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[Continued on next page]

(54) Title: FAULT CURRENT LIMITER ARRANGEMENT

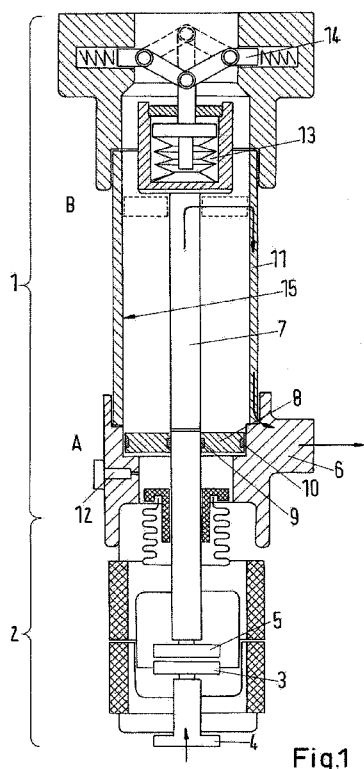


Fig.1

(57) Abstract: Fault current limiter arrangement for a low, medium to high voltage electricity grid, consisting of a fault current limiter unit (1) which is arranged in line with a vacuum interrupter (circuit breaker unit) (2) comprising a fixed electrical contact (3) which is connected to a lower electrical terminal (4) and a movable electrical contact (5) which is connected to an upper electrical terminal (6), in order to interrupt the current flow after the fault current limiter unit (1) has limited the current flow in fault event, detected by fault current detection means, wherein the fault current limiter unit (1) comprises a movable electrical sliding contact part (8) which is electrically arranged between the upper electrical terminal (6) of the vacuum interrupter (circuit breaker unit) (2) and the movable electrical contact (5) of the vacuum interrupter (circuit breaker unit) (2), and which is movable between a short circuit position (A) adjacent to the upper electrical terminal (6) and a remote position (B) far from the upper electrical terminal (6) for providing a maximum electrical resistance for the current flow.



Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

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Fault Current Limiter Arrangement

Field of the invention

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The invention relates to a fault current limiter arrangement for a low, medium to high voltage electricity grid, consisting of a fault current limiter unit, which is arranged in line with a vacuum interrupter (circuit breaker unit), comprising a fixed electrical contact, which is connected to a lower electrical terminal and a movable electrical contact which is connected to an upper electrical terminal, in order to interrupt the current flow after the fault current limiter unit has limited the current flow in fault event, detected by fault current detection means.

Background of the invention

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A fault current limiter is a device which automatically limits fault currents in electrical distribution or transmission grids, in particular low, medium to high voltage grids, to a low current value close to the nominal current. The benefit of such device is that it reduces drastically the short circuit power of the electricity grid and, thus, allows interconnect grids without increasing the short circuit power or to decrease safety margins so that other machineries connected to the network can be designed for lower short circuit power and, therefore, can be made lighter and with a lower effort.

According to the common technical knowledge in the field of fault current limiters high-temperature superconductors are well suited for use in a fault current limiter due to their property to loose superconductivity and transit from the non-resistive superconducting state to a normal state with high electric resistivity when at least one

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of the critical current, the critical temperature or the critical magnetic field of the superconductor material is exceeded.

In normal operation with nominal current, that is, in the cooled state, the superconductor material is in its superconducting state with essentially zero resistance so that there is essentially no voltage over the whole fault current limiter. In consequence, the fault current limiter is "invisible" for the electricity grid. In case of short circuit fault current the current rises to several times the nominal current exceeding the critical current of the superconductor material which causes the superconducting material to transit to the normal resistive state with generation of high voltage. That is, in normal operation in the superconducting state essentially no voltage difference is observed at both ends of the fault current limiter, whereas in fault condition a large voltage difference is measured due to increasing electrical resistance. In order to avoid overheating and damage of the fault current limiter current flow through the fault current limiter must be interrupted within a limited period of time. Thus, a circuit breaker is usually arranged in line with the fault current limiter for switching off the current flow in case of a fault signal detected by fault current detection means.

The document EP 2 242 063 A discloses such fault current detection means for a fault current limiter arrangement. A high-temperature superconductor fault current limiter makes use of a differential protection relay wherein in fault event the differential protection relay operates a triggering mechanism of a circuit breaker, whereby opening the electrical circuit and interrupting power supply to down stream components. The current limiter arrangement comprises a current incoming end and a current outgoing end. The incoming end of the fault current limiter is electrically connected to a first measuring circuit and the outgoing end of the fault current limiter to second current measuring circuit. In fault event voltage drop occurs across the current limiter with the voltage at the outgoing end of the current limiter being less than the voltage at the incoming end. Consequently, a current difference is observed by the differential protection relay. If the observed value of the current difference exceeds the predetermined value the differential protection relay sends a triggering signal to the circuit breaker and current flow is interrupted.

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For operating the fault current limiter liquid nitrogen is necessary in order to maintain the superconductance property. To provide the cooling permanent losses of energy will occur over the years.

5 Summary of the invention

It is an object of the present invention to provide a fault current limiter arrangement for a low, medium to high voltage electricity grid comprising fast acting components in order to avoid overheating and which can be operated without cooling liquid.

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According to the invention a fault current limiter unit comprises a movable electrical sliding contact part which is electrically arranged between the upper electrical terminal of the vacuum circuit breaker unit and the movable electrical contact of the vacuum circuit breaker unit, and which is movable between a short circuit position A adjacent to the upper electrical terminal and a remote position B far from the upper electrical terminal for providing a maximum electrical resistance for the current flow.

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Since no cooling liquid is necessary according to the invention no permanent energy losses from the device themselves occurs. Only the unavoidable resistive losses at the connecting terminals which are mainly made of copper or aluminum material, are existing but these can be neglectable for all fault current limiters.

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According to a preferred embodiment of the invention the movable electrical sliding contact part generates the maximum electrical resistance in connection with a metallic pushrod for acting the movable electrical contact of the vacuum interrupter (circuit breaker unit) and the metallic housing sleeve surrounding the pushrod and electrically connected to the upper electrical terminal. This special arrangement provides a compact design of the fault current limiter device.

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Furthermore, the movable electrical sliding contact part is preferably shaped as a circular disk having an inner electrical sliding contact ring for connecting to the outer surface of the pushrod and an outer electrical sliding contact ring for connecting to the inner surface of the housing sleeve, designed as a resistor part. This allows to flow the

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current from the vacuum interrupter and the movable contact part to the upper electrical terminal in close position of the vacuum interrupter connection part (circuit breaker unit).

5 Additionally, mechanical actuator means are provided for axially moving the circular disk shaped sliding contact part along the pushrod in order to switch between the short circuit position A (here with less resistance at this position) and the remote position B (at the resistor area or at the end of the resistor). Preferably the mechanical actuator means comprise a compressed gas for acting the circular disk shaped sliding contact
10 part like a piston, wherein the compressed gas is stored in or generated from a micro gas generator preferably arranged in the area between the housing sleeve and the vacuum interrupter and the movable disc. During the movement of the disk shaped sliding contact part along the pushrod from the service position with less resistance like an arrangement of a pole part) the short circuit position A and the remote position B the
15 electrical resistance will be increased by the fact that the inner material of the pushrod and the housing sleeve will be preferably made of steel as a resistance material. At the moment when the movable sliding contact part reaches the remote position B the resistance has the maximum value to limit the fault current in the electricity grid and the vacuum interrupter (circuit breaker unit) will be switched in the opened position. This
20 occurs due to mechanical impulse provided by the movable sliding contact part when it reaches the remote position B. At this moment the electrical current flows through the inner pushrod and the housing sleeve to the upper electrical terminal.

25 According to another aspect of the invention a contact force for keeping the electrical contacts of the vacuum interrupter (circuit breaker unit) closed is generated by a contact spring unit arranged at the distal end of the housing sleeve and mechanically connected to the pushrod. The contact spring unit is mechanically bistable. Preferably, the contact spring unit corresponds to a bistable mechanical mechanism unit in order to keep the electrical contacts in the closed position, which is actuated from a mechanical
30 impulse provided by the disk shaped sliding contact part in its remote position B in order to bring the electrical contacts in the opened position.

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According to another optional aspect of the invention it is recommended to provide the inner surface of the metallic housing sleeve with longitudinal cutting slots in order to increase the electrical resistance of the fault current limiter arrangement. Preferably, at least the outer surface of the metallic housing sleeve is covered with a plastic insulation material. The plastic insulation material increases the mechanical stability of the fault current limiter – resistor- part of the device.

According to another optional aspect of the invention additional driving means are provided for reset the sliding contact part from the remote position B back to the short circuit position A. The said additional driving means preferably comprises an electromagnetic drive or the like. In case that on both sides are vacuum interrupters installed the arrangement can be resetted by the operation in the opposite way. Here an additional disconnecter is needed to make the opposite operation possible, according to the figure 2.

Brief description of the drawings

The foregoing and other aspects of the invention will be con apparent following the detailed description of the invention when considered in conjunction with the enclosed drawings.

The single figure shows a side view of a fault current limiter arrangement, consisting of a fault current limiter unit arranged in line with a vacuum interrupter (circuit breaker unit).

All drawings are schematic.

Detailed description of the drawings

According to the figure 1 the fault current limiter arrangement generally consists of a fault current limiter unit 1 and a vacuum interrupter (circuit breaker unit) 2. The fault current limiter unit 1 and the vacuum interrupter (circuit breaker unit) 2 are arranged in line one to another.

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The vacuum interrupter (circuit breaker unit) 2 comprises a fixed electrical contact 3 which is connected to a lower electrical terminal 4. The fixed electrical contact 3 corresponds to a movable electrical contact 5 in order to form an electrical switch. The movable electrical contact 5 is connected to an upper electrical terminal 6. A pushrod 7 is provided for operating the movable electrical contact 5. The vacuum interrupter (circuit breaker unit) 2 interrupts the current flow through the fault current limiter arrangement after the fault current limiter unit 1 has limited a current flow in fault event. For detecting a fault event – not shown – fault current detection means are provided. The fault current limiter unit 1 further comprises a movable electrical sliding contact part 8. The electrical sliding contact part 8 is electrically arranged between the upper electrical terminal 6 of the vacuum interrupter (circuit breaker unit) 2 and the movable electrical contact 5 of the vacuum interrupter (circuit breaker unit) 2. The movable electrical sliding contact part 8 is shaped as a circular disk or as a conical shaped one side or double side disc having an inner electrically sliding contact ring 9 for connecting to the outer surface of the pushrod 7 and an outer electrical sliding contact ring 10 for connecting to the inner surface of a housing sleeve 11. The housing sleeve 11 surrounds the pushrod 7 and electrically connects the upper electrical terminal 6 to the movable electrical contact 5 of the vacuum interrupter (circuit breaker unit) 2.

The movable electrical sliding contact part 8 generates a maximum electrical resistance in connection with the metallic pushrod 7 and the metallic housing sleeve 11. Therefore, the movable electrical sliding contact part 8 is movable between a short circuit position A which is located adjacent to the upper electrical terminal 6 and a remote position B which is located far from the upper electrical terminal 6 on the top of the metallic housing sleeve 11. In the remote position B the fault current limiter unit 1 provides a maximum electrical resistance for the current flow, since the current has to flow from the upper electric terminal 6 through the housing sleeve 11, the movable electrical sliding contact part 8, the pushrod 7 to the movable electrical contact 5.

In order to move the circular disk shaped sliding contact part 8 along the pushrod 7 mechanical actuator means are provided which comprises a micro gas generator 12 which is arranged in the area between the housing sleeve 11 and vacuum interrupter insert 2. If compressed gas provided from the micro gas generator 12 load the bottom

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side of the disk shaped sliding contact part 8 it changed from the short circuit position A – as shown – to the remote position B (dotted lines). Furthermore, a contact spring unit 13 is provided for keeping the electrical contacts 3 and 5 closed. The contact spring unit 13 is arranged at the distal end of the housing sleeve 11. The contact spring unit
5 13 is mechanically connected to the respective end of the pushrod 7.

The contact spring unit 13 corresponds to a bistable mechanical mechanism unit 14 in order to keep the electrical contacts 3 and 5 in its closed position, which is actuated from a mechanical impulse provided by the disk shaped sliding contact part 8 in its
10 remote position B in order to bring the electrical contacts 3 and 5 in its opened position. Additionally – not shown – driving means are provided for reset the sliding contact part 8 from the remote position B back the short circuit position A.

In order to increase the electrical resistance of the fault current limiter unit 1 the inner
15 surface of the metallic housing sleeve 11 is provided with longitudinal cutting slots 15.

Reference signs

	1	fault current limiter unit
	2	vacuum interrupter (circuit breaker unit)
5	3	fixed electrical contact
	4	lower electrical terminal
	5	movable electrical contact
	6	upper electrical terminal
	7	metallic pushrod
10	8	movable electrical sliding contact part
	9	inner electrical sliding contact ring
	10	outer electrical sliding contact ring
	11	housing sleeve
	12	micro gas generator
15	13	contact spring unit
	14	bistable mechanical mechanism unit
	15	cutting slots
	A	short circuit position
20	B	remote position

Claims

1. Fault current limiter arrangement for a low, medium to high voltage electricity grid, consisting of a fault current limiter unit (1) which is arranged in line with a vacuum interrupter (circuit breaker unit) (2) comprising a fixed electrical contact (3) which is
5 connected to a lower electrical terminal (4) and a movable electrical contact (5) which is connected to an upper electrical terminal (6), in order to interrupt the current flow after the fault current limiter unit (1) has limited the current flow in fault event, detected by fault current detection means,
- 10 **characterized in that** the fault current limiter unit (1) comprises a movable electrical sliding contact part (8) which is electrically arranged between the upper electrical terminal (6) of the vacuum interrupter (circuit breaker unit) or a simple connection terminal without vacuum interrupter (2) and the movable electrical contact (5) of the vacuum interrupter (circuit breaker unit) (2), and which is movable between a short
15 circuit position (A) adjacent to the upper electrical terminal (6) and a remote position (B) far from the upper electrical terminal (6) for providing a maximum electrical resistance for the current flow.
2. Fault current limiter arrangement according to Claim 1,
20 **characterized in that** the movable electrical sliding contact part (8) generates the maximum electrical resistance in connection with a metallic pushrod (7) for acting the movable electrical contact (5) of the vacuum interrupter (circuit breaker unit) (2) and a metallic housing sleeve (11) surrounding the pushrod (7) and electrically connected to the upper electrical terminal (8).
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3. Fault current limiter arrangement according to Claim 1,
characterized in that that the movable electrical sliding contact part (8) is shaped as a circular or a conical disk (on one or both sides) having an inner electrical sliding contact ring (9) for connecting to the outer surface of the pushrod (7) and an outer electrical
30 sliding contact ring (10) for connecting to the inner surface of the housing sleeve (10).

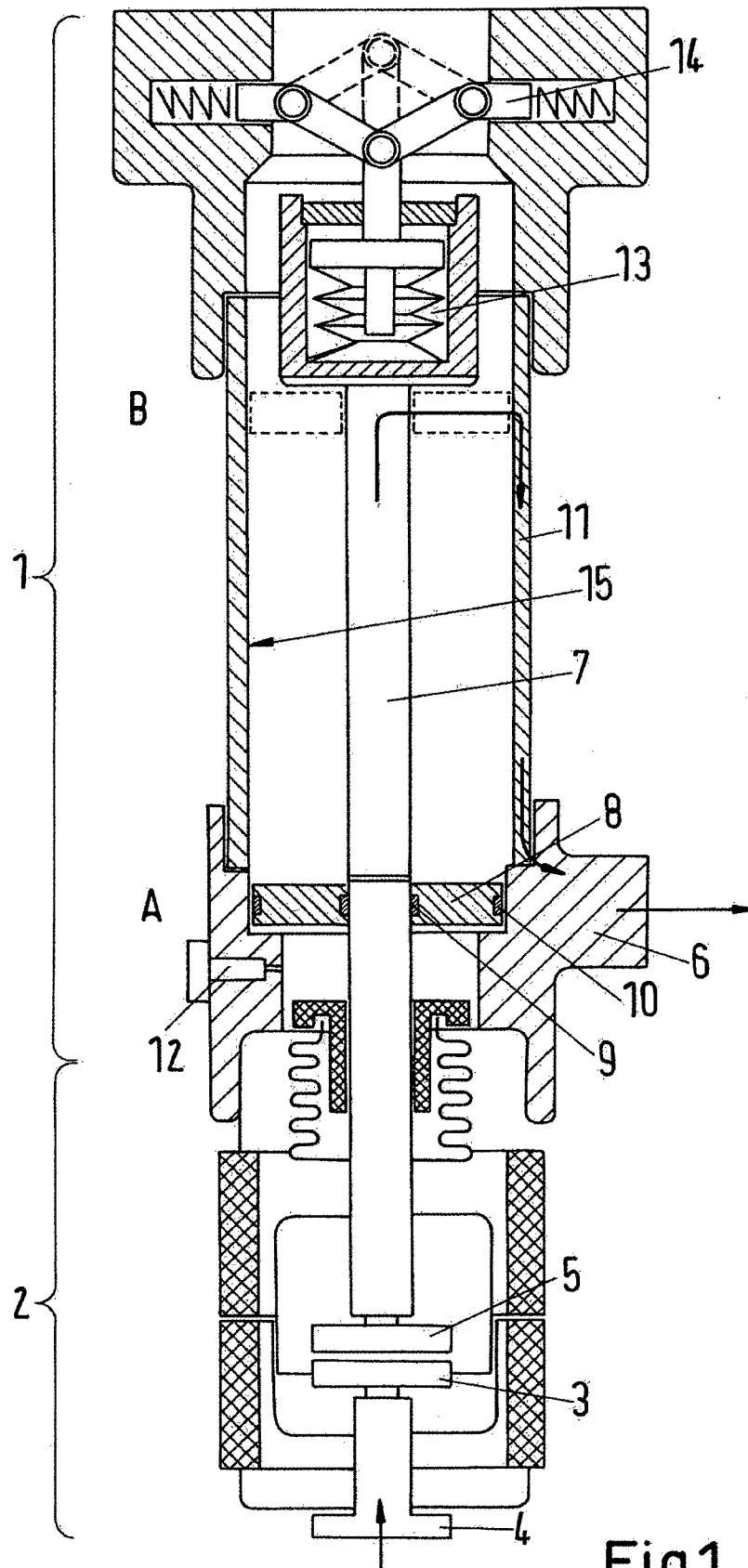
4. Fault current limiter arrangement according to Claim 3,
characterized in that mechanical actuator means are provided for axially moving the circular or conical disk shaped sliding contact part (8) along the pushrod (7) in order to switch between the short circuit position (A) and the remote position (B).
- 5
5. Fault current limiter arrangement according to Claim 4,
characterized in that the mechanical actuator means comprises a compressed gas for acting the circular disk shaped sliding contact part (8) like a piston, wherein the compressed gas is stored in or generated from a micro gas generator (12) arranged in
10 the area between the housing sleeve (11) and the vacuum interrupter insert (2).
6. Fault current limiter arrangement according to Claim 1,
characterized in that the contact force for keeping the electrical contacts (3, 5) closed is generated by a contact spring unit (13) arranged at the distal end of the housing
15 sleeve (11) and mechanically connected to the pushrod (7).
7. Fault current limiter arrangement according to Claim 6,
characterized in that the contact spring unit (13) corresponds to a bistable mechanical mechanism unit (14) in order to keep the electrical contacts (3, 5) in the closed
20 position, which is actuated from a mechanical impulse provided by the disk shaped sliding contact part (8) in its remote position (B) in order to bring the electrical contacts (3, 5) in the opened position.
8. Fault current limiter arrangement according to one of the preceding claims,
25 **characterized in that** the inner surface of the metallic housing sleeve (11) is provided with longitudinal or circumference cutting slots (15) in order to increase the electrical resistance.
9. Fault current limiter arrangement according to one of the preceding claims,
30 **characterized in that** at least the outer surface of the metallic housing sleeve (11) is covered with a plastic insulation material.

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10. Fault current limiter arrangement according to one of the preceding claims, **characterized in that** additional driving means are provided for reset the sliding contact part (8) from the remote position (B) back to the short circuit position (A).

5 11. Fault current limiter arrangement according to one of the preceding claims, **characterized in that** the arrangement is equipped with double vacuum interrupter and disconnecter switch to get a multishot device with a biposition contact after fault current limiting operation.

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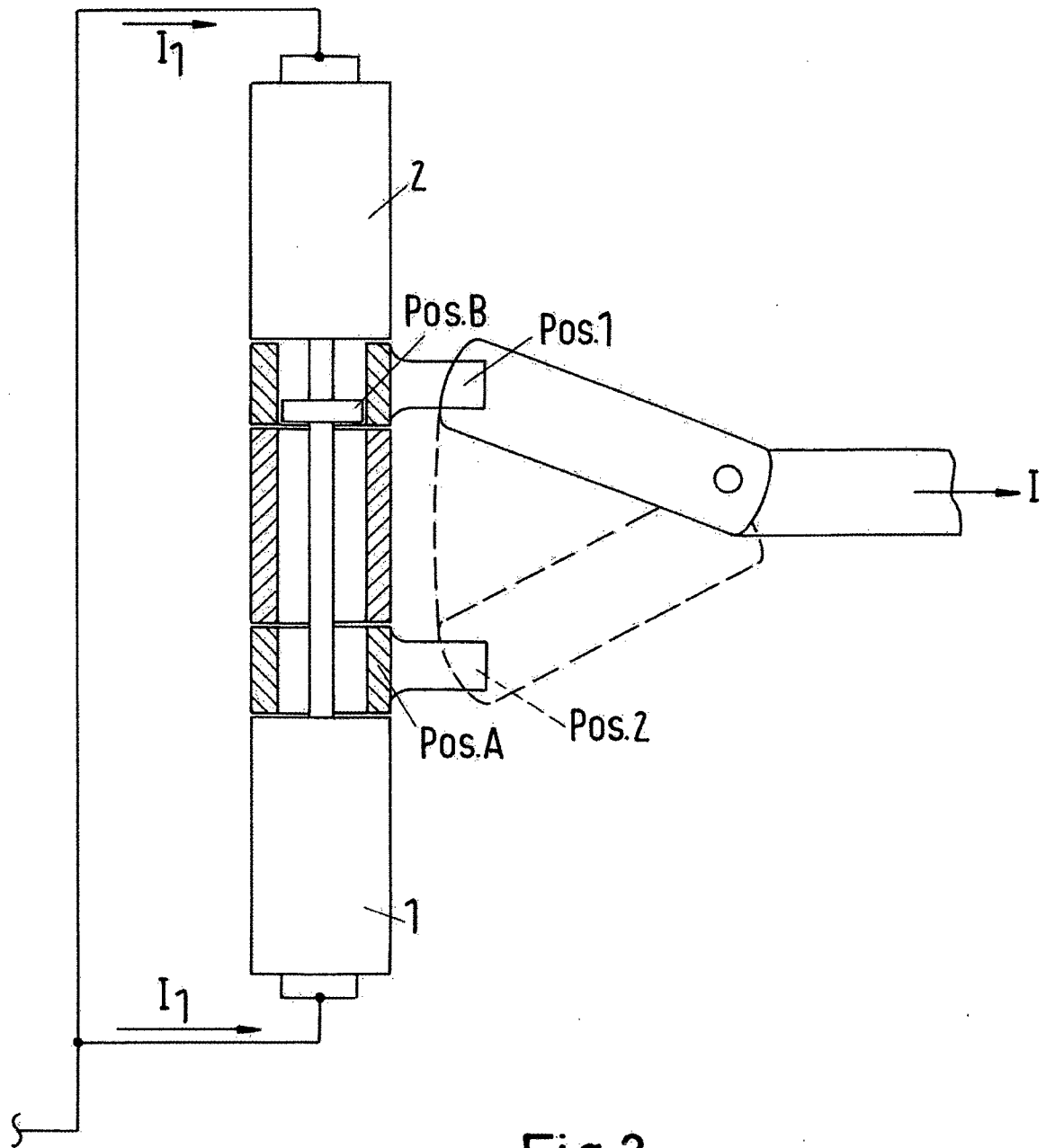


Fig.2

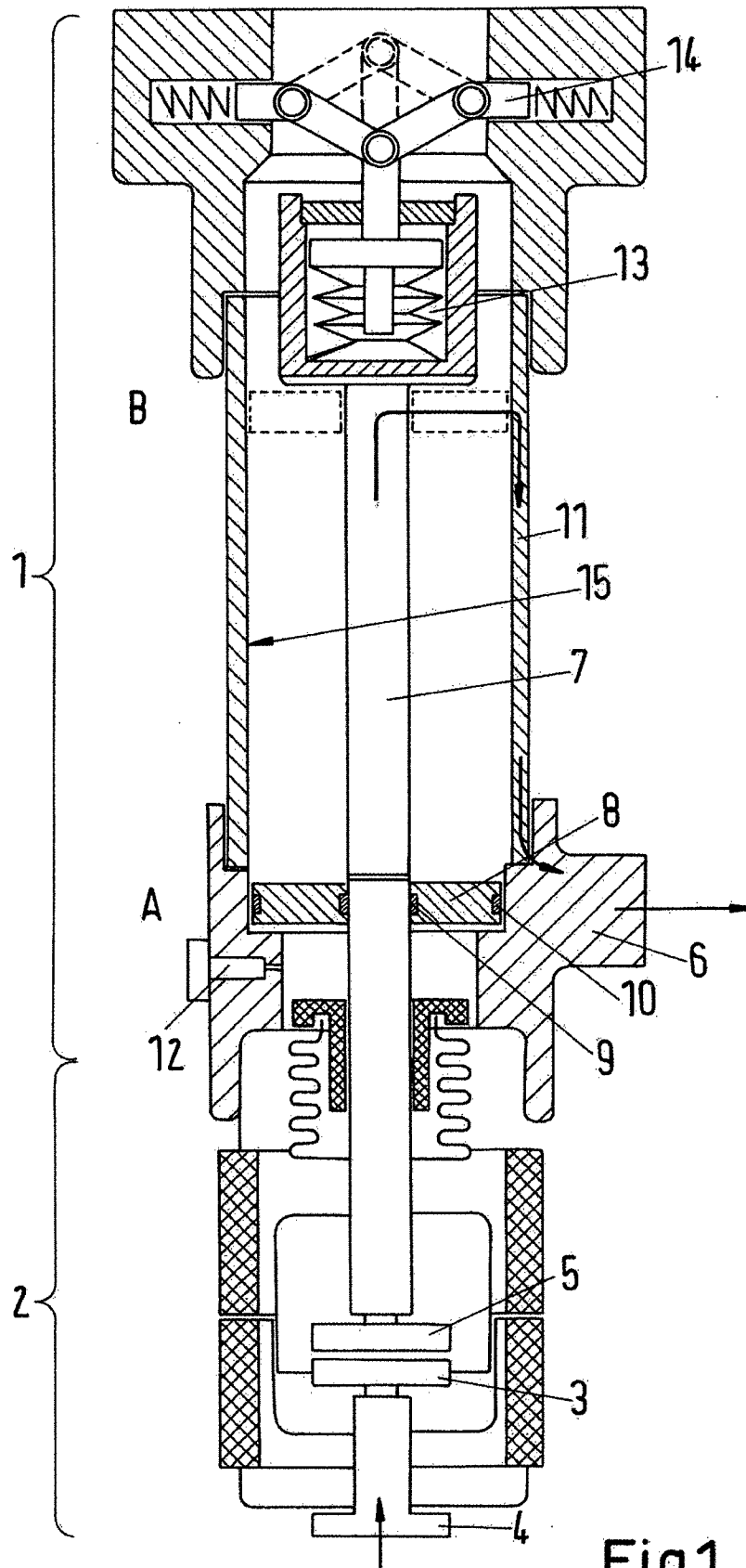


Fig.1

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/003156

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01H33/16 H01H33/66
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2012/175347 A1 (GLASER MICHAEL DAVID [US]) 12 July 2012 (2012-07-12) page 3, paragraph 0022 - page 4, paragraph 0036; figures 1-3 -----	1-11
Y	US 2012/199558 A1 (FAULKNER ROGER W [US]) 9 August 2012 (2012-08-09) page 4, paragraph 0056 - page 6, paragraph 0065; figures 1-6 -----	1-11
Y	DE 12 44 916 B (LICENTIA GMBH) 20 July 1967 (1967-07-20) column 2, line 44 - column 4, line 13; figures 1,2 -----	1-11
A	CH 242 102 A (OERLIKON MASCHF [CH]) 15 April 1946 (1946-04-15) the whole document -----	1-11



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2013/003156

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012175347 A1	12-07-2012	US 2012175347 A1	12-07-2012
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