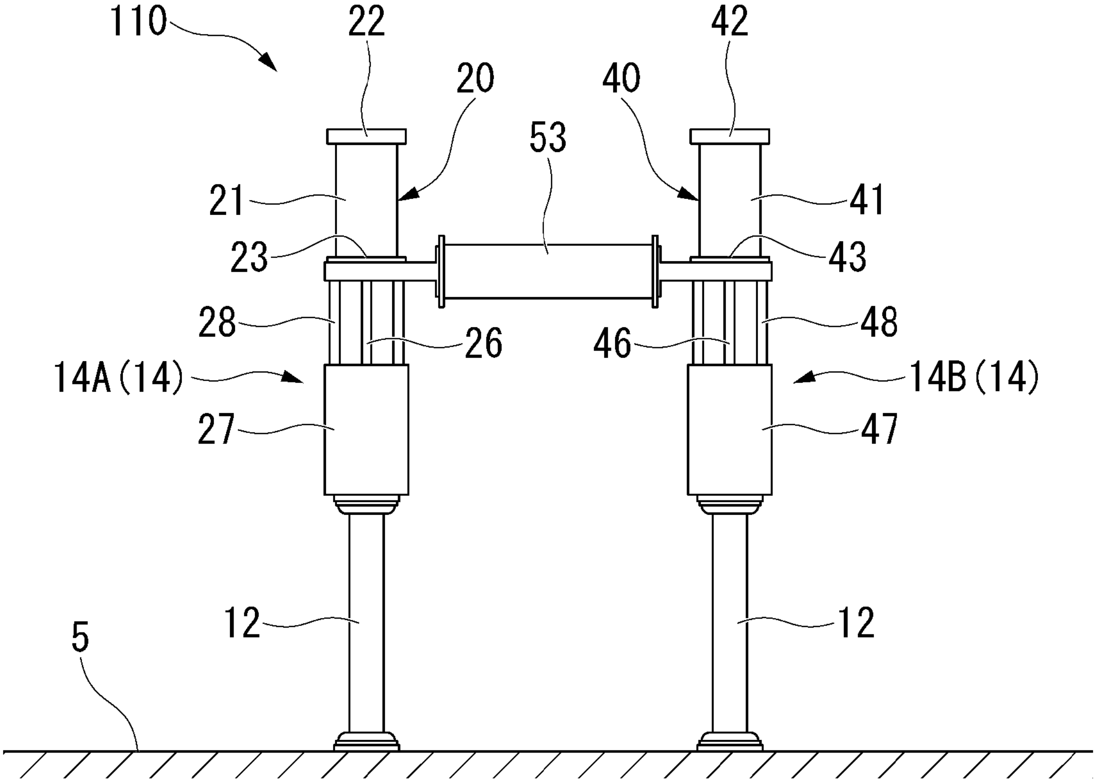
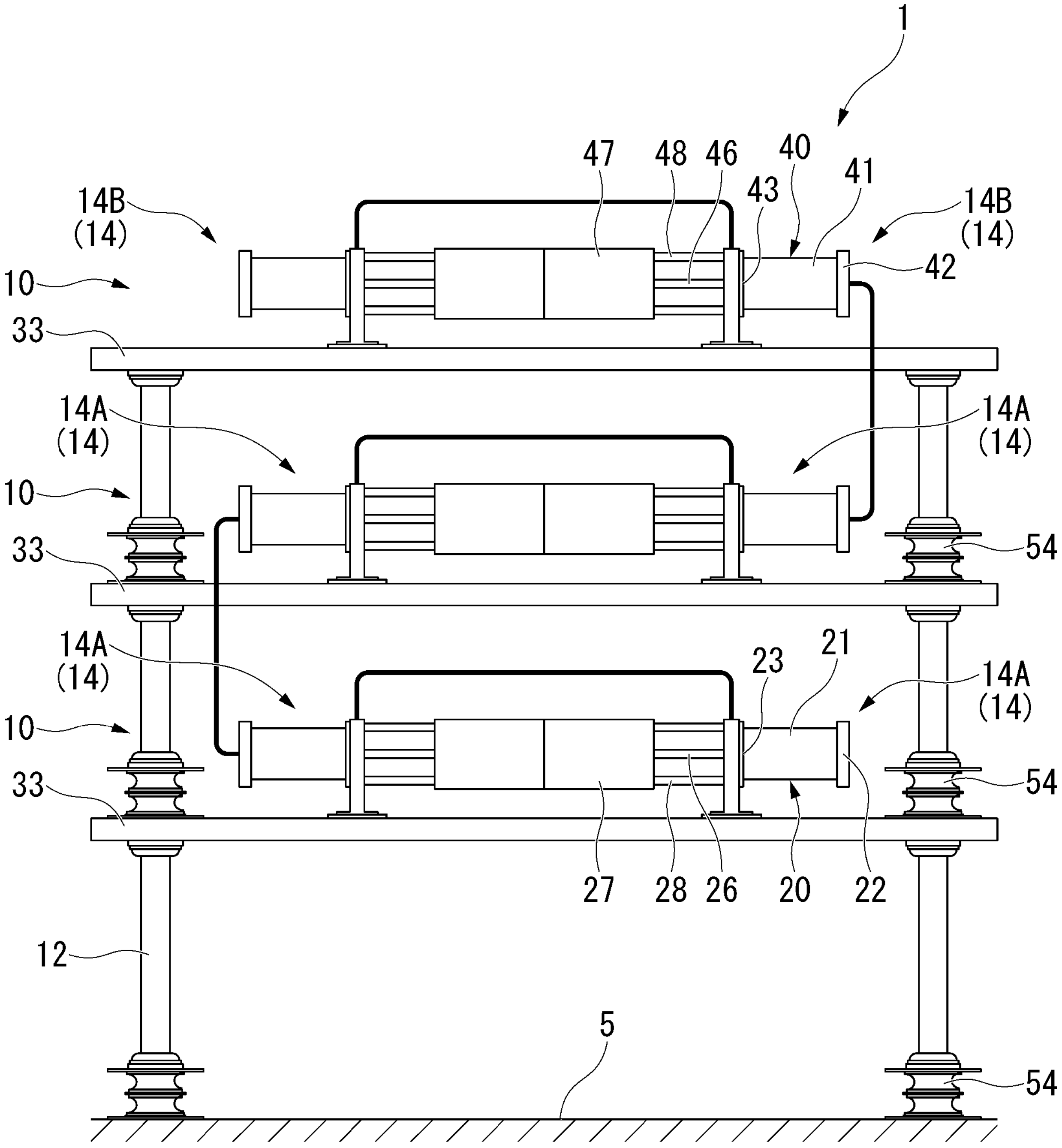


FIG. 16


1
47
48
46
40
41
43
14B
(14)
14B
(14)
42
10
33
14A
(14)
14A
(14)
10
33
54
14A
(14)
23
21
14A
(14)
10
33
54
27
28
26
20
22
12
5
54

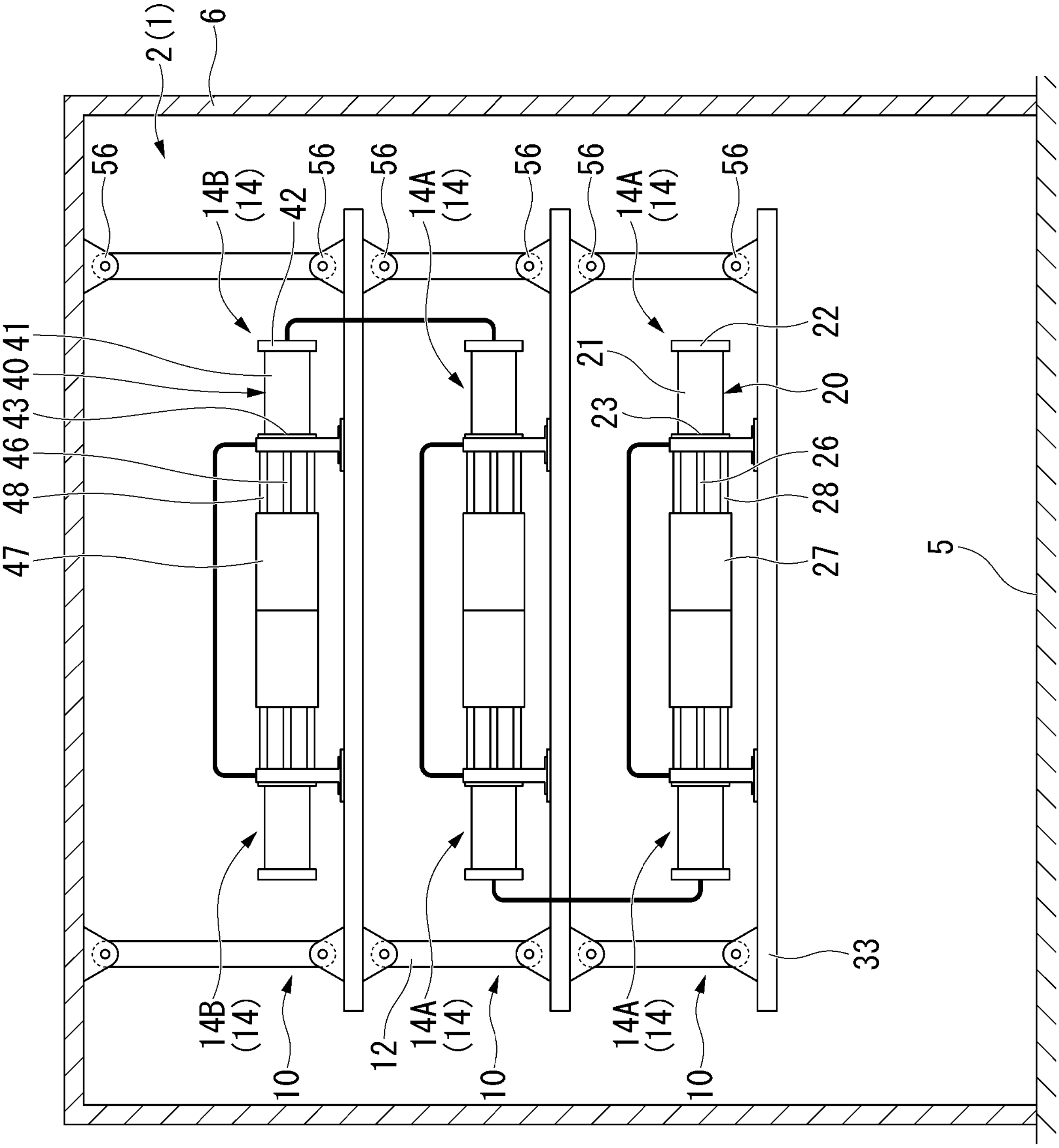

2 (1)
6
56
56
56
56
56
56
14B (14)
42
14A (14)
14A (14)
22
21
20
23
26
28
27
5
33
41
40
43
46
48
47
14B (14)
12
14A (14)
14A (14)
10
10
10

FIG. 17

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- EP 3125262 A1 **[0012]**
- JP 2016187275 A **[0013]**
- WO 2011057675 A **[0013]**
- WO 2013131582 A **[0013]**