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(54) **Method and device for overvoltage protection of direct-current electrical circuits with currents even in tens of amperes, especially of photovoltaic sources of electric current**

Methode zum Überspannungsschutz von Gleichstromkreisen mit Strom von Dutzenden von Ampère, vorzugsweise von photovoltaischen Stromquellen, und entsprechende Vorrichtung

Méthode de protection contre les surtensions de circuits électriques à courant continu de plusieurs dizaines d' ampère, spécialement de source de courant photovoltaïque, et dispositif de protection correspondant

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Description

Technical field

[0001] The invention relates to the method of overvoltage protection of direct-current electrical circuits with currents up to tens of amperes, especially of photovoltaic sources of electric energy, where a device for overvoltage protection is electrically connected to the direct-current electrical circuit, the device for overvoltage protection has a current path, in the current path is electrically connected at least one varistor, the current path contains a fixed element and a moving element, the fixed element is by soldered joint electrically connected to the moving element, the soldered joint creates point of intentional cutting off the current path between the fixed element and the moving element, the device further contains a spring-loaded moving action member assigned to the moving element the soldered joint in point and the spring-loaded moving action member creates a thermal initiated cut-out mechanism, whereas the soldered joint melts by heat generated by passing of electric direct current through the varistor or through the fixed element, the soldered joint and the moving element and the spring-loaded moving action member executes intentional cutting off the current path, during the intentional cutting off an air gap between the fixed element and moving element is intentionally created and is gradually enlarging.

[0002] The invention relates to a device for overvoltage protection of direct-current electrical circuits with currents even in tens of amperes, especially of photovoltaic sources of electric current, which comprises a contacts for connection the device to the protected circuit, between the contacts a current path is arranged, in which is connected at least one varistor with an electrode, whereas the current path between the electrode and one of the contacts contains a fixed element and a moving element, the fixed element and the moving element are electrically connected by a soldered joint, the soldered joint creates a point of intentional cutting off the current path, to the moving element is assigned a spring-loaded moving action member of a thermally initiated cut-out mechanism, the spring-loaded moving action member applies a force to the moving element in direction parallel with plane of the said soldered joint, the spring-loaded moving action member is adapted for creation and gradually enlarging of an air gap between the fixed element and the moving element after melting of the soldered joint.

Background art

[0003] It is generally known, that upon disconnecting the current path in direct current electrical circuits the electric arc occurs in a situation, when the basic conditions of minimum electric voltage between the disconnected parts of the current path and minimum values of electric current in the point of disconnecting are met. If these conditions are not met, the electric arc is not cre-

ated between the parts of current path being disconnected.

[0004] The document DE 10 2007 015 933 (or DE 20 2007 018 507 U) discloses the device for overvoltage protection of photovoltaic sources of direct-current electrical circuits, which comprises between the terminals for connection to protected circuit an inserted switched discharger and cutting-off discharger. Parallel to both dischargers between the terminals for connection to protected circuit there is connected a non-linear resistance element, which in the represented example of embodiment is formed of a pair of varistors. The device further comprises a control circuit working as a co-ordinating and supervising unit and comprising a number of further parts.

[0005] The disadvantage of this arrangement is a considerable complexity and price of the device, as the device requires installation of a number of parts, including the complex and costly control circuit.

[0006] From DE 10 2005 040432 is known solution, which comprises switch, to which is in parallel manner connected a resistance. To the switch is in parallel manner connected electronic switching device formed of a system of controlled thyristors while the electronic switching device is in a series manner connected with the condenser.

[0007] Main disadvantage of this solution is its high complexity, this also from the point of view of functioning of the device.

[0008] From WO 2006/120522, WO 2010/106411, WO2007/017736, WO 2008/104824 and further documents there are known the devices for overvoltage protection, which use varistors as non-linear resistance elements. These devices are built-in into a unified box installed on a standard unified installation slat. Inner space of the box usable for mounting of all necessary elements is considerably restricted. The box comprises contacts for connection to protected electrical circuit. Between contacts in the box there is arranged the current path, in which at least one varistor or a group of parallel connected varistors is connected. Contacts of varistor are flat, while one contact of varistor is electrically conductively coupled with one contact of the device for overvoltage protection, and the second contact of varistor is on its surface connected by means of a solder with opposite surface of the first end of flexible electrically conductive means, through which a point of intentional cutting off the current path is created. The flexible electrically conductive means is with its second end electrically conductively coupled with second contact of the device for overvoltage protection. To the first end of the flexible electrically conductive means the spring-loaded moving element is assigned, which to the first end of the electrically conductive means develops a force F in direction parallel with solder connected surfaces of the second contact of varistor and the first end of flexible electrically conductive means. Due to ageing of varistor the value of relatively small values of electric current running through varistor

and the current path increases, thus even through the point of intentional cutting off the current path. Then due to overvoltage a short-circuit of varistor occurs, as a result of which through varistor and also through current path, thus through the point of intentional cutting off the current path, the short-circuit current having values often of tens of amperes is flowing. Due to flowing of electric current and spreading of heat from varistor the parts of current path in the point of intentional cutting off the current path are being warmed and solder connecting the second contact of varistor and the first end of flexible electrically conductive means is molten, this soldered joint loses its strength and the first end of flexible electrically conductive means is by action of the spring loaded moving element pushed off in a sliding movement on surface of the second contact of varistor and in direction being parallel with surface of the second varistor contact up to the space outside contact with the second varistor contact, and the current path is cut off. At usage of this solution in circuits with alternate voltage at this cutting off the current path, at which the moving disconnected part of current path is gradually accelerated to a final speed for cutting off, while still for a certain time, when the first end of flexible electrically conductive element in a sliding manner already moves for the purpose of cutting off, there still flows electric current between the second contact of varistor and the first end of flexible electrically conductive means, which is caused by presence of a molten solder between non-moving second contact of varistor and the moving first end of flexible electrically conductive means, no electric arc is induced between the disconnected parts of current path not even at short-circuit of varistor due to overvoltage, which is caused first of all by a speed with which the first moving end of flexible electrically conductive means moves in a moment of disconnecting the current path, when the insulation strength of an air gap increases very rapidly. From movement of spring loaded moving element also an optical and possibly remote status signalling of device for overvoltage protection is derived. Nevertheless at usage of this solution in direct-current electrical circuits at short circuit of varistor due to overvoltage, when short-circuit current in tens of amperes is flowing, an uncontrolled electric arc occurs at these devices, which is not permissible according to the safety regulations. In experiments it was verified, that at these devices an uncontrolled electric arc does occur at values of electric current in units of amperes, which does not meet requirements of practice.

[0009] Known is also device for overvoltage protection, which comprises the current path with point of intentional cutting off, which is performed as a change-over switch of the current path between the branch with varistor and the short-circuit branch with a fuse cut-out, when in initial status the current path is lead through the branch with varistor. If in the point of intentional cutting off the current path is disconnected, between the parts of current path being disconnected an electric arc develops, and simultaneously the moving section of the current path being

disconnected moves into a contact with the free end of the short-circuit branch with the fuse cut-out, then after connection of moving part of the current path being disconnected with free end of the short-circuit branch with fuse cut-out the varistor is in a short circuit, the above mentioned electric arc switches off and through melting the fuse cut-out electric current is cut off.

[0010] The goal of the invention is to remove or at least minimise shortcomings of the background art at direct-current electrical circuits, especially at photovoltaic sources of electric current, at which in case of a short circuit of varistor the flowing currents achieve the values of even tens of amperes.

Principle of the invention

[0011] The goal of the invention has been achieved through the method of overvoltage protection of direct-current electrical circuits with currents even in tens of amperes, especially of photovoltaic sources of electric current, as defined in claim 1.

[0012] The principle of the device for overvoltage protection of direct-current electrical circuits with currents even in tens of amperes, especially of photovoltaic sources of electric current, is further defined in claim 3.

[0013] This invention enables in simple and price affordable means to realise a safe cutting off the current path in the device for overvoltage protection of direct-current electrical circuits with currents even in tens of amperes, especially of photovoltaic sources of electric current, this both at values of current under 10 A even above 10 A, which meets the requirements of praxis and requirements of the draft (DRAFT) of the norm prEN 50539-11. Another advantage is that only for a short time of heating the current path in a point "X" the electric current flows through the device for overvoltage protection and the protected circuit e.g. the photovoltaic source of electric current after cutting off the current path is fully functional. Another advantage is, that it is not necessary to insert into the current path of the device for overvoltage protection a fuse for direct current as it is in the background art, because the fuse for direct current including the holder is relatively expensive, so that the invention enables besides also to reduce price of the device for overvoltage protection. Another advantage is that the capacitor for the whole service life of the device for overvoltage protection without voltage, through which its voltage loadability for the whole period of service life of the device for overvoltage protection is preserved. Voltage on the capacitor is acting only from the moment of cutting off the current path in the point X till the moment the varistor insertion is replaced.

[0014] Advantageous embodiments of the invention, especially the structure of the current path of the device for overvoltage protection are described in description of exemplary embodiments and are the subject of the appended claims.

Description of the drawing

[0015] The invention is schematically represented in the drawing where the Fig. 1 shows a ground plan of one device for overvoltage protection, the Fig. 1a an example of another arrangement of the device for overvoltage protection, the Fig. 2 exemplary embodiment of the point X of intentional cutting off the current path of the device for overvoltage protection with parallel assigned capacitor, the Fig. 3a to 3d an exemplary embodiment of the point X with parallel assigned capacitor and a temporary serial resistance and the individual phases of concurrence of these elements and the Fig. 4 a time course of electric voltage and of electric current at the method according to the invention.

Examples of embodiment

[0016] The method of overvoltage protection of direct-current electrical circuits with currents even in tens of amperes, especially of photovoltaic sources of electric current, consists in that the current path is cut off in a place of intentional cutting off the current path, at the same time at this cutting off the conditions unfavourable for occurrence of uncontrolled electric arc are created, so that in the moment when between the current path elements being disconnected a nonzero interval is created, value of electric current in the point of cutting off is limited, by which occurrence of uncontrolled electric arc between the current path elements being disconnected is prevented. The value of electric current in the point of cutting off is limited due to increase of voltage through rerouting the flow of electric current to parallel current path formed of capacitor (condenser or a group of condensers). The capacitor at moment of creation of the nonzero interval between the current path elements being disconnected represents only a minor electric resistance, because the voltage on capacitor corresponds to the status before creation of the nonzero interval between the current path elements being disconnected and it is being increased in dependence on capacity of the capacitor and the value of current. Speed of mutual shifting away the current path elements being disconnected is so high, that the breakdown strength of air gap between the mutually shifting away elements of the current path being disconnected increases quicker than voltage on the capacitor, which increases due to charging the capacitor by a incoming electric charge from the rerouting flow of electric current, and this voltage grows up to the height of maximum voltage of the source of the direct-current electric current.

[0017] Such behaviour of the device for overvoltage protection may be achieved by a suitable structure of the device for overvoltage protection with respective dimensioning of individual elements.

[0018] Exemplary embodiment of the device for overvoltage protection of direct-current electrical circuits with currents even in tens of amperes, especially of photo-

voltaic sources of electric current, comprises the box 0, in which individual functional elements of the device for overvoltage protection are built-in. The device for overvoltage protection comprises contacts 00 for connection of electric conductors of protected circuit. Between the contacts 00 there is in the box 0 arranged the current path, in which as a protective element at least one non-linear resistance element is integrated, for example varistor 1 or a group of parallel integrated varistors 1.

[0019] In the current path the point X of intentional cutting off the current path is arranged. The point X in the represented example of embodiment is performed in the contact place of the upper surface of the lower electrode (fixed element) 10 of varistor 1 and of the lower surface of the first end of flexible electric conductor (moving element) 11. Both these contact surfaces are connected by means of solder 12. Function of cutting off the current path in the point X is realised by means of thermal initiated cut-out mechanism 3, which is assigned to the point X, and which in the represented example of embodiment is formed of a spring loaded moving action member, which on the flexible electric conductor 11 develops the force F in direction parallel with upper surface of the lower electrode 10 of varistor 1 and with lower surface of the first end of the flexible electric conductor 11. The force F is either developed directly in direction parallel with upper surface of the lower electrode 10 of varistor 1 and with lower surface of the first end of flexible electric conductor 11 or it acts in this direction, e.g. thanks to production deviations etc., as a component of totally acting force. The force F after melting the solder 12 as a result of increased temperature of varistor pushes off the first end of flexible electric conductor 11 from the lower electrode 10 of varistor 1 by a shearing action on the molten solder 12, i.e. by sliding motion of the first end of flexible electric conductor 11 on the lower electrode 10 of varistor 1, so that the first end of flexible electric conductor 11 at the moment of creation of nonzero interval between it and the lower electrode 10 of varistor 1 already develops a relatively high speed. Solder 12 is molten and the thermal initiated cut-out mechanism 3 is initiated by means of a heat, which is partly developed by a non-linear resistance element (varistor 1) integrated in the current path, and which is also developed by passage of electric current through the current path.

[0020] Thermal initiated cut-out mechanism 3 is coupled with means for optical and/or remote signalling of status of the device for overvoltage protection. For optical signalling of status of the device for overvoltage protection the device is provided with swing lever 4, which is coupled with thermal initiated cut-out mechanism 3.

[0021] In the Fig. 2 to the current path of the device for overvoltage protection in vicinity of the point X there is assigned the parallel current path 15 with the capacitor 16. The capacitor 16 is in parallel manner to the current path through the point X connected between the lower electrode 10 of varistor 1 and the non-moving section of the flexible electric conductor 11 only after the first end

of the flexible electric conductor 11.

[0022] In the Fig. 3a to 3d to the current path of the device for overvoltage protection in vicinity of the point X there are assigned the parallel current path 15 with the capacitor 16 and the serial temporary resistance element, which since the moment of beginning of the sliding disconnecting movement of the first end of flexible electric conductor 11 has a longer time of electric current conduction than is the conduction time of electric current through the current path through the point X since the moment of beginning of the sliding disconnecting movement of the first end of flexible electric conductor 11, when the sliding disconnecting movement is started after melting of the solder 12 through action of the force F. At the end of the lower electrode 10 of varistor 1 distant from the first end of the flexible electric conductor 11 there is electrically in a conductive manner attached the auxiliary electric conductor 13, which has distinctly higher electric resistance, than the lower electrode 10 of varistor 1 and a flexible electric conductor 11 have, e.g. it is formed of a strip made of stainless steel of a small thickness. The auxiliary electric conductor 13 runs along the lower surface of the lower electrode 10 of varistor 1 up to a free space in distance A from the edge of the lower electrode 10 of varistor 1, where it finishes with a contact edge 130 situated in a free space behind the first end of flexible electric conductor 11 outside the contact with flexible electric conductor 11. At the same time the distance A is smaller than the length of the first end of flexible electric conductor 11. Between the auxiliary electric conductor 13 and the lower electrode 10 of varistor 1 there is, with exception of the place of connection of the auxiliary electric conductor 13 to the lower electrode 10 of varistor 1, situated electric insulation 14, e.g. insulation foil. Capacitor 16 is parallel to the current path through the point X connected between the lower electrode 10 of varistor 1 and the non-moving section of the flexible electric conductor 11. still after the first end of flexible electric conductor 11.

[0023] The Fig. 3a represents full functioning status of the device for overvoltage protection without occurrence of a failure status. Solder 12 is in a solid status and holds the first end of flexible electric conductor 11 and the lower electrode 10 of varistor 1 together. The capacitor 16 shows voltage U_0 .

[0024] The Fig. 3b represents the status when solder 12 has already been molten and the spring-loaded moving action member of thermal initiated cut-out mechanism 3 has already begun to push off the first end of flexible electric conductor 11 in direction of actioning the force F parallel with surface of the lower electrode 10 of varistor 1. The first end of the flexible electric conductor 11 moves in gradually increasing speed, at the same time it is still in electric contact with the lower electrode 10 of varistor 1 and it newly has entered into electric contact with contact edge 130 of auxiliary electric conductor 13. The capacitor 16 shows voltage U_{01} .

[0025] The Fig. 3c represents status when the spring-

loaded moving action member of thermal initiated cut-out mechanism 3 has already pushed off the first end of the flexible electric conductor 11 in a still increasing speed parallel with surface of the lower electrode 10 of varistor 1 totally outside electric contact with lower electrode 10 of varistor 1, nevertheless the first end of flexible electric conductor 11 remains in electric contact with contact edge 130 of auxiliary electric conductor 13. The capacitor 16 shows voltage U_2 . The Fig. 3d represents status of total cutting off the current path of the device for overvoltage protection in the point X, when the spring-loaded moving action member of thermal initiated cut-out mechanism 3 has pushed off the first end of the flexible electric conductor 11 totally outside electric contact with contact edge 130 of the auxiliary electric conductor 13. The capacitor 16 shows voltage U_3 .

[0026] Function of the device according to the Fig. 2 is so that, once overvoltage occurs, this is eliminated by passage of electric current through varistor 1, which is thus being warmed by which also the lower electrode 10 of varistor 1 becomes warm. Once the lower electrode 10 of varistor 1 reaches the temperature for melting the solder 12, this becomes molten and releases motion of the spring-loaded moving action member of the thermal initiated cut-out mechanism 3 in direction parallel with surface of the lower electrode 10 of varistor 1. The spring-loaded moving action member starts gradually with increasing speed in sliding manner to shift the first end of the flexible electric conductor 11 on surface of the lower electrode 10 of varistor 1, while thanks to molten solder 12, electric current still passes between the first end of flexible electric conductor 11 and the lower electrode 10 of varistor 1. Once the nonzero interval occurs between the first end of the flexible electric conductor 11 and the lower electrode 10 of varistor 1, voltage between the first end of flexible electric conductor 11 and lower electrode 10 of varistor 1 is increased, by which the flowing electric current re-routes into parallel current path 15 with capacitor 16, which in this moment represents only minor electric resistance, because the voltage on capacitor 16 corresponds to status before occurrence of the nonzero interval between the current path elements being disconnected and it is increased depending on capacity of the capacitor 16 and value of the current. Thanks to sliding motion of the first end of the flexible electric conductor 11 on surface of the lower electrode 10 of varistor 1, this first end of flexible electric conductor 11 at the moment of creation of the mentioned nonzero interval reaches still a sufficient speed of its motion, so that at its further shifting away from the lower electrode 10 of varistor 1 the interval being created increases, and with it also its breakdown strength quicker than the voltage is increased on capacitor 16, which (voltage on the capacitor 16) increases due to charging the capacitor 16 by the incoming electric charge from the re-routed flow of electric current. This voltage on capacitor 16 increases till the value of maximum voltage of the source of electric direct-current. At this arrangement there will not be even at values of

electric current in tens of amperes occurrence of uncontrolled electric arc between the current path elements being disconnected at the point **X** of intentional cutting off the current path. Under the term "uncontrolled" electric arc it is understood a longer lasting electric arc. Experimentally it was proven, that upon cutting off the direct-current in values of tens of amperes using the device according to the invention being submitted, there was occurrence of only a sparkle between the first end of flexible electric conductor **11** and the lower electrode **10** of varistor **1** at the moment of creation of the nonzero interval between the first end of the flexible electric conductor **11** and the lower electrode **10** of varistor **1**. No uncontrolled electric arc was created.

[0027] Function of the device according to the Fig. 3a to 3d is following. The device is fully functional, see the Fig. 3a, no electric current flows through the varistor **1**. There is no movement of individual elements of the current path. Once overvoltage occurs, this is eliminated by passage of electric current through the varistor **1**, which is warmed this way, by which also the lower electrode **10** of varistor **1** becomes warm.

[0028] Once the lower electrode **10** of varistor **1** warms to the temperature for melting the solder **12**, this gets molten and releases motion of the spring loaded moving action member of thermal initiated cut-out mechanism **3** in direction parallel with surface of the lower electrode **10** of varistor **1**. The spring loaded moving action member starts gradually in an increasing speed to shift the first end of flexible electric conductor **11** on surface of the lower electrode **10** of varistor **1**, at the same time thanks to the molten solder **12** between the mutually moving elements of the current path, i.e. between the first end of the flexible electric conductor **11** and the lower electrode **10** of varistor **1** electric current is still passing. Consequently the first end of the flexible electric conductor **11** touches the contact edge **130** of auxiliary electric conductor **13**, while the first end of flexible electric conductor **11** is still in electrically conductive contact with the lower electrode **10** of varistor **1**, as it is represented in the Fig. 3b. Through creation of electrically conductive contact between the first end of the flexible electric conductor **11** and the contact edge **130** of auxiliary electric conductor **13** upon preservation of electrically conductive contact between the first end of flexible electric conductor **11** and the lower electrode **10** of varistor **1**, there occurs jump increase of electric resistance of current path at the point **X**, which results in that the flow of electric current is re-routed via capacitor **16**, which is being charged, the voltage $U_{01} \geq U_0$ and through the current path through the point **X** only fraction of original value of electric current is flowing. By further shifting the first end of the flexible electric conductor **11**, the Fig. 3c, electrically conductive connection of the first end of the flexible electric conductor **11** and of the lower electrode **10** of varistor **1** is cancelled, so that the point **X** is disconnected, most of electric current flows through capacitor **16**, which is being charged, the voltage $U_2 > U_{01} \geq U_0$, but simultaneously

the voltage is $U_2 < U_{arc}$ (arc voltage), so that there is no uncontrolled electric arc between the elements of current path being disconnected in the point **X**. By further shifting the first end of the flexible electric conductor **11**, the Fig. 3d, also electrically conductive connection of the first end of flexible electric conductor **11** and of contact edge **130** of auxiliary electric conductor **13** is cancelled, while the moving first end of the flexible electric conductor **11** shows such speed of its motion, that the insulation strength of air gap between the first end of flexible electric conductor **11** and the contact edge **130** of auxiliary electric conductor **13** increases quickly and no uncontrolled electric arc occurs. It is obvious, that at embodiment according to the Fig. 3a to 3d the total resistance of the current path is increased, by which redistribution of current between the current path in the point **X** and the parallel current path **15** with the capacitor **16** is increased.

[0029] As it is seen from the Fig. 4, through the method and the device according to this invention an effective restriction of conditions necessary for creation of (uncontrolled) electric arc between the elements of current path being disconnected is achieved, as at increase of voltage there is significant drop in value of electric current.

Industrial applicability

[0030] The invention is applicable at overvoltage protection of direct current electric circuits with currents even in tens of amperes, especially of photovoltaic sources of direct current.

Claims

1. Method of overvoltage protection of direct-current electrical circuits with currents up to tens of amperes, especially of photovoltaic sources of electric energy, where a device for overvoltage protection is electrically connectable to the direct-current electrical circuit, the device for overvoltage protection has a current path, in the current path is electrically connected at least one varistor (1), the current path contains a fixed element (10) of the varistor (1) and a moving element (11), the fixed element (10) is by a soldered joint (12) electrically connected to the moving element, the soldered joint creates a point (X) of intentional cutting off the current path between the fixed element and the moving element, the device further contains a spring-loaded moving action member assigned to the moving element (11), the soldered joint in point (X) and the spring-loaded moving action member create a thermal initiated cut-out mechanism (3), in that the soldered joint in point (X) melts by heat generated by passing of electric direct current through the varistor (1) or through the fixed element, the soldered joint and the moving element and the spring-loaded moving action member applies a force (F) to the moving element (11) in di-

rection parallel with an upper surface of the fixed element (10) of varistor (1) and with a lower surface of the moving element (11), the force (F) after melting the soldered joint (12) as a result of increased temperature of varistor (1) pushes off the moving element (11) from the fixed element (10) of varistor (1) by sliding motion of the moving element (11) on the fixed element (10) of varistor (1),

the spring-loaded moving action member executes intentional cutting off the current path in the point (X), during the intentional cutting off an air gap between the fixed element and moving element is intentionally created and is gradually enlarging, **characterised in that**, during the intentional cutting off of the current path in the point (X), the value of direct electric current in the point of cutting off is limited through rerouting the flow of direct electric current to a parallel current path (15) formed by a capacitor (16), during the creation and the enlarging of the air gap the moving element is moving with so high speed, that breakdown strength of the simultaneously created and gradually enlarging air gap between the fixed element and moving element increases quicker than an increase of a voltage on the capacitor (16), the voltage on the capacitor (16) increases due to charging the capacitor (16) by an incoming electric charge from the rerouting flow of electric direct-current, and this voltage grows up to a height of a maximum voltage of the source of the direct-current electric current and occurrence of uncontrolled electric arc between the fixed element and the moving element is prevented.

2. Method according to the claim 1, **characterised in that**, during creating and enlarging of the air gap a temporary resistance element (13) with higher electric resistance than the fixed and moving elements (10,11) is temporarily connected between the fixed element and the moving element to increase redistribution of electric current flow between point (X) and the parallel current path (15) with capacitor (16).
3. Device for overvoltage protection of direct current electric circuits with currents up to tens of amperes, especially of photovoltaic sources of electric energy, which comprises contacts (00) for electric connection of the device to the protected circuit, between the contacts (00) there is arranged a current path, in which is connected at least one varistor (1) with a fixed element (10), the current path between the fixed element (10) and one of the contacts (00) contains a moving element (11), the fixed element and the moving element are electrically connected by a soldered joint (12), the soldered joint creates a point (X) of intentional cutting off the current path between the fixed element (10) and the moving element (11), to the moving element is assigned a spring-loaded moving action member, the soldered joint (12) in the

point (X) and the spring-loaded moving action member create a thermal initiated cut-out mechanism (3), in that the soldered joint (12) in the point (X) melts by heat generated by passing of electric direct current through the varistor (1) or through the fixed element (10), the soldered joint (12) and the moving element (11) and the spring-loaded moving action member applies a force (F) to the moving element in direction parallel with an upper surface of the fixed element (10) of varistor (1) and with a lower surface of the moving element (11), the force (F) after melting the soldered joint (12) as a result of increased temperature of varistor (1) pushes off the moving element (11) from the fixed element (10) of varistor (1) by sliding motion of the moving element (11) on the fixed element (10) of varistor (1), the spring-loaded moving action member is, adapted for creation and gradually enlarging of an air gap between the fixed element and moving element after melting of the soldered joint in point (X), **characterised in that** to the current path through the point (X) is assigned a parallel current path (15), in which a capacitor (16) is connected, the spring-loaded moving action member is so spring-loaded to shift the moving element with so high speed, that breakdown strength of the created and gradually enlarging air gap increases quicker than an increase of a voltage on the capacitor (16), which increases due to charging the capacitor (16) by an incoming electric charge from the rerouting flow of electric direct-current, and this voltage grows up to a height of a maximum voltage of the source of the direct-current electric current and occurrence of uncontrolled electric arc between the fixed element and the moving element is prevented.

4. Device according to the claim 3, **characterised in that**, the parallel current path (15) with capacitor (16) is connected between the fixed element (10) of the varistor (1) and the moving element (11).
5. Device according to the claim 3, **characterised in that**, to the point (X) of intentional cutting off the current path there is assigned a temporary serial resistance
6. Device according to the claim 4, **characterised in that**, to the point (X) of intentional cutting off the current path there is assigned a temporary serial resistance which is formed of an auxiliary electric conductor (13), which is at one of its ends electrically connected to the fixed element (10) of varistor (1), and on its second end it is provided with contact edge (130) situated at a distance (A) from the fixed element (10, distance (A) is smaller than the length of the moving element (11).
7. Device according to the claim 6, **characterised in that**, the auxiliary electric conductor (13) is formed

of a steel strip made of stainless steel of a small thickness.

8. Device according to any of the claims 6 or 7, **characterised in that**, between the auxiliary electric conductor (13) and the fixed element (10) of varistor (1) there is, with exception of the place of connection of the auxiliary electric conductor (13) to the fixed element (10) of varistor (1), situated electric insulation (14).

Patentansprüche

1. Verfahren zum Überspannungsschutz von Gleichstromkreisen mit den Strömen auch in einigen Zehnen von A, insbesondere von Photovoltaikquellen der elektrischen Energie, bei dem eine Überspannungsschutzeinrichtung an einen Gleichstromkreis elektrisch anschließbar ist, die Überspannungsschutzeinrichtung eine Strombahn aufweist, in der Strombahn mindestens ein Varistor (1) elektrisch angeschlossen ist, die Strombahn ein stationäres Element (10) eines Varistors (1) und ein bewegliches Element (11) aufweist, das stationäre Element (10) durch eine Lötverbindung (12) mit dem beweglichen Element elektrisch verbunden ist, die Lötverbindung eine Stelle (X) zu einer beabsichtigten Entkopplung der Strombahn zwischen dem stationären Element und dem beweglichen Element aufweist, die Einrichtung weist weiter ein abgefedertes bewegliches Aktionsglied auf, das dem beweglichen Element (11) zugeordnet ist, die Lötverbindung in der Stelle (X) und das abgefederte bewegliche Aktionsglied bilden einen temperaturinitiierten Entkopplungsmechanismus (3), in dem die Lötverbindung in der Stelle (X) durch die Wärme verschmolzen wird, die durch den Durchgang eines Gleichstromes über Varistor (1) oder über stationäres Element, Lötverbindung und bewegliches Element generiert wird, wobei das abgefederte bewegliche Aktionsglied mit einer Kraft (F) auf das bewegliche Element (11) in solcher Richtung wirkt, die mit der oberen Seite des stationären Elementes (10) des Varistors (1) und mit der unteren Seite des beweglichen Elementes (11) parallel laufend ist, die Kraft (F) nach dem Verschmelzen der Lötverbindung (12) infolge einer erhöhten Temperatur des Varistors (1) das bewegliche Element (11) vom stationären Element (10) des Varistors (1) durch eine Schiebbewegung des beweglichen Elementes (11) auf dem stationären Element (10) des Varistors (1) wegdrückt, das abgefederte bewegliche Aktionsglied eine beabsichtigte Entkopplung der Strombahn in der Stelle (X) ausübt, während der beabsichtigten Entkopplung ein Luftspalt zwischen dem stationären Element und dem beweglichen Element gebildet wird und dieser kontinuierlich größer wird, **dadurch gekennzeichnet, dass** während der beabsichtigten

Entkopplung der Strombahn in der Stelle (X) der Gleichstromwert in der Stelle der Entkopplung durch eine Umlenkung des Gleichstromflusses in eine parallel laufende Strombahn (15) begrenzt wird, die durch einen Kapazitor (16) gebildet wird, während sich das bewegliche Element bei der Bildung und Vergrößerung des Luftspaltes mit so hoher Geschwindigkeit bewegt, dass die Durchschlagfestigkeit des gleichzeitig zu bildenden und kontinuierlich sich vergrößernden Luftspaltes zwischen dem stationären Element und dem beweglichen Element schneller wächst, als das Wachstum der Spannung auf dem Kapazitor (16) ist, die Spannung auf dem Kapazitor (16) durch die Ladung des Kapazitors (16) mit einer elektrischen Ladung wächst, die aus dem umgelenkten Gleichstromfluss kommt, und diese Spannung bis in die Höhe der Maximalspannung einer Gleichstromquelle steigt und so der Entstehung eines nicht kontrollierten elektrischen Bogens zwischen dem stationären Element und dem beweglichen Element vorbeugt.

2. Verfahren nach dem Anspruch 1, **dadurch gekennzeichnet, dass** während der Bildung und Vergrößerung des Luftspaltes zwischen das stationäre Element und das bewegliche Element ein vorübergehender Widerstandselement (13) mit einem höheren elektrischen Widerstand als beim stationären und beweglichen Element (10, 11) zur Erhöhung einer Flussumverteilung des elektrischen Stromes zwischen der Stelle (X) und der parallel laufenden Strombahn (15) mit einem Kapazitor (16) vorübergehend angeschlossen wird.

3. Überspannungsschutzeinrichtung von Gleichstromkreisen mit den Strömen auch in einigen Zehnen von A, insbesondere von Photovoltaikquellen der elektrischen Energie, die Kontakte (00) zum elektrischen Anschluss der Einrichtung an geschützten Kreis aufweist, zwischen Kontakten (00) ist eine Strombahn angeordnet, in der mindestens ein Varistor (1) mit einem stationären Element (10) geschaltet ist, die Strombahn weist zwischen dem stationären Element (10) und einem der Kontakte (00) ein bewegliches Element (11) auf, das stationäre Element und das bewegliche Element sind durch eine Lötverbindung (12) elektrisch verbunden, die Lötverbindung (12) bildet eine Stelle (X) zu einer beabsichtigten Entkopplung der Strombahn zwischen dem stationären Element (10) und dem beweglichen Element (11), dem beweglichen Element ist ein abgefedertes bewegliches Aktionsglied zugeordnet, die Lötverbindung (12) in der Stelle (X) und das abgefederte bewegliche Aktionsglied bilden temperaturinitiierte Entkopplungseinrichtung (3), wo die Lötverbindung (12) in der Stelle (X) durch die Wärme verschmolzen wird, die durch einen Durchgang vom Gleichstrom durch Varistor (1) oder stationäres Element (10), Löt-

verbindung (12) und bewegliches Element (11) generiert wird, das abfederte bewegliche Aktionsglied übt Kraft (F) auf das bewegliche Element in der mit der oberen Seite des stationären Elementes (10) des Varistors (1) und mit der unteren Seite des beweglichen Elementes (11) parallel laufenden Richtung auf, die Kraft (F) nach dem Verschmelzen der Lötverbindung (12) drückt infolge einer erhöhten Temperatur des Varistors (1) das bewegliche Element (11) von dem stationären Element (10) des Varistors (1) durch eine Schiebbewegung des beweglichen Elementes (11) auf dem stationären Element (10) des Varistors (1) weg, das abgefederte bewegliche Aktionsglied ist zur Bildung und kontinuierlichen Vergrößerung eines Luftspaltes zwischen dem stationären Element und dem beweglichen Element nach dem Verschmelzen der Lötverbindung in der Stelle (X) angepasst, **dadurch gekennzeichnet, dass** der Strombahn über die Stelle (X) eine parallel laufende Strombahn (15) zugeordnet ist, in der ein Kapazitor (16) geschaltet ist, das abgefederte bewegliche Aktionsglied so abgefedert ist, dass es mit dem beweglichen Element mit so hoher Geschwindigkeit bewegt, dass die Durchschlagfestigkeit des zu bildenden und sich kontinuierlich vergrößernden Luftspaltes schneller wächst, als das Wachstum der Spannung auf dem Kapazitor (16) ist, die durch die Ladung des Kapazitors (16) mit einer elektrischen Ladung wächst, die aus dem umgelenkten Gleichstromfluss kommt, und diese Spannung bis in die Höhe einer Maximalspannung einer Gleichstromquelle wächst und so der Entstehung eines nicht kontrollierten elektrischen Bogens zwischen dem stationären Element und dem beweglichen Element vorbeugt.

4. Einrichtung nach dem Anspruch 5, **dadurch gekennzeichnet, dass** die parallel laufende Strombahn (15) mit dem Kapazitor (16) zwischen das stationäre Element (10) eines Varistors (1) und das bewegliche Element (11) geschaltet ist.
5. Einrichtung nach dem Anspruch 3, **dadurch gekennzeichnet, dass** der Stelle (X) einer beabsichtigten Entkopplung der Strombahn ein vorübergehender Reihenwiderstand zugeordnet ist.
6. Einrichtung nach dem Anspruch 4, **dadurch gekennzeichnet, dass** der Stelle (X) einer beabsichtigten Entkopplung der Strombahn ein vorübergehender Reihenwiderstand zugeordnet ist, der ein elektrischer Hilfsleiter (13) ist, der an einem seiner Enden mit dem stationären Element (10) eines Varistors (1) elektrisch verbunden ist und an seinem anderen Ende eine Kontaktkante (130) aufweist, die im Abstand (A) von dem stationären Element (10) situiert ist, der Abstand (A) kleiner als die Länge des beweglichen Elementes (11) ist.

7. Einrichtung nach dem Anspruch 6, **dadurch gekennzeichnet, dass** der elektrische Hilfsleiter (13) durch einen Stahlstreifen aus einem rostfreien Stahl mit einer kleinen Stärke gebildet wird.

8. Einrichtung nach einem der Ansprüche 6 oder 7, **dadurch gekennzeichnet, dass** zwischen dem elektrischen Hilfsleiter (13) und dem stationären Element (10) eines Varistors (1) mit Ausnahme der Anschlussstelle des elektrischen Hilfsleiters (13) an stationäre Element (10) eines Varistors (1), eine elektrische Isolation (14) angebracht ist.

15 Revendications

1. Procédé de protection contre les surtensions des circuits électriques à courant continu avec des courants jusqu'aux dizaines d'ampères (A), en particulier des sources photovoltaïques d'énergie électrique, dans lequel le dispositif de protection contre les surtensions est connectable électriquement à un circuit électrique à courant continu, le dispositif de protection contre les surtensions dispose d'une voie de courant, dans la voie de courant est électriquement connecté au moins un varistor (1), la voie de courant comprend l'élément fixe (10) du varistor (1) et l'élément mobile (11), l'élément fixe (10) est électriquement connecté par un joint soudé (12) à l'élément mobile, le joint soudé crée le point (X) d'ouverture intentionnelle de la voie de courant entre l'élément fixe et l'élément mobile, le dispositif comprend ensuite un élément à ressorts mobile rattaché à l'élément mobile (11), le joint soudé sur le point (X) et l'actionneur mobile à ressorts créent un mécanisme de déconnexion à déclenchement thermique (3) dans lequel le joint soudé sur le point (X) fond sous l'effet de la chaleur générée par le passage du courant continu par le varistor (1) ou par l'élément fixe, le joint soudé et l'élément mobile, tandis que l'actionneur mobile à ressorts exerce une force (F) sur l'élément mobile (11) dans le sens parallèle à la surface supérieure de l'élément fixe (10) du varistor (1) et à la surface inférieure de l'élément mobile (11), la force (F) après la fonte du joint soudé (12) à la suite de la température élevée du varistor (1) repousse l'élément mobile (11) de l'élément fixe (10) du varistor (1) par mouvement coulissant de l'élément mobile (11) sur l'élément fixe (10) du varistor (1), l'actionneur mobile à ressorts effectue une ouverture intentionnelle de la voie de courant sur le point (X), lors de l'ouverture intentionnelle est créé de manière intentionnelle un espace d'air entre l'élément fixe et l'élément mobile qui s'agrandit progressivement, **caractérisé en ce que** lors de l'ouverture intentionnelle de la voie de courant sur le point (X), la valeur de courant continu est, sur le point de l'ouverture, limitée par le changement de direction de flux de courant

continu sans la voie de courant (15) parallèle, créée par le condensateur (16), lors de la création et l'agrandissement de l'espace d'air l'élément mobile se déplace avec une vitesse si élevée, que la résistance à la rupture de l'espace d'air entre l'élément fixe et l'élément mobile, qui est créé en même temps et qui s'agrandit progressivement, augmente plus rapidement que l'augmentation de la tension sur le condensateur (16), la tension sur le condensateur (16) augmente par le chargement du condensateur (16) avec la charge électrique sortie du flux de courant continu redirigé, et cette tension augmente jusqu'à la tension maximale de la source du courant continu pour empêcher ainsi la formation d'un arc électrique non-contrôlé entre l'élément fixe et l'élément mobile.

2. Dispositif selon la revendication 1, **caractérisé en ce que** lors de la création et l'agrandissement de l'espace d'air, un élément de résistance temporaire (13) est temporairement connecté entre l'élément fixe et l'élément mobile, disposant d'une résistance électrique plus élevée que celle des éléments fixe et mobile (10, 11), pour augmenter la redistribution du flux de courant électrique entre le point (X) et la voie de courant parallèle (15) avec condensateur (16).
3. Dispositif de protection contre les surtensions des circuits électriques à courant continu avec des courants jusqu'aux dizaines d'ampères (A), en particulier des sources photovoltaïques d'énergie électrique, avec contacts (00) permettant une connexion électrique du dispositif au circuit protégé, entre les contacts (00) est disposée la voie de courant dans laquelle est connecté au moins un varistor (1) avec un élément fixe (10), la voie de courant dispose d'un élément fixe (11) situé entre l'élément fixe (10) et l'un des contacts (00), l'élément fixe et l'élément mobile sont électriquement connectés par un joint soudé (12), le joint soudé (12) crée le point (X) de l'ouverture intentionnelle de la voie de courant entre l'élément fixe (10) et l'élément mobile (11), à l'élément mobile est associé un actionneur mobile à ressorts, le joint soudé (12) sur le point (X) et l'actionneur mobile à ressorts créent un mécanisme de déconnexion à déclenchement thermique (3) où le joint soudé (12) sur le point (X) fond sous l'effet de la chaleur générée par le passage du courant continu par le varistor (1) ou par l'élément fixe (10), le joint soudé (12) et l'élément mobile (11), l'actionneur mobile à ressorts exerce une force (F) sur l'élément mobile dans le sens parallèle à la surface supérieure de l'élément fixe (10) du varistor (1) et à la surface inférieure de l'élément mobile (11), la force (F) après la fonte du joint soudé (12) à la suite de la température élevée du varistor (1) repousse l'élément mobile (11) de l'élément fixe (10) du varistor (1) par mouvement

couissant de l'élément mobile (11) sur l'élément fixe (10) du varistor (1), l'actionneur mobile à ressorts est adapté à la création et l'agrandissement progressif de l'espace d'air entre l'élément fixe et l'élément mobile à la suite de la fonte du joint soudé sur le point (X), **caractérisé en ce que** à la voie de courant passant par le point (X) est associée une voie de courant parallèle (15) dans laquelle est connecté le condensateur (16), et l'activité de l'actionneur mobile à ressorts est si intense que celui-ci actionne l'élément mobile avec une vitesse tellement élevée que la résistance à la rupture de l'espace d'air qui s'agrandit progressivement augmente plus rapidement que la tension du condensateur (16), qui augmente avec le chargement du condensateur (16) avec la charge électrique sortie du flux de courant continu redirigé, et cette tension augmente jusqu'à la tension maximale de la source du courant continu pour empêcher ainsi la formation d'un arc électrique non-contrôlé entre l'élément fixe et l'élément mobile.

4. Dispositif selon la revendication 5, **caractérisé en ce que** la voie de courant parallèle (15) avec condensateur (16) est connectée entre l'élément fixe (10) du varistor (1) et l'élément mobile (11).
5. Dispositif selon la revendication 3, **caractérisé en ce qu'**au point (X) de l'ouverture intentionnelle de la voie de courant est associée une résistance temporaire en série.
6. Dispositif selon la revendication 4, **caractérisé en ce qu'**au point (X) de l'ouverture intentionnelle de la voie de courant est associée une résistance temporaire en série qui représente un conducteur électrique auxiliaire (13) connecté électriquement à l'élément fixe (10) du varistor (1) sur l'une de ses extrémités, et sur l'autre extrémité muni d'un bord de contact (130) situé à la distance (A) de l'élément fixe (10), où la distance (A) est plus courte que la longueur de l'élément mobile (11).
7. Dispositif selon la revendication 6, **caractérisé en ce que** le conducteur électrique auxiliaire (13) est représenté par une bande en acier inoxydable de faible épaisseur.
8. Dispositif selon la revendication 6 ou 7, **caractérisé en ce qu'**entre le conducteur électrique auxiliaire (13) et l'élément fixe (10) du varistor (1) se situe, avec pour exception le point de connexion du conducteur électrique auxiliaire (13) à l'élément fixe (10) du varistor (1), une isolation électrique (14).

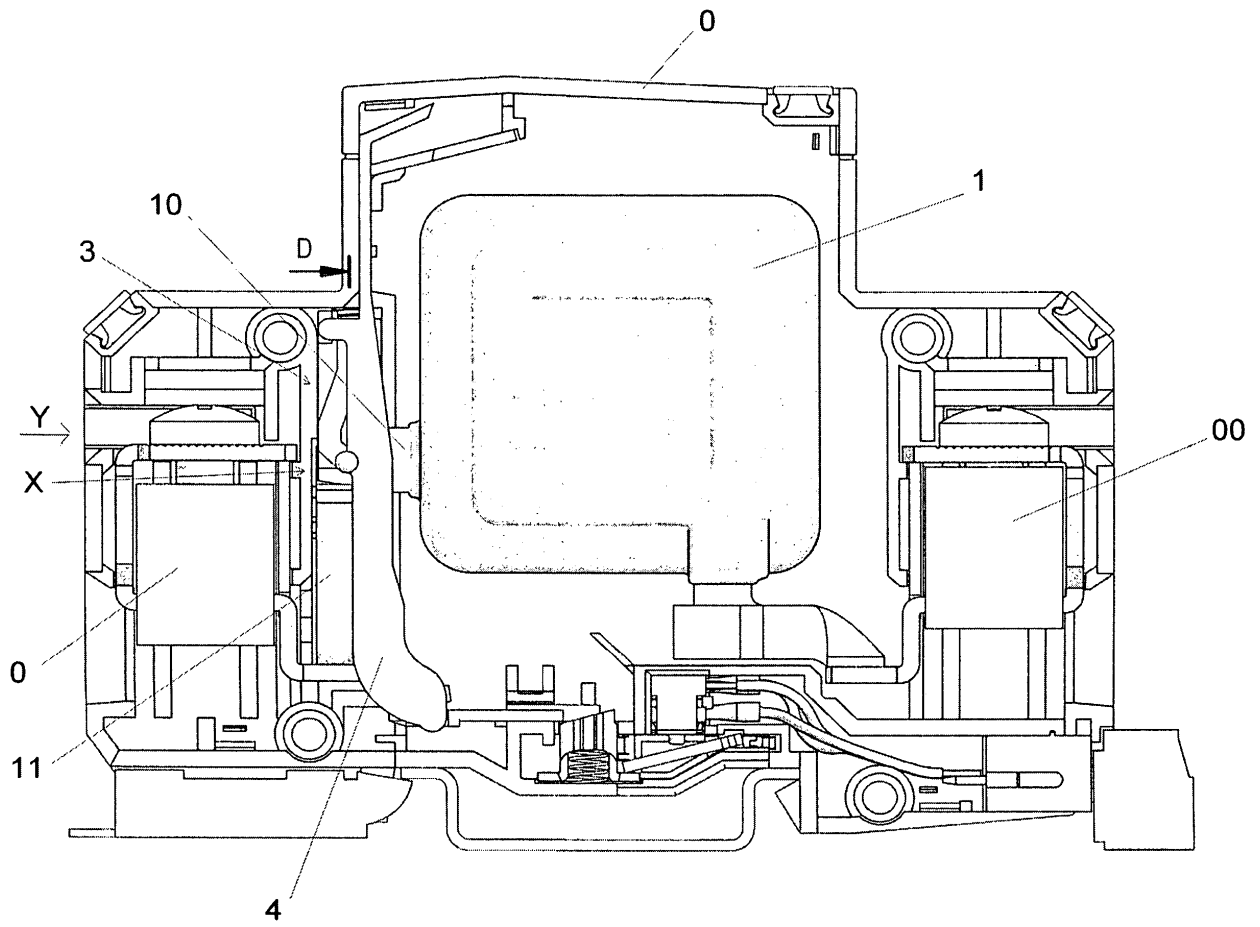


Fig. 1

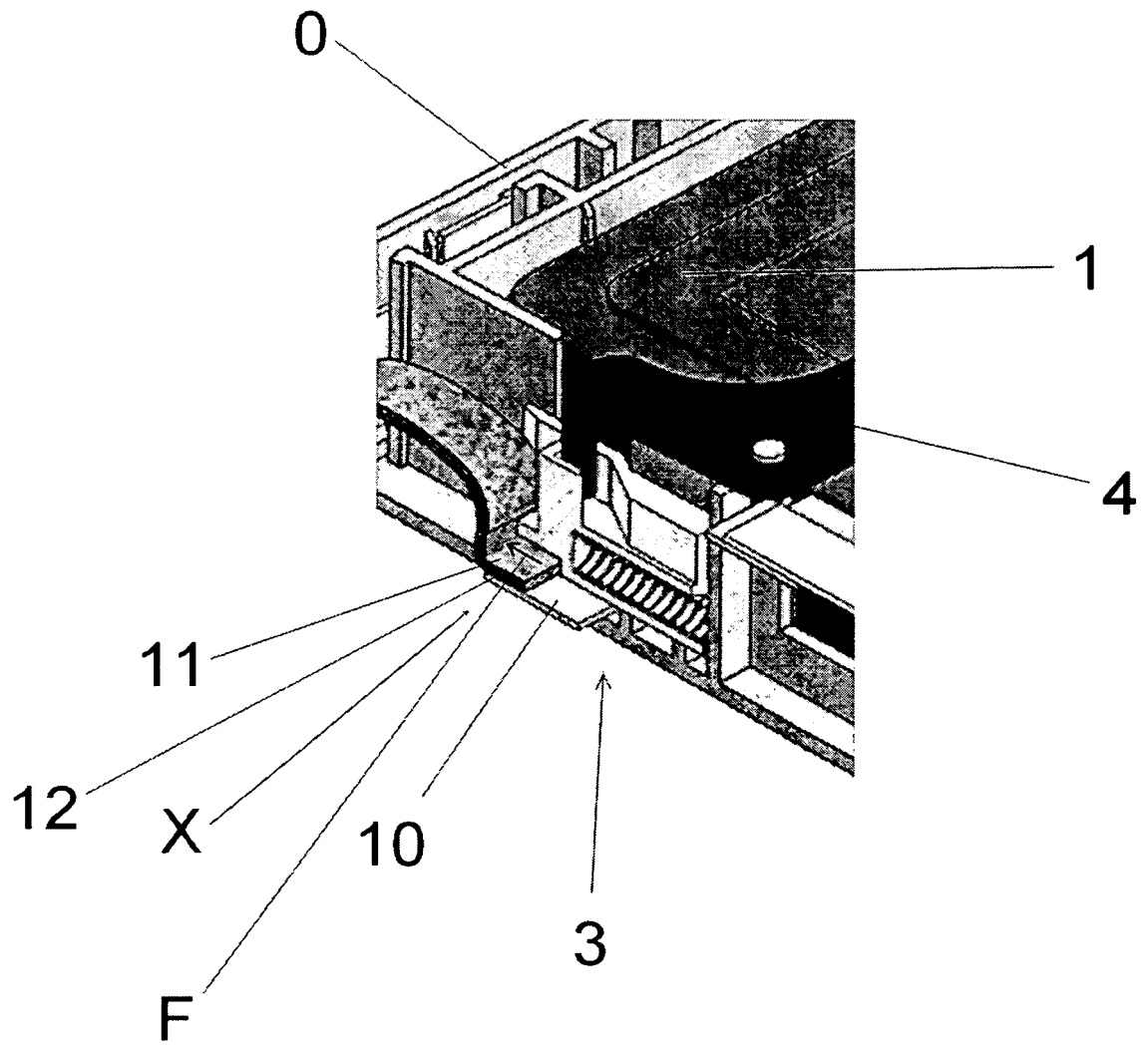


Fig. 1a

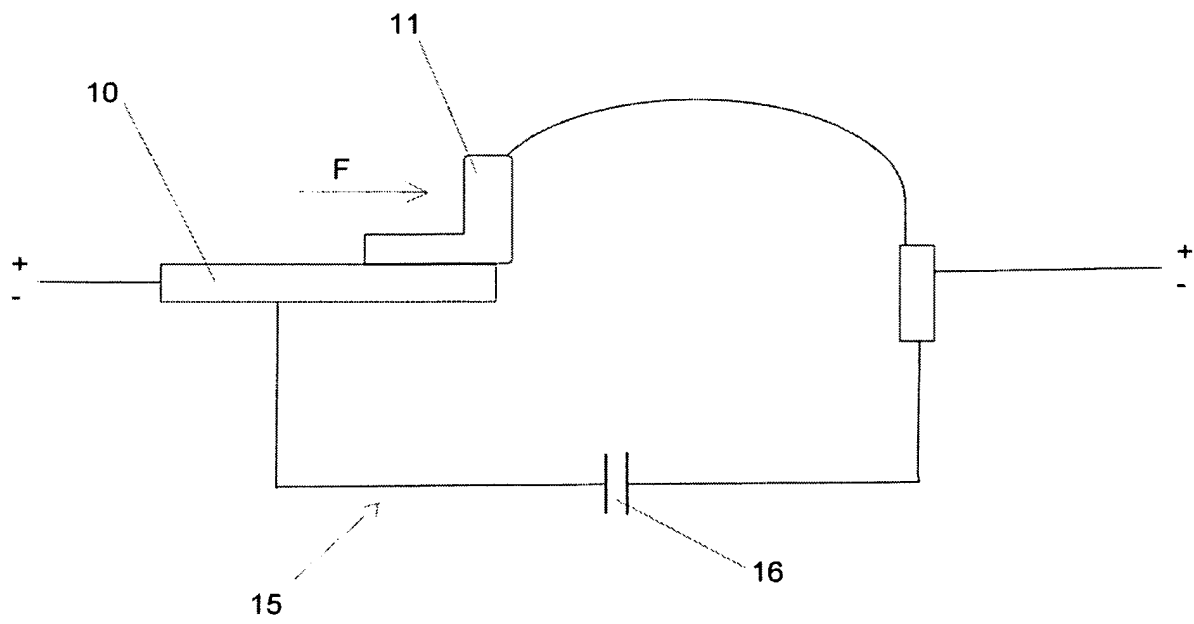


Fig. 2

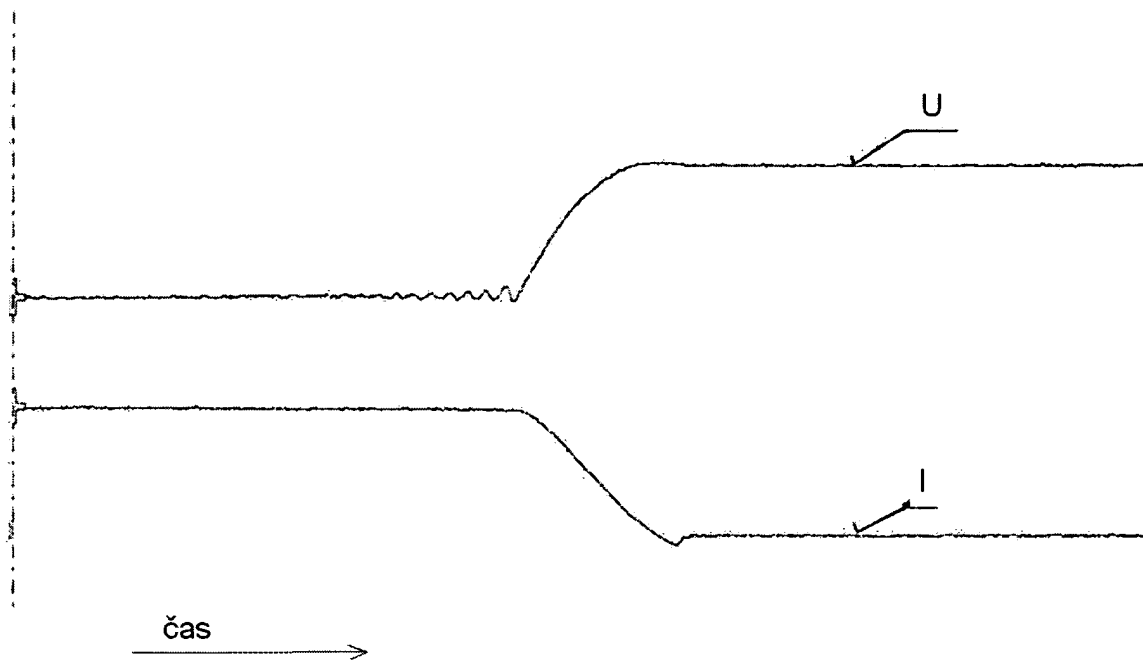


Fig. 4

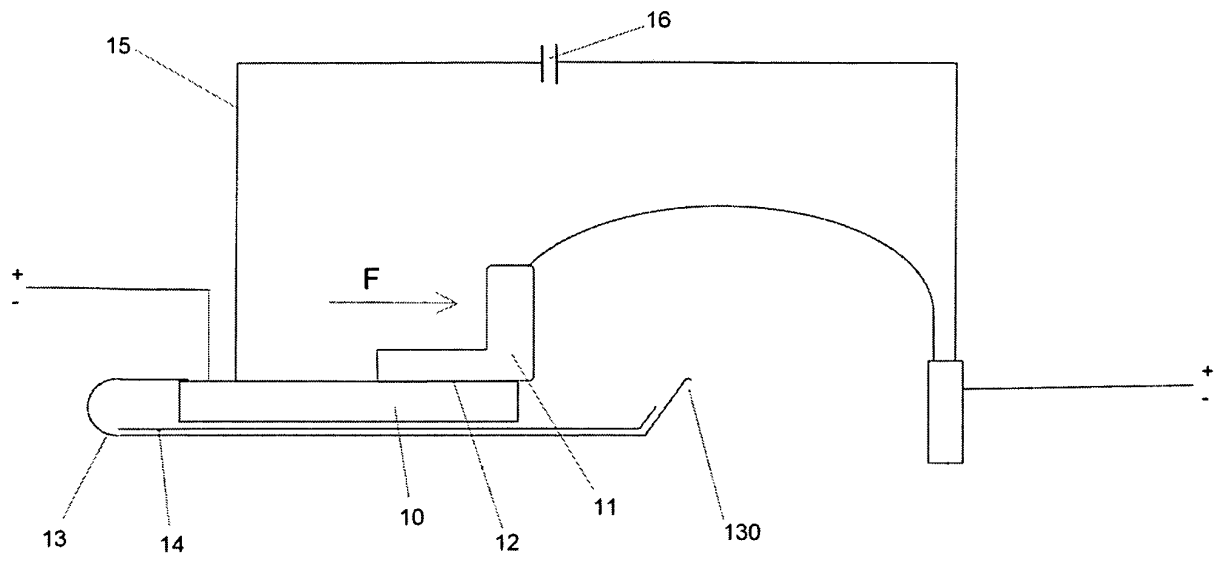


Fig. 3a

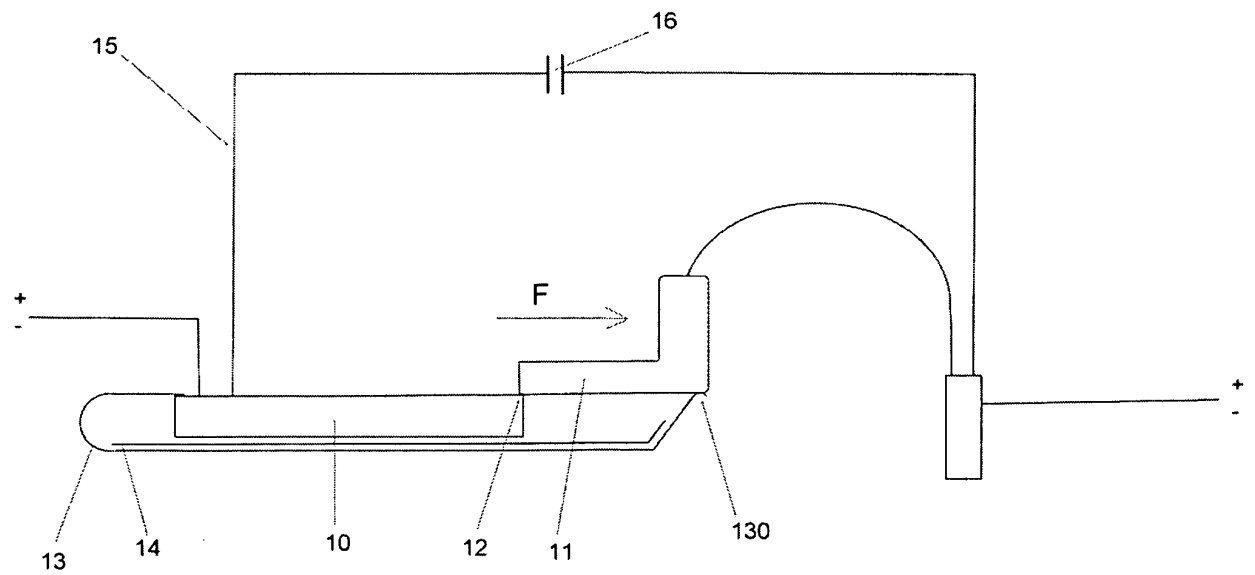


Fig. 3b

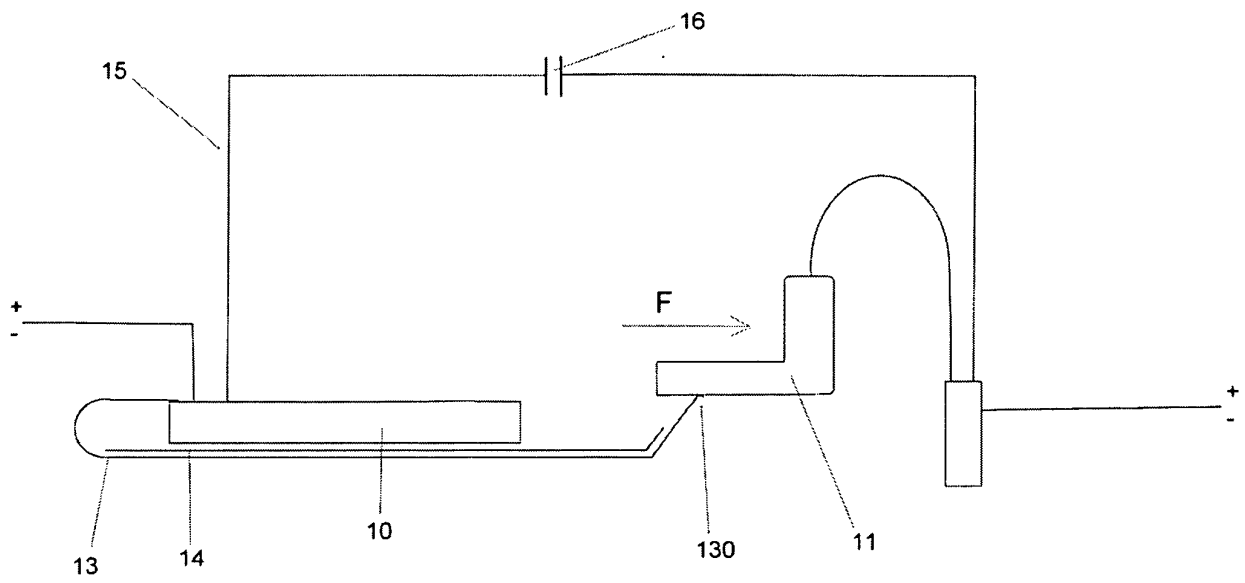


Fig. 3c

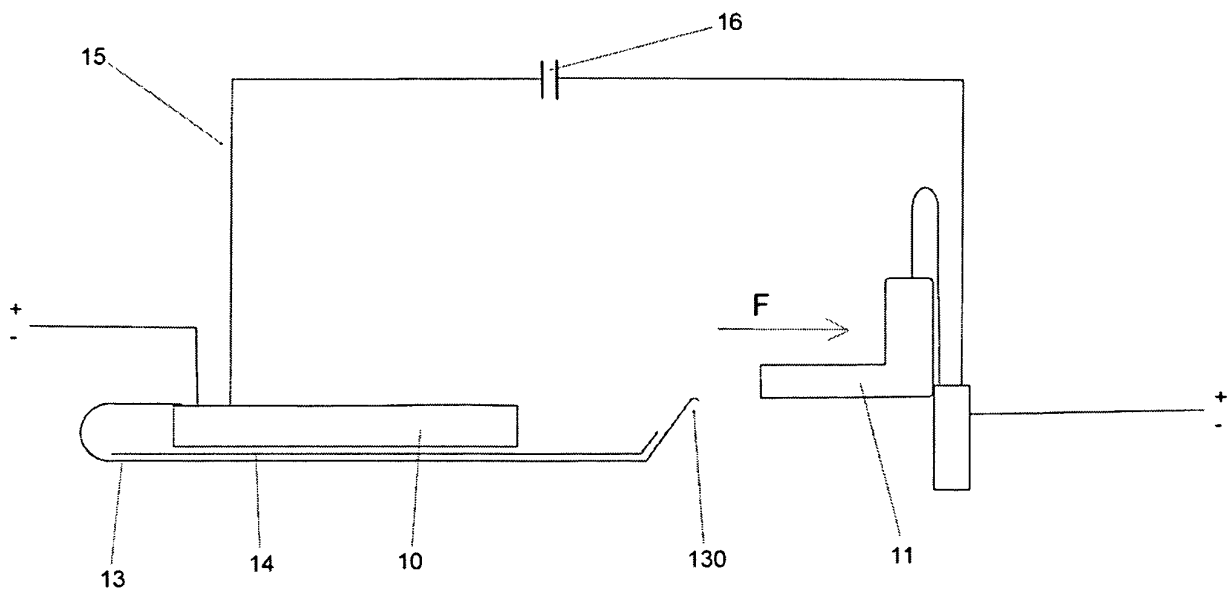


Fig. 3d

REFERENCES CITED IN THE DESCRIPTION

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