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(54) Multi-block hybrid vacuum circuit breaker having in series connected vacuum interrupters

(57) The invention relates to a multi-block hybrid vacuum circuit breaker (1) comprising at least two blocks (2) with at least one semiconductor component and one vacuum interrupter (3) comprising a vacuum switching chamber (4) for accommodating a pair of electrical contacts comprising a fixed electrical contact (5) and a axial movable electrical contact (6), which can be moved in translation for switching purpose, wherein the at least one semiconductor component is connected in parallel to the vacuum interrupter (3).

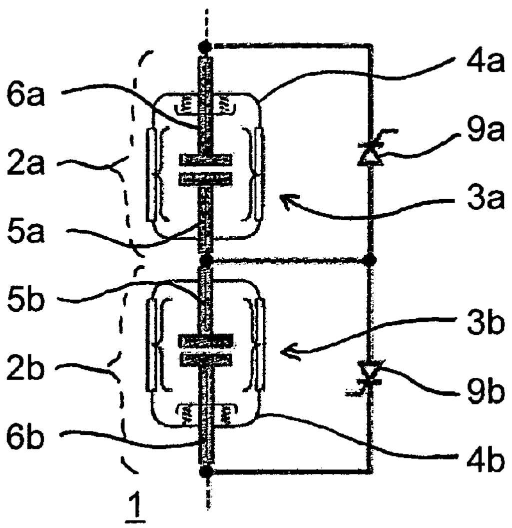

Fig.3

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Description

Field of the invention

[0001] The invention relates to a multi-block hybrid vacuum circuit breaker comprising at least two blocks with at least one semiconductor component and one vacuum interrupter comprising a vacuum switching chamber for accommodating a pair of electrical contacts comprising a fixed electrical contact and an axial movable electrical contact, which can be moved in translation for switching purpose.

Background of the invention

[0002] Vacuum interrupters are used for short circuit interruption and for load current switching as well. For protecting circuits from over-currents, circuit breakers are provided which are triggered and opened in the case of a fault situation, thereby interrupting a main current path in the circuit. The circuit breakers are generally provided as mechanical switches. These switches typically have at least two electrical contacts, which are initially pressed against each other and conduct the current in normal operation. Herein, nominal contacts are defined as separable contacts which conduct an operating current, or at least a major part of the operating current flowing through the switch when the switch is closed and in normal operation. However, for capacitive switching and for high-voltage switching applications in general, the vacuum interrupter might fail due to the high voltage stress after current interruption, which might lead to a breakdown.

[0003] In case of a fault, a mechanism which separates the two contacts of the switch is triggered. If current is flowing at this instant, it will continue to flow through the opened gap by heating up the contacts and/or insulating gas surrounding the contacts, until the material of the contacts and/or the gas is ionized and becomes conductive, i.e. a plasma state is reached. Thereby an electric arc is created. The arc can only be sustained, if the current, and with it the electric heating of the plasma, is sufficiently high. This is typically the case for fault current conditions.

[0004] In order to break the current, the arc has to be extinguished. This can be achieved by decreasing the current and with it the heating power below a certain threshold, below which the heating is not sufficient to sustain the arc. The plasma cools down and loses its conductivity. Such a situation can typically only be reached around a current zero crossing of the AC current, as with vanishing current the heating of the plasma disappears, as well.

[0005] Hence, conventional circuit breakers are switching off the current at a zero crossing. However, a further limiting factor for the performance of the circuit breaker has to be considered: Around current zero the current profile can be approximately described, in a current-over-time diagram, by a linear ramp. For a low steepness (slow increase of the current after the zero-crossing) of the current the cooling power is larger than the heating for a long period of time, and is hence sufficient to increase the resistance of the arc and with it to switch off the current. On the other hand, if the steepness of the linear ramp is increased successively (towards higher increase of the current after the zero-crossing), at some steepness the cooling period will not be sufficiently long anymore and the arc will reignite after the zero-crossing. For a variety of circuit breakers this is one of the main limiting factors of the performance.

[0006] According to the common knowledge of a skilled person vacuum interrupters can basically operate at voltage levels up to 36kV; for higher voltage applications, connection of at least two vacuum interrupters in series should be considered, also called multi-break vacuum circuit breaker. The experience has shown that a vacuum breaker with two vacuum interrupters in series withstands the high voltage tests better than a single vacuum interrupter, and its insulation reliability is better as well. But when designing a circuit breaker with series vacuum interrupters, one has to take into account the inequality of voltage distribution.

[0007] The document US 6,498,315 B1 discloses a high-voltage switching device having at least two series-connected vacuum switching chambers. The vacuum switching chambers, which are disposed in series, are configured differently with regard to their physical size and/or contact configuration, such as the contact diameters, a separation between the contacts, and contact types. At least one vacuum switching chamber of a first type is provided, and at least one vacuum switching chamber of a second type is provided. The vacuum switching chambers are selected in such a manner that reignitions and restrikes of a vacuum switching chamber of the first type are coped with by at least one other vacuum switching chamber of the second type. The opening of the contacts of the two vacuum switching chambers at different times is used as an additional method for operation of the high-voltage switching device.

[0008] Furthermore, the document US 7,508,636 B2 relates to a circuit breaker device comprising a main branch comprising a mechanical switch element and an auxiliary branch containing a semiconductor breaking cell, wherein the auxiliary branch being mounted in parallel with the main branch. The main branch comprises a serial switching assistance module in series with the mechanical switch element, comprising a semiconductor breaking cell controllable in opening in parallel with impedance. The auxiliary branch comprises a parallel switching assistance module comprising an impedance, which includes at least one capacitor type element. The semiconductor breaking cell controllable in opening includes at least one serial assembly with a diode and an IGCT type thyristor.

Summary of the invention

[0009] It is an object of the present invention to provide a multi-block hybrid vacuum circuit breaker with increased current interruption performance and decreased breakdown probability after interruption. This object is achieved by the subject-matter of the independent Claim 1. Further exemplary embodiments are evident from the dependent Claims and the following description.

[0010] According to the invention the at least one semiconductor component is connected in parallel to the vacuum interrupter of each block. Thus, each block comprises one vacuum interrupter and at least one semiconductor component connected in parallel to the vacuum interrupter.

[0011] Preferably, the vacuum interrupters of the at least two blocks are connected in series and constitute the main current part. An auxiliary semiconductor path is connected in each block parallel to the vacuum interrupter and can be formed of many semiconductor components, which should fulfill at least the voltage requirement of one vacuum interrupter.

[0012] According to a preferred embodiment two in series connected vacuum interrupters are in parallel connected with two back-to-back arranged diodes. Two back-to-back semiconductor parts are necessary for AC current, while only one part is enough for DC current case. This embodiment has the advantage of easy implementation, as two or more vacuum interrupters are used. The semiconductor part, which has either a single diode or series diodes with the required rating, should be connected in parallel to each vacuum interrupter. Furthermore, there is no need of a precise synchronised opening, since the diode part starts to conduct as soon as the arc voltage is built up across the vacuum interrupter contacts gap.

[0013] Moreover, a mechanical switch is arranged between the two vacuum interrupters and the back-to-back arranged diodes in order to create a galvanic separation. The mechanical switch might be necessary to fulfil the BIL tests requirements.

[0014] According to a further preferred embodiment a third vacuum interrupter is arranged between the two vacuum interrupters in order to create a galvanic separation. Using three vacuum interrupters in series, in which one vacuum interrupter is kept without a semiconductor component, replace the function of the mechanical switch.

[0015] According to a further preferred embodiment of the multi-block hybrid vacuum circuit breaker two in series connected vacuum interrupters are in parallel connected with two back-to-back arranged thyristors. The one thyristor is in reverse blocking mode and the other thyristor is in forward blocking mode. The thyristor in forward blocking mode can quickly switch to forward conducting mode when the gate receives a current trigger. A trigger signal can be generated when a voltage drop is created through the vacuum interrupter. Thus, an arcing voltage can be used to generate the trigger signal applied to the gate.

[0016] According to the invention another multi-block hybrid vacuum circuit breaker comprising at least two blocks with at least two semiconductor components and one double break vacuum interrupter comprising a vacuum switching chamber for accommodating a pair of axial movable electrical contacts which can be moved in translation for switching purpose, and a static electrode, which separates the axial movable electrical contacts and creates an upper vacuum compartment and a lower vacuum compartment wherein the at least two semiconductor components are connected in parallel to the double break vacuum interrupter. Preferably the at least two semiconductor components are diodes. An advantage of this embodiment is the use of a single double break vacuum interrupter instead of two vacuum interrupters in series. It can be achieved a considerable material saving while keeping the same performance. According to a preferred embodiment the at least two semiconductor components are thyristors.

Brief description of the drawings

[0017] The foregoing and other aspects of the invention will become apparent following the detailed description of the invention, when considered in conjunction with the enclosed drawings.

Figure 1 shows a diagram of a multi-block hybrid vacuum circuit breaker with a mechanical switch being arranged between two vacuum interrupters and two diodes in order to create a galvanic separation,

Figure 2 shows a diagram of a multi-block hybrid vacuum circuit breaker with a vacuum interrupter being arranged between two vacuum interrupters in order to create a galvanic separation,

Figure 3 shows a diagram of a multi-block hybrid vacuum circuit breaker with two in series connected vacuum interrupters being in parallel connected with two back-to-back arranged thyristors,

Figure 4a shows a diagram of a multi-block hybrid vacuum circuit breaker with a double gap vacuum interrupter and two diodes being parallel connected to the double break vacuum interrupter, and

Figure 4b shows a diagram of a multi-block hybrid vacuum circuit breaker with a double gap vacuum interrupter and two thyristors being parallel connected to the double break vacuum interrupter.

Figure 5a shows a diagram of a multi-block hybrid vacuum circuit breaker with double gap vacuum interrupter having only one single actuator and two diodes being parallel connected to the double break vacuum interrupter, and

Figure 5b shows a diagram of a multi-block hybrid vacuum circuit breaker with a double gap vacuum interrupter having only one single actuator and two thyristors being parallel connected to the double break vacuum interrupter.

[0018] The reference symbols used in the drawings, and their meanings, are listed in summary form in the list of reference symbols. All drawings are schematic.

Detailed description of the drawings

[0019] Figure 1 shows a multi-block hybrid vacuum circuit breaker 1 according to the present invention comprising two blocks 2a and 2b with a vacuum interrupter 3a and 3b each and with one diode 7a and 7b each. The vacuum interrupters 3a and 3b have a vacuum switching chamber 4a and 4b each, including a fixed electrical contact 5a and 5b each and an axial movable electrical contact 6a and 6b each, which can be moved in translation for switching purpose. The electrical contacts 5a, 6a and 5b, 6b are coaxial arranged to each other and hold in contact position by several spring elements 14. The diodes 7a and 7b are connected back-to-back, wherein middle connection points are connected over a mechanical switch 8 to the intermediate connection of the two vacuum interrupters 3a and 3b. The mechanical switch 8 is arranged between the two vacuum interrupters 3a and 3b and the back-to-back arranged diodes 7a and 7b in order to create a galvanic separation.

[0020] For nominal operation the nominal current flows through the two vacuum interrupters 3a and 3b, wherein the electrical contacts 5a, 6a and 5b, 6b are in closed position. At current interruption operation, the electrical contacts 5a, 6a and 5b, 6b are opened at the same time, wherein there is no need of precise synchronizing opening. The current would flow first through the initial vacuum arcs ignited between the contacts 6a and 5a in vacuum interrupter 3a and between the contacts 5b and 6b in vacuum interrupter 3b, wherein the mechanical switch 8 is closed. The voltage drop through each arc (usualy in the range of 20V) is much higher than the onstate voltage of the diode branch, and the current would immediately commute to the forward-biased diode 7b, or 7a (depending on the current polarity) which are connected in parallel to the vacuum interrupters 3b or 3a. There is a very short arcing phase before current commutation to the forward biased diodes 7a or 7b. If the diode 7b is forward biased for one current polarity, at current zero crossing the vacuum arc between the contacts 5a and 6a disappears, interrupting thereby the current and the forward biased diode 7b turns to blocking mode. The vacuum contacts 5b and 6b of the parallel vacuum interrupter 3b are cold enough to withstand the subsequent TRV because there was almost no arcing.

[0021] In view of Figure 2 which shows a preferred embodiment according to the present invention, wherein a third vacuum interrupter 3c is arranged between two vacuum interrupters 3a and 3b of the blocks 2a and 2b. The third vacuum interrupter 3c is kept without a diode 7. This interrupter provides galvanic separation between the two vacuum interrupters 3a and 3b so that no mechanical switch is needed. The galvanic separation is realised by a fixed electrical contact 5c and an axial movable electrical contact 6c, which are arranged in a vacuum switching chamber 4c.

[0022] According to Figure 3 another embodiment of a multi-block hybrid vacuum circuit breaker 1 comprises two blocks 2a and 2b with a vacuum interrupter 3a and 3b each and with a thyristor 9a and 9b each. Figure 3 constitutes the same concept like Figure 1 with the difference of no mechanical switch 8. Furthermore, the diodes 7a and 7b are replaced with thyristors 9a and 9b. The replacement of the diodes 7a and 7b by thyristors 9a and 9b creates unique advantages, wherein the interruption process takes a slightly different scenario.

[0023] When the vacuum interrupters 3a and 3b are in closed position, the current flows through them with minimum current losses, representing the main path of current flow. Once the electrical contacts 5a, 6a and 5b, 6b are opened the current will continue flowing through the main current path, i.e. through the vacuum arcs ignited between the electrical contacts 5a, 6a and 5b, 6b at both vacuum interrupters 3a and 3b. One thyristor 9a is in reverse blocking mode and the other thyristor 9b is in forward blocking mode. The thyristor 9b in forward blocking mode can quickly switch to forward conducting mode when the gate receives a current trigger. The trigger signal can be generated when a voltage drop is created through the vacuum interrupter 3. An arcing voltage can be used to generate the trigger signal applied to the gate. The arcing voltage in a vacuum interrupter is usually = 20V at arc ignition, then increases rapidly with current and the contacts separation distance.

[0024] Once the thyristor 9b starts current conducting, the vacuum arc will quickly disappear, due to high arcing voltage compared to the forward voltage drop across the thyristors 9b, and thereby establishes a full current commutation. The current will continue flowing through the forward biased thyristor 9b and the vacuum arc of the vacuum interrupter 3a, until the current zero crossing. At current zero crossing the burning arc is extinguished and the thyristor 9b turns to reverse blocking mode. The thyristor 9a is now in forward blocking mode while there is no arc ignition at vacuum interrupter 3a. The electrical contacts 5b and 6b of vacuum interrupter 3b are cold enough to withstand the subsequent TRV.

[0025] Figure 4a shows an alternative embodiment of a multi-block hybrid vacuum circuit breaker 1 with a double break vacuum interrupter 10 instead of two vacuum interrupters 3a and 3b in series. The double break vacuum interrupter 10 comprises an upper vacuum compartment 11 and a lower vacuum compartment 12 which in one preferred embodiment are hermetically separated. In another embodiment, the upper vacuum compartment 11 and the lower vacuum compartment 12 are not hermetically separated. The vacuum compartments comprise axial movable electrical contacts 6a and 6b each. A fixed electrical contact 5, which separates the two compartments 11 and 12, is arranged between the axial movable electrical contacts 6a and 6b. The fixed electrical contact 5 is connected to a middle shield 13. For nominal current conduction, both axial movable electrical contacts 6a and 6b are closed. When current interruption is needed the axial movable electrical contacts 6a and 6b open simultaneously, wherein there is no need for precise synchronised opening. The current interruption scenario is the same as explained in the description of Figure 1.

[0026] According to Figure 4b an alternative embodiment of a multi-block hybrid vacuum circuit breaker 1 comprises instead of the diodes 7a and 7b according to Figure 4a thyristors 9a and 9b. The current interruption scenario happens as described in the description of Figure 3.

[0027] As an alternative embodiment of the double-break concept in Fig.4a, the double-break assembly can take the form of the Fig.5a in which only one contact 6a is moving, thus only a single actuator is necessary. The double break vacuum interrupter 15 comprises an upper vacuum compartment 11 and a lower vacuum compartment 12. The vacuum compartments comprise axial movable electrical contact 6a, a fixed electrical contact 6b, and a movable intermediate contact 16 which is connected to an internal spring element 17. For nominal current conduction, the axial movable electrical contact 6a and the movable intermediate electrical contact 16 are closed. In this position the spring element 17 is compressed by the closing force applied to the axial movable contact 6a. The movable intermediate contact 16 is separated from the lateral coaxial contact 18 to be in contact with the fixed contact 6b. When the switch 15 is in closed position the nominal current flows through the contacts 6a, 16 and 6b. When current interruption is needed the axial movable electrical contact 6a is pulled for opening operation purpose, wherein there is no need for precise synchronised opening. This operation leads to a simultaneous separation of the contacts 16 and 6b under the reaction force of the released spring 17. An electrical arc is then ignited between the movable intermediate contact 16 and the fixed contact 6b, and eventually a second electrical arc is ignited between the axial movable contact 6a and the intermediate movable contact 16. The intermediate movable contact 16 which is pushed by the spring 17 is immediately stopped by the lateral coaxial contact 18 creating thereby an electrical conducting path. The current interruption scenario at this stage is the same as explained in the description of Figure 1.

[0028] According to Figure 5b an alternative embodiment of a multi-block hybrid vacuum circuit breaker 1 comprises instead of the diodes 7a and 7b according to Figure 5a thyristors 9a and 9b. The current interruption scenario happens as described in the description of Figure 3.

Reference signs

[0029]

1	multi-block hybrid vacuum circuit breaker
2a, 2b	block
3a, 3b, 3c	vacuum interrupter
4a, 4b, 4c	vacuum switching chamber
5a, 5b, 5c	fixed electrical contact
6a, 6b, 6c	axial movable electrical contact
7a, 7b	diode
8	mechanical switch
9a, 9b	thyristor
10	double break vacuum interrupter
11	upper vacuum compartment
12	lower vacuum compartment
13	middle shield
14a, 14b	metallic bellows
15	double break vacuum interrupter with a single actuator
16	movable intermediate electrical contact
17	spring element
18	lateral coaxial electrical contact

Claims

1. A multi-block hybrid vacuum circuit breaker (1) comprising at least two blocks (2) with at least one semiconductor component and one vacuum interrupter (3) comprising a vacuum switching chamber (4) for accommodating a pair of electrical contacts comprising a fixed electrical contact (5) and a axial movable electrical contact (6), which can be moved in translation for switching purpose,
characterized in that the at least one semiconductor component is connected in parallel to the vacuum interrupter (3) of each block (2).

2. A multi-block hybrid vacuum circuit breaker (1) of Claim 1,
characterized in that the vacuum interrupters (3) of the at least two blocks (2) are connected in series and constitute the main current path.

3. A multi-block hybrid vacuum circuit breaker (1) of Claim 1,
characterized in that two in series connected vacuum interrupters (3a, 3b) are in parallel connected

with two back-to-back arranged diodes (7a, 7b).

4. A multi-block hybrid vacuum circuit breaker (1) of Claim 3, **characterized in that** a mechanical switch (8) is arranged between the two vacuum interrupters (3a, 3b) and the back-to-back arranged diodes (7a, 7b) in order to create a galvanic separation.

5. A multi-block hybrid vacuum circuit breaker (1) of Claim 3, **characterized in that** a third vacuum interrupter (3c) is arranged between the two vacuum interrupters (3a, 3b) in order to create a galvanic separation.

6. A multi-block hybrid vacuum circuit breaker (1) of Claim 1, **characterized in that** two in series connected vacuum interrupters (3a, 3b) are in parallel connected with two back-to-back arranged thyristors (9a, 9b).

7. A multi-block hybrid vacuum circuit breaker (1) comprising at least two blocks (2) with at least two semiconductor components and one double break vacuum interrupter (10) comprising a vacuum switching chamber (4) for accommodating a pair of axial movable electrical contacts (6a, 6b) which can be moved in translation for switching purpose, and a static electrode (5), which separates the axial movable electrical contacts (6a, 6b) and creates an upper vacuum compartment (11) and a lower vacuum compartment (12), **characterized in that** the at least two back-to-back arranged semiconductor components are connected in parallel to the double break vacuum interrupter (10).

8. A multi-block hybrid vacuum circuit breaker (1) of Claim 7, **characterized in that** the at least two semiconductor components are diodes (7).

9. A multi-block hybrid vacuum circuit breaker (1) of Claim 7, **characterized in that** the at least two semiconductor components are thyristors (9).

10. A multi-block hybrid vacuum circuit breaker (1) comprising at least two blocks (2) with at least two semiconductor components and one double break vacuum interrupter (15) comprising a vacuum switching chamber (4) for accommodating an axial movable electrical contacts (6a) which can be moved in translation for switching purpose, and a fixed electrical contact (6b), and a movable intermediate electrical contact (16) which separates the axial movable electrical contact (6a) and the fixed electrical contact (6b), and creates an upper vacuum compartment (11) and a lower vacuum compartment (12), and connected to a spring element (17) allowing its axial motion for switching purpose, and a fixed lateral coaxial electrical contact (18), which becomes connected to the movable intermediate electrical contact (16) while and after opening the switching chamber (4) **characterized in that** the at least two back-to-back arranged semiconductor components are connected in parallel to the double break vacuum interrupter (15).

11. A multi-block hybrid vacuum circuit breaker (1) of Claim 10, **characterized in that** the at least two semiconductor components are diodes (7).

12. A multi-block hybrid vacuum circuit breaker (1) of Claim 10, **characterized in that** the at least two semiconductor components are thyristors (9).

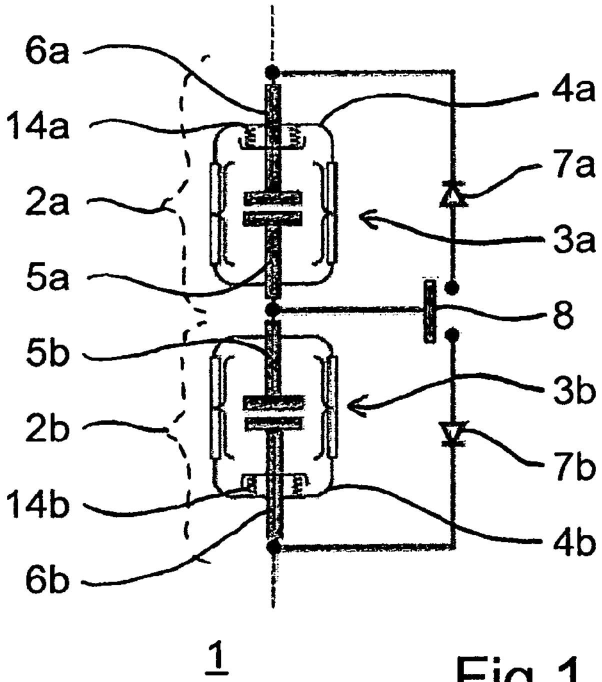
6a
14a
2a
5a
5b
2b
14b
6b
4a
7a
3a
8
3b
7b
4b
1

Fig.1

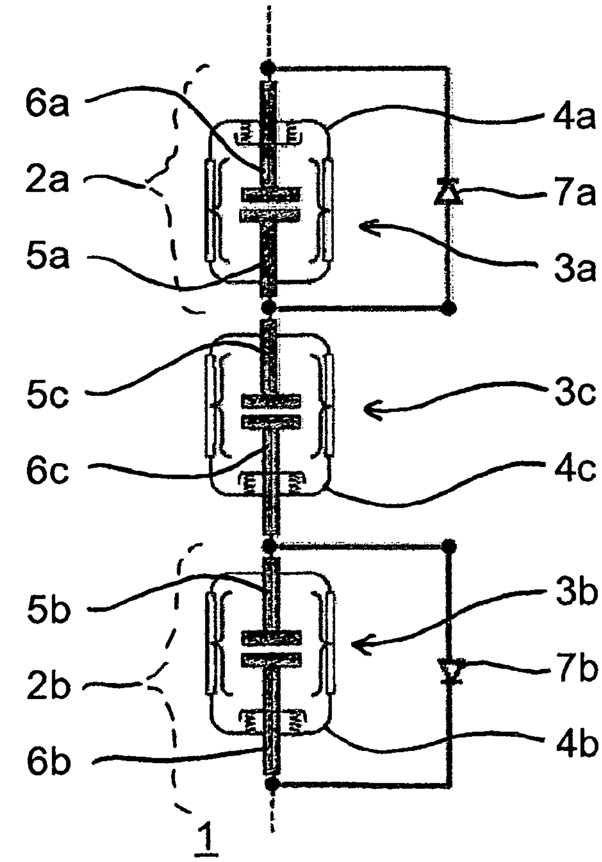
6a
2a
5a
5c
6c
5b
2b
6b
4a
7a
3a
3c
4c
3b
7b
4b
1

Fig.2

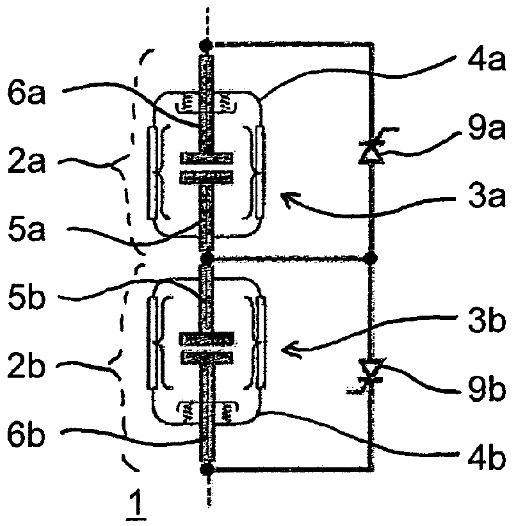

Fig.3

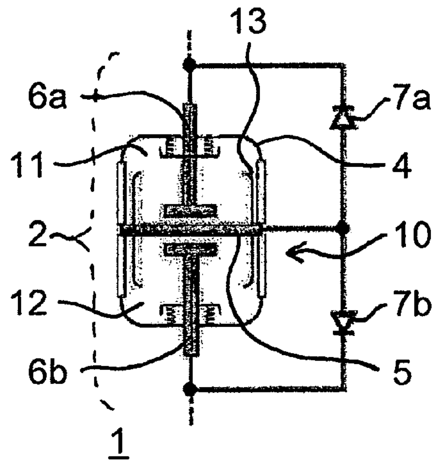

Fig.4a

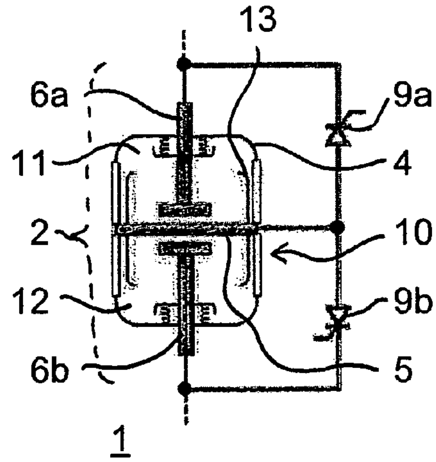

Fig.4b

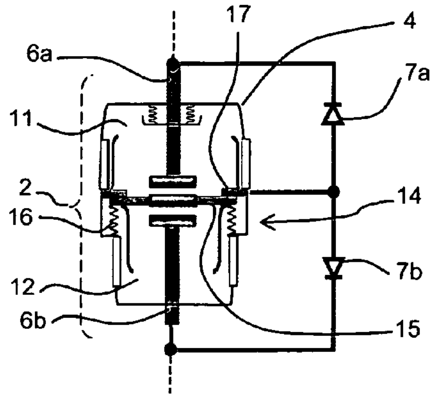

Fig.5a

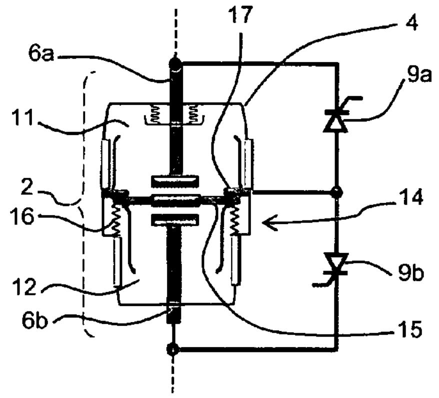

Fig.5b

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EUROPEAN SEARCH REPORT

Application Number
EP 12 00 7165

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	1 March 2013	Findeli, Luc

CATEGORY OF CITED DOCUMENTS

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