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(54) **APPARATUS TO SWITCH A LED**

(57) An apparatus (1, 1a-c, **1a'-c'**) to switch a light-emitting diode (2) or another load, comprising a mechanical switch (3), which comprises a moving electrode (4), wherein the moving electrode (4) is a contact, which electrically gets in connection with a further contact or electrode to enable a current flow while a closing phase and while an operation time and which moving electrode (4) can be separated from the further contact or electrode to interrupt current flow while a breaking phase of the mechanical switch (3), **characterized in that** the apparatus (1, 1a-c, **1a'-c'**) comprises a solid-state-device (5), which is arranged in such a manner that current at least partially flows through the solid-state-device (5) while a closing or breaking phase and that current at least partially flows through the mechanical switch (3) in closed position while the operation time, achieves the object to drastically limit the arcing duration during the inrush current phase or switching on phase as well as during the breaking current phase or even to avoid any arcing.

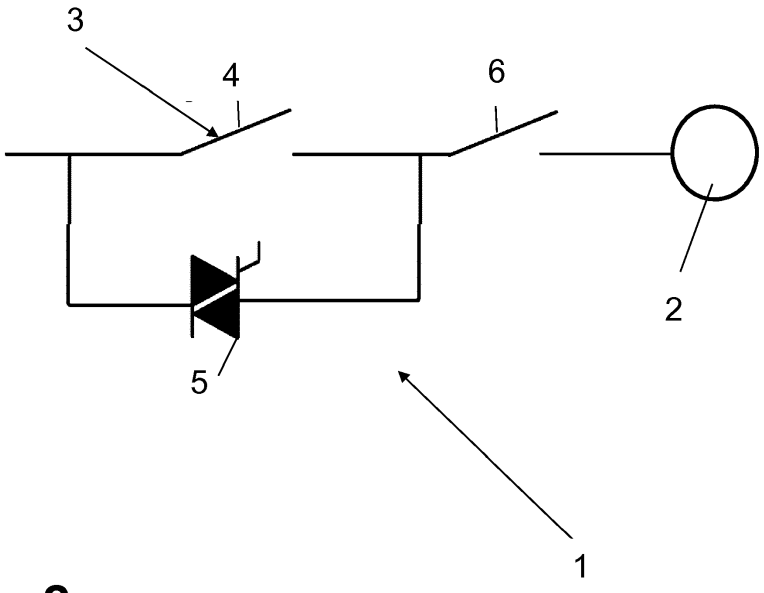

Fig. 2

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Description

[0001] The invention is related to an apparatus to switch a light-emitting diode (LED) or another load, comprising a mechanical switch, which comprises a moving electrode, wherein the moving electrode is a contact, which electrically gets in connection with a further contact or electrode to enable a current flow while a closing phase and while an operation time and which moving electrode can be separated from the further contact to interrupt current flow while a breaking phase of the mechanical switch.

[0002] Nowadays LED lamps are replacing the traditional light bulbs for the sake of their more efficient conversion of electricity into light. This change is even enforced by regulation in most of the countries worldwide.

[0003] However, when switching on a LED lamp, a high inrush current occurs during the first milliseconds due to the sudden charge of capacitors located in the LED driver (AC/DC converter), as illustrated in Fig. 1. Typical inrush peak currents are ranging about 10 times higher than **the** rated current, and have to be in accordance with the international standards (for instance, IEC 60669-1 for "Switches for household and similar fixed electrical installations - Part 1. General requirements").

[0004] One of the issues of mechanical switches is that there is a certain bouncing of the moving electrode during the closing or making phase. The kinetic energy of the moving electrode cannot be dissipated efficiently, which generates a bouncing.

[0005] The main problem comes when mechanical switches are used to switch on LEDs, for instance. Since the bounces occur while the current flows, then an arc forms between the two contacts. Due to the very high inrush current that can be reached in switching on LEDs, this can lead to an accelerating contact ageing, or even to a welding of the two contacts.

[0006] The object of the invention therefore is to drastically limit the arcing duration during the inrush current phase or switching on phase as well as during the breaking current phase or even to avoid any arcing.

[0007] The object of the invention is achieved by means of the features of claim 1.

[0008] According to this claim the apparatus comprises a solid-state-device, which is arranged in such a manner that current at least partially flows through the solid-state-device while a closing or breaking phase and that current at least partially flows through the mechanical switch in closed position while the operation time.

[0009] According to the invention it has been found that to drastically limit the arcing duration during the inrush current phase or switching on phase as well as during the breaking current phase, or even to avoid any arcing, the proposed solution is to combine a solid-state-device in parallel to a mechanical switch.

[0010] The main idea is to have the current flow through the solid-state-device, preferably a triac, during the making and breaking phases, which last a few milliseconds, while the current flows through the switch in its closed position during all the rest of the time.

[0011] The advantage of this system is to have a quasi arc-free switching during the on and off phases, which prevent an excessive erosion of the contacts. In addition, in closed position the mechanical switch ensures very low electrical losses, compared to a fully solid-state solution.

[0012] Advantageously the solid-state-device is a semi-conductor-device, which is paralleled to the mechanical switch. Semi-conductor-devices are highly reliable.

[0013] Further advantageously the solid-state-device is a triac, namely a triode for alternating current, which is paralleled to the mechanical switch. A triac is an electronic element having a structure of sheets comprising semi-conductors. A triac comprises two thyristors in anti-parallel configuration. Through this it is possible to switch alternating current, whereas a single thyristor only can switch in one direction and in activated modus functions like a diode. The triac may be fired over a gate and stays conductive as long as a holding current is higher than a critical current.

[0014] Further advantageously it is also possible that the solid-state-device is a thyristor, which is in anti-parallel configuration to the mechanical switch.

[0015] Advantageously the apparatus comprises a triggering system for the solid-state-device. An appropriate triggering system can switch the solid-state-device by taking influence on its gate.

[0016] Further advantageously the triggering system electronically or mechanically controls the gate of the solid-state-device. Advantageously the gate of the triac can be activated mechanically with a direct or indirect linkage to the mechanical switch. Alternatively the gate can be activated independently of the mechanical switch. The triac is triggered as soon as a current through the gate is higher than a device threshold. The current is originated either directly by a network when closing the gate of the triac, which is the making phase, or by the arc voltage if the gate of the triac is closed when the mechanical switch opens, which is the breaking phase.

[0017] Advantageously the triggering system controls the gate of the solid-state-device by a difference of a voltage on the switch, as described before.

[0018] Further advantageously a gate switch is embodied as a mechanical switch. So the gate of the triac can be mechanically activated. The gate of the triac is connected, especially via the mechanical switch or gate switch to the source side of the network. As a consequence there preferably is no need for any capacitance and/ or resistance on the

path of the gate. The gate switch or mechanical switch may open and close the gate. So when the main switch, which preferably is a rocker light switch, is disconnected, the triac is also disconnected. Like this there is no opportunity that a current would inadvertently flow from the source to the load with the main switch opened.

[0019] The gate switch may be closed and opened in coordination with the main switch, which preferably is a rocker light switch. The gate switch is closed slightly before the main switch and opened slightly after the main switch, so that the triac is always connected in parallel to the main switch during the nominal current. Like this, the nominal current will flow through the main switch, which preferably is a rocker light switch, because it has a lower resistance than the triac. However, when an over-voltage occurs on the main switch, like in the case of an arc for instance, the current will commute directly into the triac. This will preserve the contacts of the main switch from erosion. Due to the fact that the gate of the triac is closed a bit before the main switch and it is opened a bit after the main switch, then the main switch will see almost no arcing at all.

[0020] The gate of the triac is closed before the main switch and opened after the main switch, so that the main switch is by-passed by the triac as soon as an arc develops between its contacts. This procedure passively occurs without any contact separation detector. Therefore, a triggering of the gate of the triac with a mechanical switch coupled with the main switch, which preferably is a rocker light switch, is possible.

[0021] Further advantageously a gate switch is embodied as a FET (field effect transistor), which is controllable by the voltage, which is applied to the mechanical switch. Field effect transistors are highly reliable.

[0022] Advantageously the gate switch blocks flow of electrical current through the solid-state-device and electrical current flows through the mechanical switch, if the voltage is under a threshold value of voltage, and at least a part of the electrical current flows through the solid-state-device, if the voltage exceeds the threshold value. Through this, the mechanical switch can be preserved.

[0023] Further advantageously the mechanical switch and the gate switch are mechanically linked together, so that both switches can be closed simultaneously or in succession within a short period of time.

[0024] Advantageously the mechanical switch is a rocker light switch. Such mechanical switches are highly reliable and are cost effective.

[0025] Further advantageously the apparatus comprises a disconnector. A disconnector has to be added in series in order to insure a galvanic insulation.

[0026] Advantageously the rated voltage level, which is applied to the mechanical switch is smaller than 1000 V, especially smaller than 600 V, and/ or the rated current which flows through the mechanical switch is smaller than 20 A and/ or the inrush current, when the mechanical switch is closed, is smaller than 250 A. Such a switch at least complies with the requests of international standards. The peak inrush current, as well as the energy during the making operation, are given in these standards. Such a switch complies with the standard "Switches for household and similar fixed electrical installations", which is the IEC 60669-1 Edition 4.0, 2017-02.

[0027] Advantageously a method of closing an apparatus comprises the following steps: In a first step a disconnector is closed, in a second step a gate switch is closed and in a third step the mechanical switch is closed. Immediately when the gate switch is closed, especially a triac conducts. The main current runs through the triac. The current may have several Amperes, whereas only Milliamperes run through the gate.

[0028] Further advantageously a method of opening an apparatus comprises the following steps: In a first step a mechanical switch is opened, in a second step a gate switch is opened and in a third step a disconnector is opened. When the mechanical switch as a main switch opens, the current immediately flows into especially a triacs gate. This opens the triac, which conducts the main current. At the next current zero the triac stays in non-conductive mode. Then the disconnector can be opened.

[0029] In the drawings:

Fig. 1 shows an inrush current which occurs, when the switch closes with a LED load, it is shown that a fast transient phase occurs, which is smaller than 2ms, with a peak inrush current reaching up to about ten times the rated current,

Fig. 2 shows an illustration of the combined system, comprising a mechanical switch and a semi-conductor-device, made to drastically limit the arcing duration during the current making and breaking phases by using a triac, while ensuring low electrical losses in closed position by using the switch,

Fig. 3 shows an illustration of the combined system, comprising a mechanical switch and a solid-state-device, with two controlling possibilities, the possibility A schematically shows, that the gate of the solid-state-device is controlled electronically, and the possibility B schematically shows, that the gate of the solid-state-device is controlled by the difference of voltage on the mechanical switch, which is activated mechanically, when the switch closes, and is deactivated mechanically when the switch opens,

Fig. 4 shows an illustration of the simplest hybrid switch system, this includes the concept of triggering of a triac, the mechanical switch is a rocker light switch and further a triac gate switch is given, in the closed position, the gate of the triac is connected, so that the triac can be fired as soon as the minimum current is reached, in an open position, it ensures that the rated current is stopped to flow through the triac, the triac is fired only, when the voltage drop in the rocker light switch is higher than a certain threshold, typically around 10 V, which would correspond to arcing into the switch,

Fig. 4a the system according to Fig. 4 further simplified without resistors,

Fig. 5 shows an illustration of an improved triggering system for a triac including resistors chosen as to limit the current in the gate and in the triac main path,

Fig. 5a shows a triggering system similar to that of Fig. 5, which is simplified, wherein resistors may be needed to limit current,

Fig. 6 shows an alternative electrical diagram of the hybrid switch, it contains varistors, or Zener diodes, between the gate and one of the triac in order to insure a voltage drop in the specifications of the triac, as well as to protect the triac's gate from over-currents, and

Fig. 6a shows a triggering system similar to that of Fig. 6, which is simplified, wherein resistors may be needed to limit current.

[0030] Fig. 1 illustrates, that a high inrush current occurs during the first milliseconds due to the sudden charge of capacitors located in a LED driver (AC/DC converter), when switching on a LED lamp. Typical inrush peak currents are ranging about 10 times higher than then rated current. Exact conditions are described in the standard. For instance, IEC 60699-1 Edition 4.0 2017-02 for the International Electrotechnical Commission.

[0031] Fig. 2 schematically shows an apparatus 1 to switch a light-emitting diode (LED) 2, comprising a mechanical switch 3, which comprises a moving electrode 4.

[0032] The moving electrode 4 is a contact, which electrically gets in connection with a further contact or electrode to enable a current flow while a closing phase and while an operation time and which moving electrode 4 can be separated from the further contact to interrupt current flow while a breaking phase of the mechanical switch 3.

[0033] The apparatus 1 comprises a solid-state-device 5, which is arranged in such a manner that current flows through the solid-state-device 5 while a closing or breaking phase and that current flows through the mechanical switch 3 in closed position while the operation time.

[0034] The solid-state-device 5 is a semi-conductor-device, which is paralleled to the mechanical switch 3. The solid-state-device 5 is a triac, namely a triode for alternating current, which is paralleled to the mechanical switch 3. The mechanical switch 3 is a rocker light switch. The apparatus 1 also comprises a disconnector 6.

[0035] The working principle of the apparatus 1 is a follows:
In a switching on phase (current make), first the mechanical switch 3 is in open position and the disconnector 6 is closed. At this point no current flows into the apparatus 1. While the mechanical switch 3 is closing, the triac, namely the solid-state-device 5, is fired either slightly before the contacts' touch, or when the contacts reopen (bounce).

[0036] In case the triac is fired before the switch contacts' touch, then the inrush current is initiated through the triac, arcing-less. As soon as the contacts of the mechanical switch 3 are in closed position, the current commutes from the triac to the mechanical switch 3 due to the much lower resistance path. The voltage drop is about 10 mV into the mechanical switch 3 for 10A/16A, while the on-state voltage drop is in the range of 1 V into the triac.

[0037] In case the triac is fired after the switch contacts' touch, the inrush current flows through the contacts in closed position of the mechanical switch 3. In case of bouncing of the contacts, an arc voltage will appear, which is usually > 10 V. The scheme protected with this description, as one part of this invention, is described hereafter.

[0038] However, it is such that as soon as a 10 V voltage drop appears on the mechanical switch 3, a current commutation through the triac is initiated. Typical commutation times expected are in the range of 1 μs for 1A and 10 μs for 100 A. Within this duration, limited damages are done to the switch electrodes. Eventually, when the contacts are in a stable closed position after about 1 ms, the current commutates from the triac to mechanical switch 3.

[0039] In a switching off phase (current break), to break the current, the mechanical switch 3 is opened first. As soon as the arc appears between the two contacts, e.g. when a voltage drop > 10 V is given, then the current commutes into the triac. When the current reaches a current zero, the current is stopped. At this point the disconnector 6 opens in order to insure the galvanic insulation of the system.

[0040] For both phases described above (current make and current break), only a very short arc duration appears into the mechanical switch 3, which allows a quasi-arc free rocker light switch.

[0041] Fig. 3 schematically shows that the apparatus 1 comprises a triggering system 12 for the solid-state-device 5. The triggering system 12 electronically controls the gate of the solid-state-device 5 or the triggering system 12 controls the gate of the solid-state-device 5 by a difference of a voltage on the switch 3. The gate especially of a triac must be closed with a further mechanical switch before it fires in the difference of a voltage on the switch.

[0042] The triggering system 12 of the solid-state-device 5 works as follows:
The triggering of the solid-state device 5 and its synchronization with the mechanical switch 3 is very important. There are essentially two schemes shown in Fig. 3 that can be used to control the solid-state-device's gate.

[0043] Fig. 3 shows an illustration of the combined system, comprising the mechanical switch 3 and the solid-state-device 5, with two controlling possibilities A and B.

[0044] The possibility A schematically shows, that the gate of the solid-state-device 5 is controlled electronically, and the possibility B schematically shows, that the gate of the solid-state-device 5 is controlled by the difference of voltage on the mechanical switch 3, which is activated mechanically, when the switch 3 closes, and is deactivated mechanically when the switch 3 opens. There must also be a further mechanical switch that closes the gate of the triac.

[0045] The first scheme on the left side of Fig. 3 is to control the solid-state-device's gate by electronic only, using rectifiers, transistors, operational amplifiers, and/or a microcontroller.

[0046] The second scheme on the right side of Fig. 3 controls the solid-state-device's gate with a mechanical connection to the mechanical switch 3.

[0047] With respect to Fig. 4 it becomes clear, that this allows to synchronize the mechanical switch 3 of apparatus 1a in Fig. 4 with the gate switch 7. Because the current flowing through the triac gate has to be limited in a range between 10 - 50 mA, the exact values depend on the triac specifications, the gate switch 7 can be small in comparison to mechanical switch 3.

[0048] Additionally, it will carry this current only for a limited time, usually for a time shorter than 10 ms during the making and breaking phases, so that it does not have to be specially optimized to limit electrical losses or to avoid overheating, unlike the main switch 3. Therefore, the gate switch 7 can be very simple in design.

[0049] It also means that the triac can be chosen for a current lower than the rated current, since it does not have to carry it continuously, which may help to lower the costs. The triggering system 12 is developed such, that, when a voltage difference is larger than a few volts, namely about 10 V, which corresponds to an arc in the main switch 3.

[0050] The role of the disconnector 6 is to ensure the galvanic insulation of the system. Without disconnector 6, the leakage current through the triac would continue to flow.

[0051] Fig. 4 shows an illustration of the simplest hybrid switch system, this includes the concept of triggering of a triac, the mechanical switch 3 is a rocker light switch and further a triac gate switch 7 is given. In the closed position, the gate of the triac is connected, so that the triac can be fired as soon as the minimum current is reached. In an open position, it ensures that the rated current is stopped to flow through the triac, resistors 13, 14 are chosen so, that the triac is fired only, when the voltage drop in the rocker light switch is higher than a certain threshold, typically around 10 V, which would correspond to arcing into the switch 3.

[0052] Fig. 4a shows an alternative scheme without resistors 13, 14. This apparatus 1a' works as described before.

[0053] Resistors may be added in order to limit the current in the gate and/or on the main current path in the triac, in order to protect the device.
Fig. 5 and 5a show further apparatuses 1b, 1b'.

[0054] Finally, an alternative electrical scheme concerning apparatus 1c is proposed that protects the triac's gate in case of over-current and over-voltage. It is shown in Fig. 6 and uses Zener diodes 10, 11 or varistors to fulfil this task. In the system of Fig. 6a only one Zener diode 11 is used.

[0055] The concept of a mechanical switch 3 in parallel to a triac shown here implies that the switching on and off sequences are not done by relays, but by a rocker light switch. Further it is implied that the solid-state device 5 must not be controlled with a microprocessor and/ or transistors, i.e. microelectronically. Further the controlling aspect of the triac implies to use the energy of the electrical network directly and to mechanically synchronize the triac with the switch. Some systems of the state of the art must have a permanent DC supply to operate their equipment synchronously.

[0056] The field of the invention relates to mechanical switches 3, in particular to mechanical switches 3 at low voltages, namely smaller 1 kV, such as rocker light switches. The invention relates to applications of light switches with LED lamps, or any other type of loads with high inrush currents occurring during the making of the current.

[0057] Advantageously the rated voltage level, which is applied to the mechanical switch is smaller than 1000 V, especially smaller than 600 V, and/ or the rated current which flows through the mechanical switch is smaller than 20 A and/ or the inrush current when the mechanical switch is closed is smaller than 250 A. Such a switch at least complies with the requests of international standards. The peak inrush current, as well as the energy during the making operation, are given in these standards. Such a switch complies with the standard "Switches for household and similar fixed electrical installations", which is the IEC 60669-1 Edition 4.0, 2017-02.

Reference numbers

1, 1a, 1b, 1c, **1a', 1b', 1c'**	Apparatus
2	Light emitting diode (LED)
3	Mechanical switch
4	Moving electrode
5	Solid-state-device
6	Disconnector
7	Gate switch
8, 9	Diode
10, 11	Zener diode, **or varistor**
12	Triggering system
13, 14	Resistor

Claims

1. Apparatus (1, 1a-c, 1a'-c') to switch a light-emitting diode (2) or another load, comprising a mechanical switch (3), which comprises a moving electrode (4), wherein the moving electrode (4) is a contact, which electrically gets in connection with a further contact or electrode to enable a current flow while a closing phase and while an operation time and which moving electrode (4) can be separated from the further contact or electrode to interrupt current flow while a breaking phase of the mechanical switch (3),
characterized in that the apparatus (1, 1a-c, 1a'-c') comprises a solid-state-device (5), which is arranged in such a manner that current at least partially flows through the solid-state-device (5) while a closing or breaking phase and that current at least partially flows through the mechanical switch (3) in closed position while the operation time.

2. Apparatus according to claim 1, **characterized in that** the solid-state-device (5) is a semi-conductor-device, which is paralleled to the mechanical switch (3).

3. Apparatus according to claim 1 or 2, **characterized in that** the solid-state-device (5) is a triac, namely a triode for alternating current, which is paralleled to the mechanical switch (3).

4. Apparatus according to claim 1 or 2, **characterized in that** the solid-state-device (5) is a thyristor, which is in anti-parallel configuration to the mechanical switch (3).

5. Apparatus according to one of the preceding claims, **characterized in that** the apparatus (1, 1a-c, 1a'-c') comprises a triggering system (12) for the solid-state-device.

6. Apparatus according to claim 5, **characterized in that** the triggering system (12) electronically or mechanically controls the gate of the solid-state-device (5).

7. Apparatus according to claim 6, **characterized in that** the triggering system (12) controls the gate of the solid-state-device (5) by a difference of a voltage on the mechanical switch (3).

8. Apparatus according to one of the preceding claims, **characterized in that** a gate switch (7) is embodied as a mechanical switch.

9. Apparatus according to one of the claims 6 or 7, **characterized in that** a gate switch (7) is embodied as a FET (field effect transistor), which is controllable by the voltage, which is applied to the mechanical switch (3).

10. Apparatus according to claim 8 or 9, **characterized in that** the gate switch (7) blocks flow of electrical current through the solid-state-device (5) and electrical current flows through the mechanical switch (3), if the voltage is under a threshold value of voltage, and that at least a part of the electrical current flows through the solid-state-

device (5), if the voltage exceeds the threshold value.

11. Apparatus according to one of claims 8 to 10, **characterized in that** mechanical switch (3) and gate switch (7) are mechanically linked together, so that both switches can be closed simultaneously or in succession within a short period of time.

12. Apparatus according to one of the preceding claims, **characterized in that** the mechanical switch (3) is a rocker light switch.

13. Apparatus according to one of the preceding claims, **characterized in that** the apparatus (1, 1a-c, 1a'-c) comprises a disconnector (6).

14. Apparatus according to one of the preceding claims, **characterized in that** the rated voltage level, which is applied to the mechanical switch (3), is smaller than 1000 V, especially smaller than 600 V, and/ or the rated current, which flows through the mechanical switch (3), is smaller than 20 A and/ or the inrush current, when the mechanical switch (3) is closed, is smaller than 250 A.

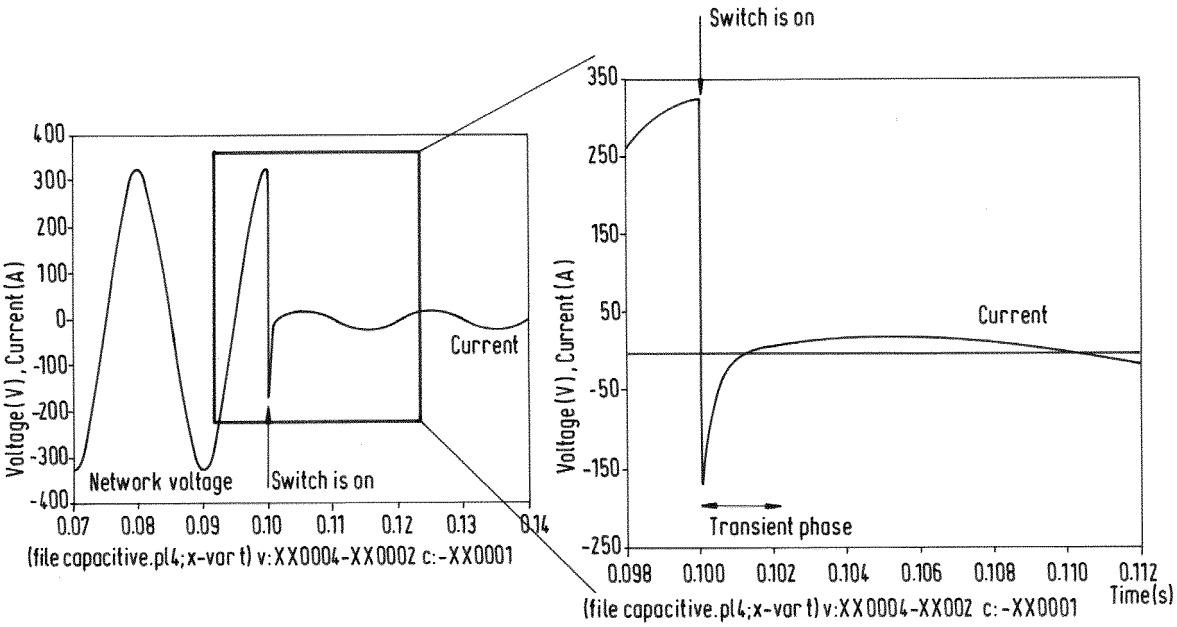
15. Method of use of an apparatus (1, 1a-c, 1a'-c') according to one of the preceding claims to avoid any arcing in the mechanical switch (3).

16. Method of closing an apparatus (1, 1a-c, 1a'-c') according to claim 13 or 14, comprising the following steps:

- In a first step disconnector (6) is closed,
- In a second step a gate switch (7) is closed,
- In a third step the mechanical switch (3) is closed.

17. Method of opening an apparatus (1, 1a-c, 1a'-c') according to claim 13 or 14, comprising the following steps:

- In a first step mechanical switch (3) is opened,
- In a second step gate switch (7) is opened,
- In a third step disconnector (6) is opened.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300
200
100
0
-100
-200
-300
-400
Voltage (V), Current (A)
Current
Network voltage
Switch is on
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0.08
0.09
0.10
0.11
0.12
0.13
0.14
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0.102
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Fig.1

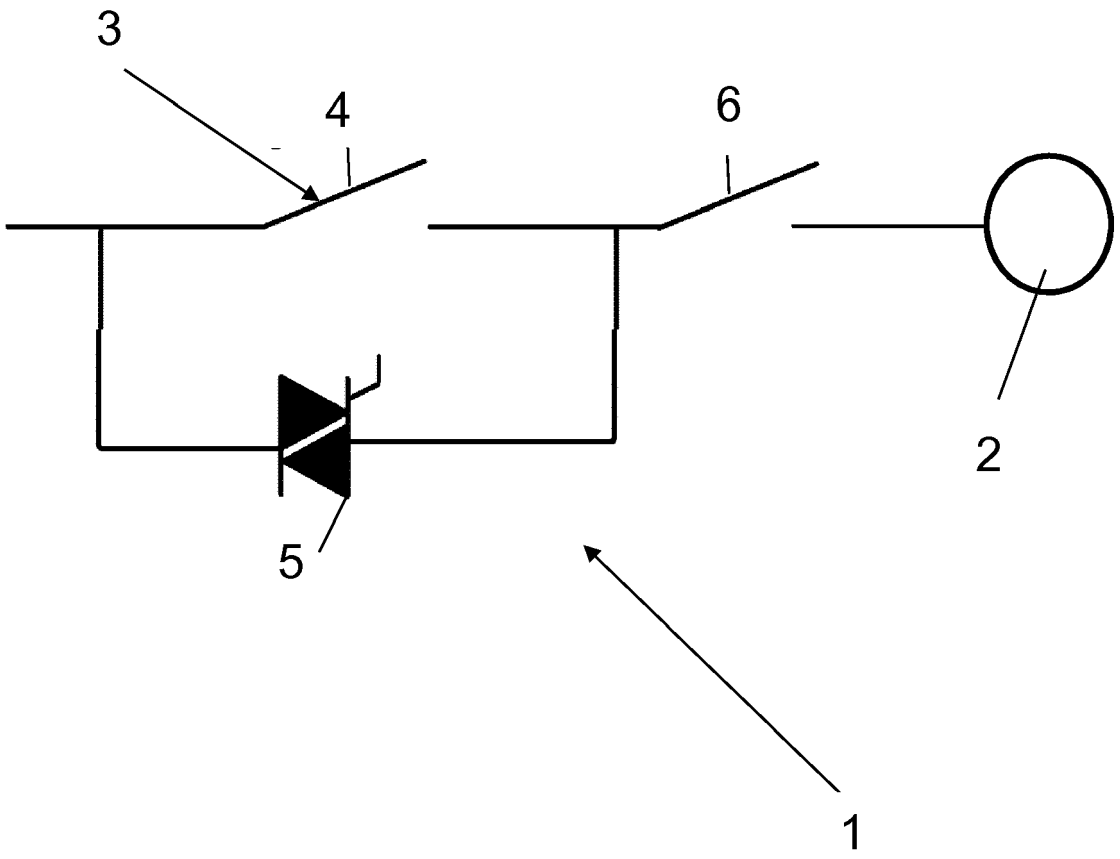

Fig. 2

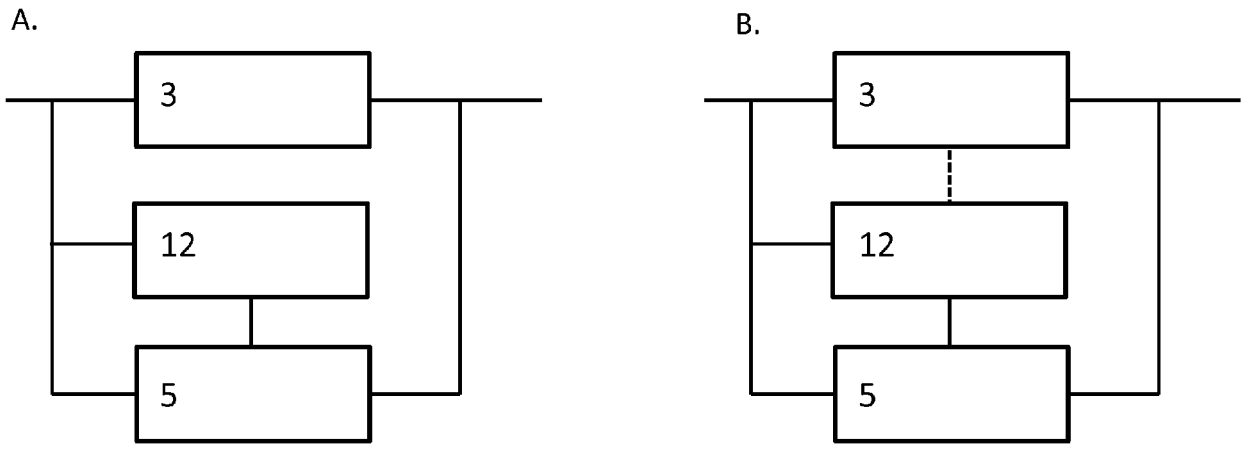

Fig. 3

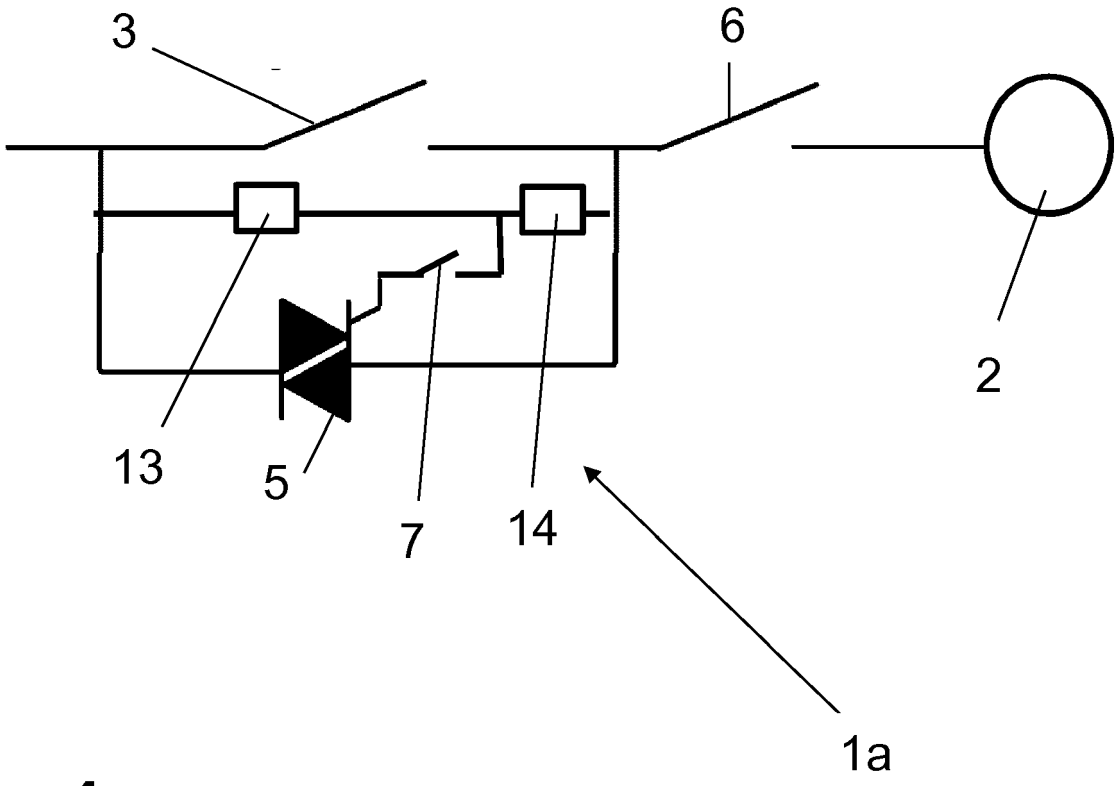

Fig. 4

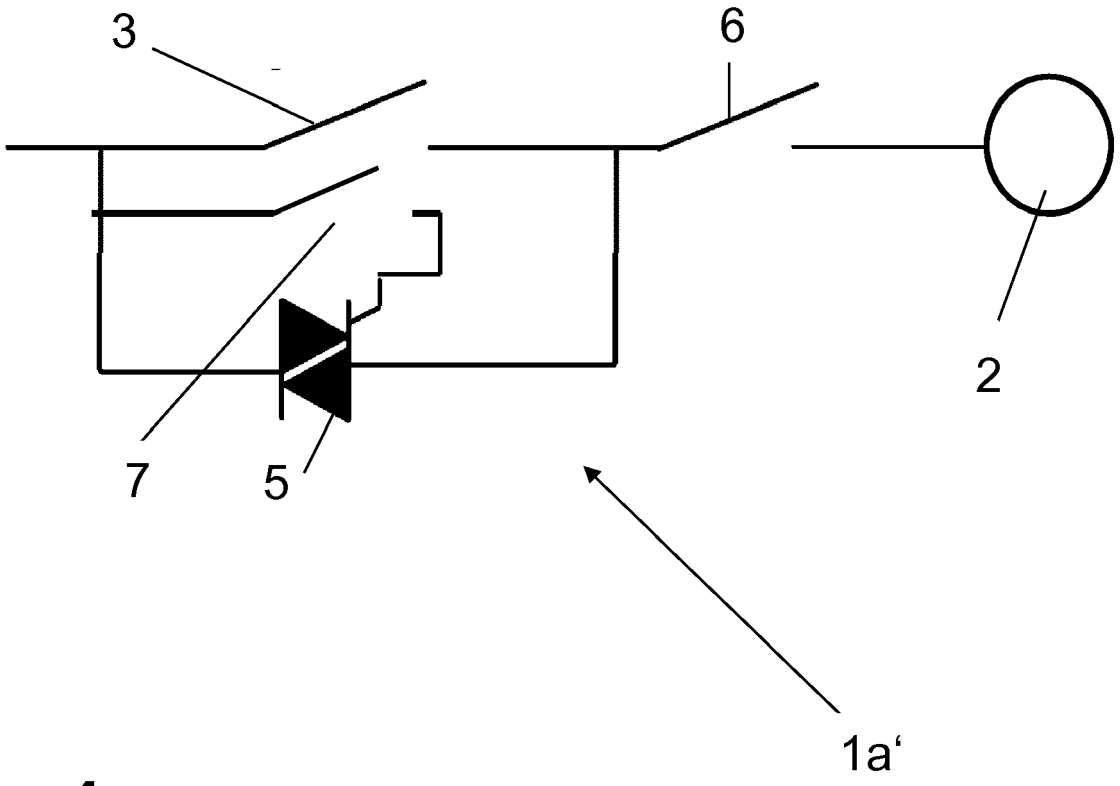

Fig. 4a

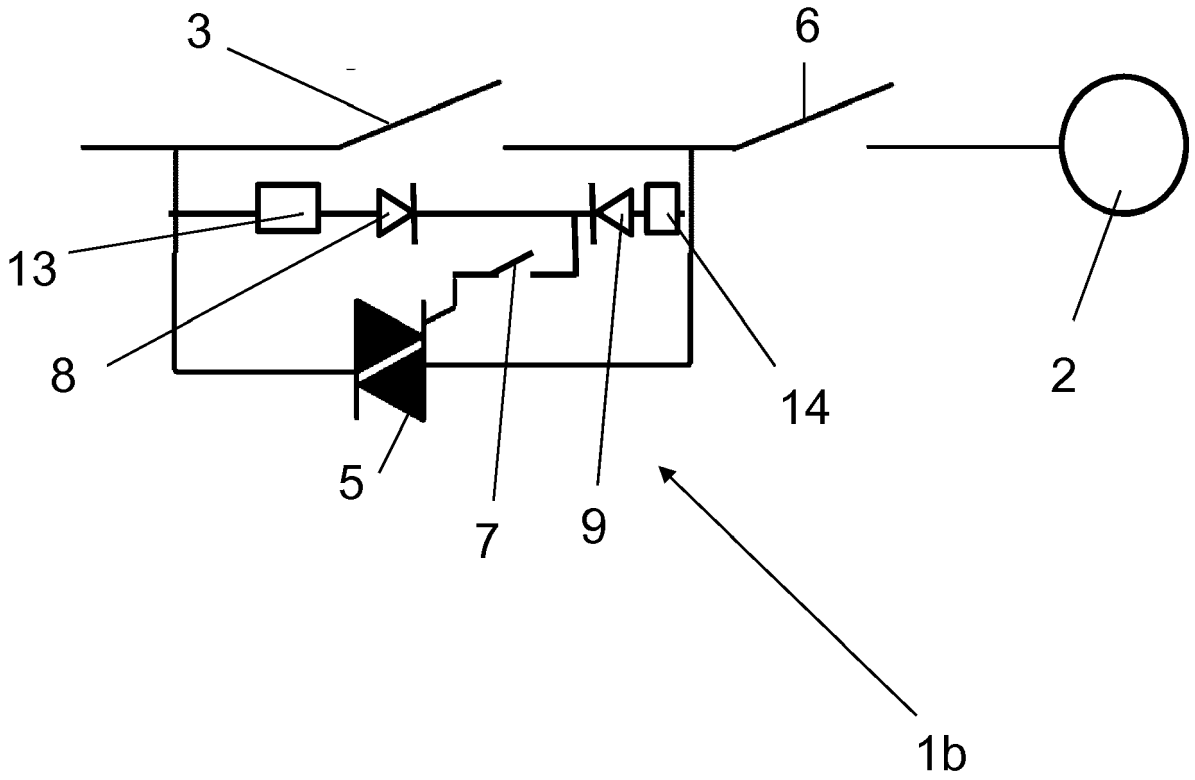

Fig. 5

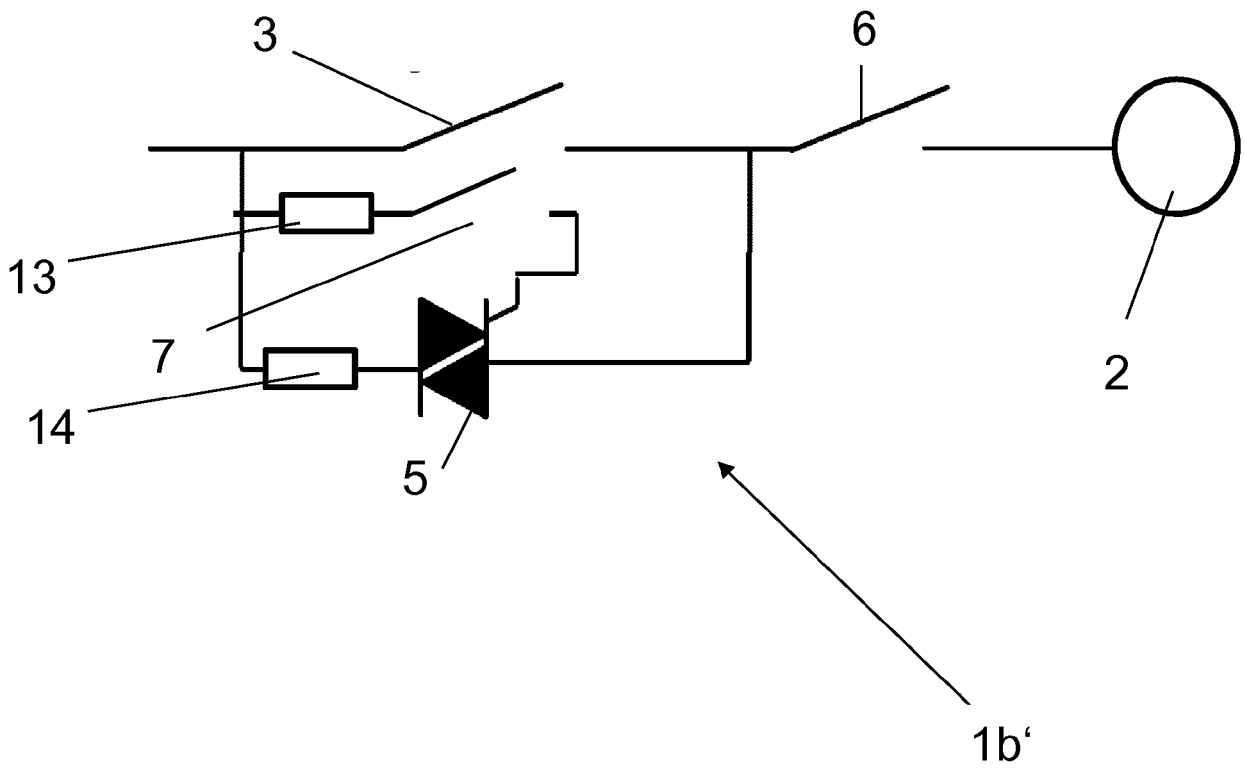

Fig. 5a

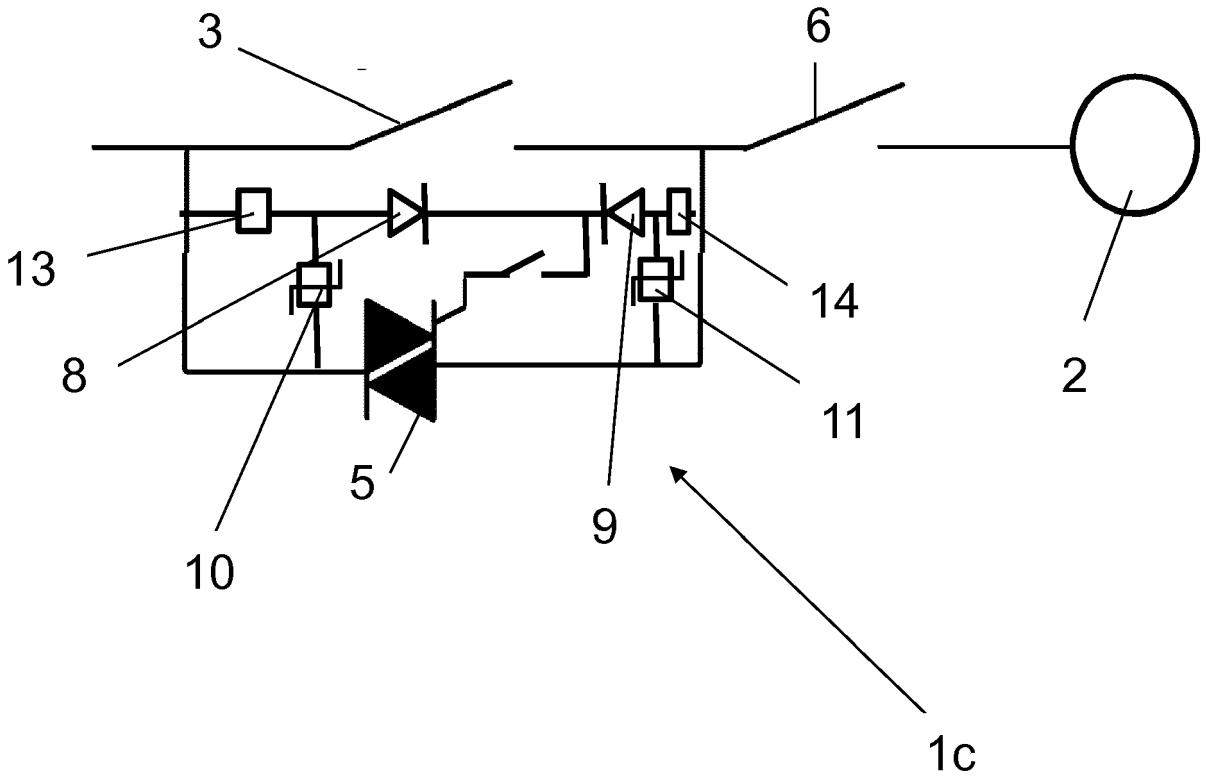

Fig. 6

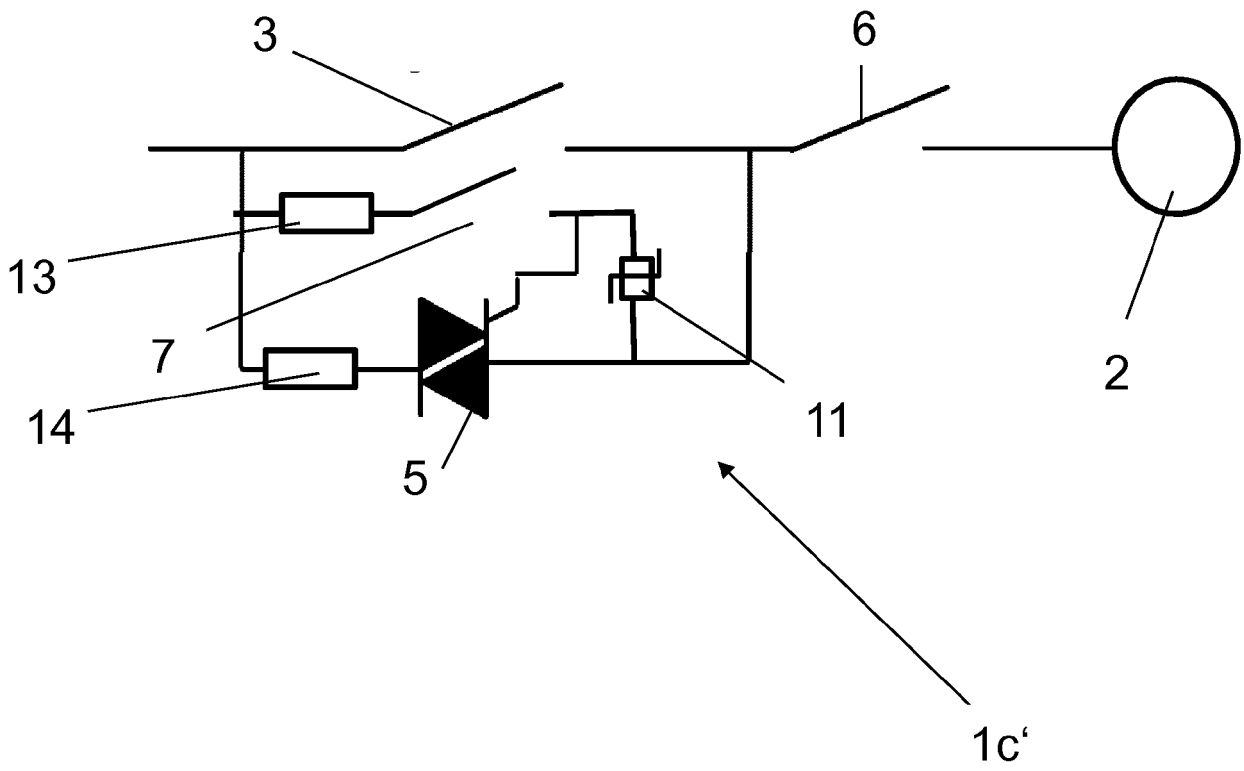

Fig. 6a

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EUROPEAN SEARCH REPORT

Application Number
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