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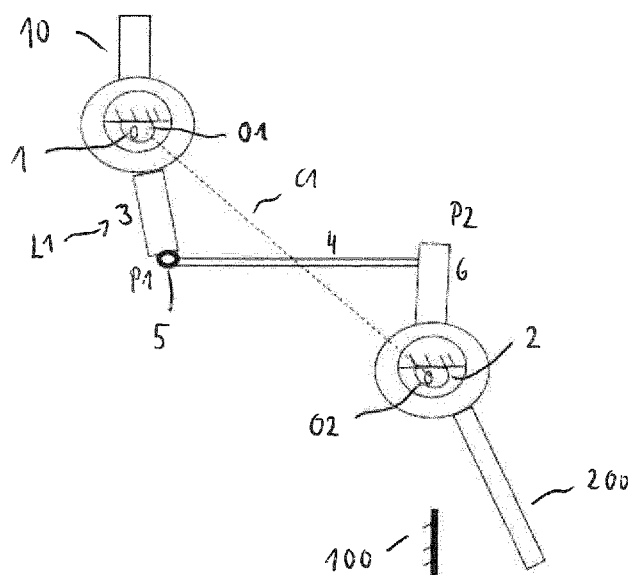
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(54) Title: CIRCUIT BREAKER WITH REDUCED NUMBER OF COMPONENTS

FIG 4



(57) Abstract: A circuit breaker (CB) with reduced number of components, comprises a fixed contact (100), a moving contact (200) and a breaker mechanism (300) to move the moving contact (200) between an open state and a closed state of the circuit breaker, wherein, in the open state, the moving contact (200) is isolated from the fixed contact (100), and, in the closed state, the moving contact (200) is electrically connected to the fixed contact (100). The breaker mechanism (300) comprises an actuation element (10) to manually switch the circuit breaker between the open and the closed state. The breaker mechanism (300) comprises a plurality of elements (3, 4, 7) being coupled to each other to provide a compliant structure that is deformed in dependence on the movement of the actuation element (10) and causes a movement of the moving contact (200).



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Description

CIRCUIT BREAKER WITH REDUCED NUMBER OF COMPONENTS

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Technical Field

The invention is directed to a circuit breaker, for example a low-voltage miniature circuit breaker, having a reduced number of components.

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Background

A circuit breaker is an automatically operated electrical switch that is used to protect an electrical circuit from damage caused by the occurrence of a short circuit or by a large current that is lower than the current in the case of the short circuit but large enough to damage the electrical circuit. Figure 1 illustrates the functionality of a circuit breaker. The circuit breaker comprises a movable contact that may be moved in a closed and an open state. In the closed state, the movable contact is in electrical contact with a fixed/stationary contact of the circuit breaker so that the circuit breaker allows a current flow from an input terminal to an output terminal of the circuit breaker. In an open state of the circuit breaker, the movable contact is separated from the fixed contact so that the flow of current between the input and output terminals of the circuit breaker is interrupted.

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The block diagram shows the major input and output ports of the mechanism. The manual input port represents the force/displacement inputs from the user for the circuit breaker opening and closing operation. The tripping input

port represents the force/displacement inputs from the actuator, for example a solenoid and a bi-metallic strip, for opening the circuit breaker contacts during short circuit or overload events.

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In order to control the movement of the movable contact by means of the manual input or the tripping input, a kinematic chain inside the circuit breaker is provided to transfer the forces between the moving contact and the manual input, for example an actuation arm, and between the tripping input, for example a solenoid or a bi-metallic strip, and the moving contact. The kinematic chain is usually composed of a large number of components such as levers, joints, springs, etc..

15 It is desirable to provide a circuit breaker having a reduced number of components, particularly with reference to the kinematic chain of a circuit breaker.

Summary

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This aim and other objects that will become apparent hereinafter are achieved by a circuit breaker as specified in claim 1. The circuit breaker comprises a fixed contact, a moving contact and a breaker mechanism to move the moving contact between an open state and a closed state of the circuit breaker. The breaker mechanism serves as the kinematic chain between the moving and the fixed contact. In the open state of the circuit breaker, the moving contact is isolated from the fixed contact. In the closed state, the moving contact is electrically connected to the fixed contact. The breaker mechanism further comprises an actuation element to manually switch the circuit breaker between the open and the closed state. The breaker mechanism comprises a plurality of elements being coupled to each other to provide

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a compliant structure. The compliant structure of the breaker mechanism is arranged between the actuation element and the moving contact. The compliant structure of the breaker mechanism is configured to transmit a force from the
5 actuation element to the moving contact to move the moving contact between the open and the closed state.

The compliant structure is deformed so that the moving contact is moved between the closed and open state, when the
10 actuation element is moved. The compliant structure is effective as a force-transmitting means between the actuation element and the moving contact.

The breaker mechanism may be configured as a compliant based
15 monolithic structure incorporating the key features of the circuit breaker, such as manual opening, manual closing, tripping, being operated trip-free, snap opening, snap closing and latching, and facilitates the circuit breaker mechanism's major functions. The proposed embodiment of the
20 circuit breaker uses a compliant four-bar mechanism to control the movement of the moving contact by the manual and tripping input.

A regular rigid body four-bar mechanism consists of three
25 links connected with four pin joints or revolute joints. These three links are the input link, the coupling link and the output link. To simplify this rigid body four-bar mechanism, it is suggested to combine two or three links by removing revolute joints between them. As a result, a fixed
30 connection, i.e. a fixed joint, between the combined links is obtained. To give some "mobility" to this mechanism one or more links are configured as being compliant, i.e. flexible, links.

As later explained in detail, according to a possible embodiment of the circuit breaker, compliant-based structures with optimum stiffness are used at the critical joint locations in order to obtain the desired functionality with respect to various inputs. According to another possible embodiment, a ball and socket joint is used at the critical joint. According to a further embodiment of the circuit breaker, a multi-material based concept, where a material with very good compliance is used in the regions of high flexure, is provided to attain the desired functionality.

Compliant-based structures can provide manufacturing and assembly ease for the circuit breaker mechanisms. Injection molding and rapid prototyping based technics can be preferred for manufacturing plastics/polymer-based compliant structures. Stamping and punching operations can be preferred for manufacturing metal-based compliant structures. Using plastics/polymers for the compliant-based structures provides new solutions for better designs and manufacturing processes pertaining to complex shapes and structures.

Plastics/polymers provide good opportunities to attain the required dielectric properties by the addition of appropriate quantities and types of filler materials. The addition of filler materials can help to improve other properties as well and can provide added benefits. Using plastics/polymers with better dielectric properties can provide new solutions for smaller designs as this can potentially reduce the required installation distances of live parts. Compliant-based structures in conjunction with smart materials like shape memory polymers/alloys and piezoelectric materials can add new opportunities to reduce the number of assembly components and simplifying the overall circuit breaker mechanisms.

Brief Description of the Drawings

Figure 1 illustrates the functionality of a circuit breaker.

5 Figure 2A presents a basic block diagram of a circuit breaker.

Figure 2B shows an embodiment of a breaker mechanism of a circuit breaker.

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Figure 2C shows the individual components of the breaker mechanism shown in Figure 2B.

15 Figure 3 shows a four-bar configuration used for the breaker mechanism shown in Figure 2B.

Figure 4 illustrates a first topology of a breaker mechanism of a circuit breaker.

20 Figure 5 shows a practical realization of the first topology of the breaker mechanism of a circuit breaker.

Figure 6 shows a first embodiment of a breaker mechanism of a circuit breaker.

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Figure 7 shows a circuit breaker comprising a compliant-based breaker mechanism.

30 Figure 8A illustrates a compliant-based breaker mechanism for a circuit breaker being in an open state.

Figure 8B illustrates a compliant-based breaker mechanism for a circuit breaker being in a closed state.

Figure 9 shows a second embodiment of a compliant-based breaker mechanism for a circuit breaker.

Figure 10 shows a third embodiment of a compliant-based
5 breaker mechanism for a circuit breaker.

Figure 11 shows a fourth embodiment of a breaker mechanism for a circuit breaker using a ball and socket joint.

10 Figure 12 shows a fifth embodiment of a breaker mechanism for a circuit breaker using on a multi-material based concept.

Figure 13 shows a second embodiment of a breaker mechanism for a circuit breaker.

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Figure 14 shows a third embodiment of a breaker mechanism for a circuit breaker,

Figure 15 shows a fourth embodiment of a breaker mechanism
20 for a circuit breaker.

Figure 16 shows a fifth embodiment of a breaker mechanism for a circuit breaker.

25 Figure 17 shows a sixth embodiment of a breaker mechanism for a circuit breaker.

Figure 18 shows a practical realization of the sixth embodiment of the breaker mechanism of the circuit breaker.

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Detailed Description

Figure 2A shows an embodiment of an automatic circuit breaker CB. The circuit breaker comprises a static/fixed contact 100

and a moving contact 200. In the open configuration of the circuit breaker, the moving contact 200 is electrically isolated from the fixed contact 100. In the closed configuration, the moving contact 200 is in electrical
5 contact with the fixed contact 100.

The circuit breaker comprises terminals 800 and 900 for fixing electrical wires to connect the circuit breaker to an electrical circuit. In a closed state of the circuit breaker,
10 a current flows through the circuit breaker from one of the terminals 800, 900 via the connection of the fixed and the moving contact to the other one of the terminals 800, 900. In case of a short circuit in the electrical circuit to which the circuit breaker is connected to, the high current flowing
15 through the circuit breaker is interrupted by separating the moving contact 200 from the fixed contact 100. In this case an arc is generated.

In order to provide a propagation path for the arc, the circuit breaker comprising an arc runner 700 coupled to an
20 arc chute 500. The arc chute 500 comprises a stack of mutually insulated parallel metal plates which divide and cool the arc. By splitting the arc into smaller arcs within the arc chute 500, the arc is cooled down while the arc
25 voltage is increased and serves as an additional impedance which limits the current through the circuit breaker.

In order to manually control the movement of the moving contact 200 between the open and the closed state of the circuit breaker, a knob 400 is provided. The knob 400 is
30 coupled to a breaker mechanism 300'. In the case of a short circuit in the electrical circuit connected to the circuit breaker, a solenoid 1000 provides a magnetic field exciting a force to the moving contact 200 so that the moving contact

200 is moved away from the fixed contact 100 and the current flow between the end terminals 800 and 900 is interrupted.

5 The circuit breaker further comprises a bi-metallic strip 600 which heats up in the case of a large current flowing through the circuit breaker. This current is large enough to damage the electrical circuit coupled to the circuit breaker but is too low for opening the movable contact by means of the solenoid 1000. A thermal trip actuator 1100 connects the bi-
10 metallic strip 600 with the breaker mechanism 300'. The expansion of the bi-metallic strip 600 in the case of a large current flowing through the circuit breaker enables to move the moving contact 200 in the open position so that the electrical path between the fixed contact 100 and the moving
15 contact 200 is interrupted

Figure 2B shows the breaker mechanism 300' providing the coupling structure/kinematic chain between the knob 400 and the moving contact 200 to exert a force by the movement of
20 the knob 400 to the moving contact 200 to control the movement of the movable contact 200. The different parts of the breaker mechanism 300' as well as the knob 400 are shown in Figure 2C as separate components. It is obvious that the large number of components shown in Figure 2C causes high
25 production costs, difficulties in assembly as well as complexity of design, high sensitivity for working tolerances, and possible play and vibration.

Figure 3 shows a four-bar mechanism used for the breaker
30 mechanism 300' of the circuit breaker shown in Figures 2A, 2B and 2C. The four-bar mechanism consists of three links C1, C2 and C4 and four joints O1, O2, P1 and P2. The three links C1, C2 and C3 are formed between the four joints. The link C1 is the input link, the link C2 is the coupling link and the link

C3 is the output link C3. A fourth link C4 is a virtual link between the joints O1 and O2 and is always grounded. One end of the input link C1 is connected to ground by a pin joint O1 and the other end is connected to the coupler link by a pin joint P1. The output link C3 is connected to ground by pin joint O2 and the other end of the output link C3 is connected to the coupling link C2 by the pin joint P2.

According to the embodiments of a circuit breaker according to the present invention, the number of joints and links in the four-bar mechanism shown in Figure 3 is reduced by the following ways: Two different links may be combined with flexure hinges; two different links may be combined with rigid joint and flexible elements; and two different links may be combined with flexible elements.

According to the different embodiments of the circuit breaker shown in Figures 4 and 13 to 17, the circuit breaker CB comprises a fixed contact 100, a moving contact 200 and a breaker mechanism 300. The breaker mechanism 300 is configured to move the movable contact 200 between an open state and a closed state of the circuit breaker. The movable contact 200 is isolated from the fixed contact 100 in the open state of the circuit breaker. In the closed state of the circuit breaker, the moving contact 200 is electrically connected to the fixed contact 100. The circuit breaker CB further comprises an actuation element 10 to manually switch the circuit breaker between the open and the closed state.

As shown according to the different topologies of Figures 4 and 13 to 17, the breaker mechanism CB comprises a plurality of elements/links 3, 4 and 7 being coupled to each other to provide a compliant structure. The compliant structure of the breaker mechanism 300 is arranged between the actuation

element 10 and the moving contact 200. The compliant structure of the breaker mechanism 300 is configured to transmit a force from the actuation element 10 to the moving contact to move the moving contact between the open and the closed state. The force is transmitted from the actuation element 10 to the moving contact 200, when the actuation element 10 is moved between an open and a closed position.

The compliant structure of the breaker mechanism is configured such that at least one of the plurality of elements/links 3, 4 and 7 is deformed when subjected to mechanical stress to switch the circuit breaker between the closed and the open state. The compliant structure effects as a force-transmitting means between the actuation element 10 and the moving contact 200. The compliant structure is deformed, for example, when the at least one of the plurality of elements 3, 4, 7 is subjected to mechanical stress exerted to the breaker mechanism 300 by moving the actuation element 10.

In contrast to the configuration shown in Figure 3, the four-bar breaker mechanism is simplified according to the embodiments shown in Figures 4 and 13 to 17 by combining two or three links and removing the revolute joints P1 and P2 between them. Instead of connecting the links between revolute joints, at least two of the links are connected by a fixed connection, i.e. a fixed joint. In order to obtain some mobility to the breaker mechanism one or more links are configured as compliant/ flexible links.

According to the embodiment of the breaker mechanism CB shown in Figure 4, the breaker mechanism 300 comprises a first lever L1 constituted by a single body that comprises an input link 3 being coupled to the actuation element 10. The

actuation element 10 is coupled to the input link 3 by the joint 1. The input link 3 is configured as a rigid portion of the first lever L1. The breaker mechanism 300 comprises a second lever L2 constituted by a single body that comprises a coupling link 4 and an output link 7 being coupled to each other by a fixed joint 6. The coupling link 4 comprises at least a flexible portion and the output link 7 is configured as a rigid portion of the second lever L2. The output link of the second lever L2 is coupled to the moving contact 200. The moving contact 200 is coupled to the output link 7 by a joint 2.

The input link 3 and the actuation element 10 are pivoted around the joint 1 being configured as one of a revolute joint and a slider joint/prismatic joint. The output link 7 and the moving contact 200 are pivoted around the joint 2 being configured as one of a revolute joint and a slider joint/prismatic joint. The revolute joints 1 and 2 are virtually coupled by a ground connection C1. The breaker mechanism 300 further comprises a joint 5 that may be configured as a revolute joint. The input link 3 of the first lever L1 is coupled to the coupling link 4 of the second lever L2 by the joint 5. The revolute joint 5 can alternatively be replaced with a flexure hinge to further reduce the number of components.

Figure 5 shows a practical realization of components of the circuit breaker based on the embodiment of the breaker mechanism shown in Figure 4. The configuration comprises the actuation element 10 that may be configured as an actuation arm. The actuation element 10 is connected to the input link/element 3. The actuation element 10 and the input link/element 3 are pivotably mounted to the revolute joint 1. The input link/element 3 is configured as a compliant based

torsional spring and comprises compliant stays 3a and 3b. The input link/element 3 is coupled by the revolute joint 5 at location P1 to the coupling element/link 4. The coupling link/element 4 represents the flexible portion of the second lever L2 shown in Figure 4.

The coupling link/element 4 comprises a coupling arm 13, flexure hinges 6, 8 and an engaging element 11. The coupling arm 13 is coupled to the engaging element 11 by the flexure hinge 6 at location P2. The flexure hinge 6 provides rotational and translational degrees of freedom. The engaging element 11 engages to a latching element 21 at a latch point P3. The engaging element 6 is coupled to the output link/element 7 by the flexure hinge 8. The output link/element 7 is configured as the rigid portion of the second lever. The output link/element 7 is coupled to a latching element 21 via a revolute joint 2 fixed to ground. The output link 7 and the latching element 21 are coupled to the revolute joint 2 by means of flexible beams 9. The movable contact is coupled, for example riveted, to the output link 7 at location P4. The solenoid force input point at the engaging element 8 is marked by P5.

Figure 6 shows a cross-sectional illustration of a practical realization of an embodiment of the breaker mechanism 300 shown in Figure 4. The circuit breaker comprises a latching element 21. The coupling link 4 of the breaker mechanism 300 comprises the output link 7, an engaging element 11, a flexible joint 12 and a coupling arm 13. The input link that may be realized by the compliant-based torsional spring as, for example, shown in Figure 5, is not shown in Figure 6.

The coupling arm 13 has a first end section E13a coupled to the input link 3 by the revolute joint 5. A second end

section E13b of the coupling arm 13 is coupled to the engaging element 11 and the flexible joint 12. The engaging element 11 has a first end E11a being configured to be engaged in the latching element 21. The engaging element 11
5 has a second end E11b being connected to a first end E12a of the flexible joint 12. The flexible joint 12 has a second end E12b connected to the output link 7. The output link 7 is arranged between the flexible joint 12 and the movable contact 200. The moving contact 200 is connected to the
10 output link 7. According to the embodiment of the breaker mechanism shown in Figure 6, the flexible joint 12 is configured as a c-shaped structure.

The output link 7 is fixed to ground by a revolute joint 14.
15 The output link 7 is coupled to the latching element 21 by means of a flexible beam/flexure hinge 15. The flexible/flexure hinge 15 may be configured as a stay next to the revolute joint 14. The reference sign P6 marks the point of contact from the thermal trip actuator 1100 to the bi-
20 metallic strip 600. The reference sign P5 marks the point of contact for the short circuit actuator, for example the solenoid 1000. The movable contact 200 may be connected to the output link 7 by riveting at point P4. The guiding element 16 is used to couple the thermal trip actuator 1100
25 being in mechanical contact to the bi-metallic strip to the breaker mechanism.

Figure 7 shows an embodiment of a circuit breaker CB comprising the main components as shown for the circuit
30 breaker in Figure 2A. In contrast to the embodiment of the circuit breaker shown in Figure 2A, the breaker mechanism 300' is replaced by the breaker mechanism 300 as described with reference to Figure 6. The coupling link/element 4 of the breaker mechanism 300 is coupled to the input

link/element 3 by the revolute joint 5. The coupling link/element 4 is coupled to the output link/element 7 by means of the flexible joint 12. The output link/element 7 is connected to the movable contact 200.

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In contrast to the embodiment of the breaker mechanism 300', the breaker mechanism 300 shown in Figures 6 and 7 is realized as a compliant-based monolithic structure that incorporates the key features of the circuit breaker, i.e. manual opening, manual closing, tripping, operating trip-free, snap open, snap close and latching.

Figures 8A and 8B show the breaker mechanism 300 that is arranged between the actuation element 10 and the moving contact 200. The output link 7 is coupled to the movable contact 200. The output link 7 is further coupled to the coupling arm 13 via the flexible joint 12. The engaging element 11 is engaged at the latching point P3 to the latching element 21. The input link 3 is coupled by the revolute joint 5 to the coupling arm 13.

The movable contact 200 may be moved by a deformation of the compliant structure of the breaker mechanism 300, i.e. the flexible joint 12, when the actuation element 10 is moved, such that the moving contact 200 is separated from the fixed contact 100, as shown in Figure 8A. The configuration shown in Figure 8A shows the open state of the circuit breaker. If the actuation element 10 is moved in the anti-clockwise direction, as shown in Figure 8B, the compliant structure of the breaker mechanism, in particular the flexible joint 12, is deformed such that the movable contact 200 is moved towards the fixed contact 100. Figure 8B shows the closed state of the circuit breaker, wherein the movable contact 200 is in electrical contact with the fixed contact 100.

Figure 9 shows a cross-sectional view of another realization of an embodiment of the breaker mechanism 300 shown in Figure 4. The breaker mechanism 300 comprises the coupling link 4 and the output link 7. The coupling link 4 comprises the engaging element 11, the flexible joint 12, a coupling arm 13 and a compliant element 17. The input link 3 is not shown in Figure 9.

The coupling arm 13 has a first end section E13a coupled to the input link 3, not shown in Figure 9. The coupling arm 13 may be coupled to the input link 3 by means of a revolute joint 5. The input link 3 may be configured as a torsional spring, as shown in Figure 5. The coupling arm 13 comprises an end section E13b coupled to the compliant element 17. The compliant element 17 couples the engaging element 11 and the flexible joint 12 to the coupling arm 13. The engaging element 11 is configured to be engaged in the latching element 21. The flexible joint 12 has a first end E12a connected to the compliant element 17 and a second end E12b connected to the output link 7. The output link 7 is connected to the moving contact 200. The flexible joint 12 may be configured as a c-shaped structure between its first end E12a and its second end E12b.

The output link 7 is fixed to ground by a revolute joint 14. The output link 7 is coupled to the latching element 21 by means of a flexible beam/flexure hinge 15. The flexible/flexure hinge 15 may be configured as a stay next to the revolute joint 14. The movable contact 200 may be connected to the output link 7 by riveting at point P4. The reference sign P5 marks the point of contact for the short circuit actuator, for example the solenoid 1000. The reference sign P6 marks the point of contact from the thermal

trip actuator 1100 to the bi-metallic strip 600. The guiding element 16 is used to couple the coupling arm 1100 being in mechanical contact to the bi-metallic strip to the breaker mechanism.

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Figure 10 shows a cross-sectional illustration of another realization of the circuit breaker 300 shown in Figure 4. The breaker mechanism 300 shown in Figure 10 is similarly configured as the breaker mechanism shown in Figure 9. The same reference signs used in Figure 10 designate the same components of the breaker mechanism as shown in Figure 9. The breaker mechanism 300 of Figure 10 differs from the breaker mechanism of Figure 9 in the configuration of the flexible joint 12 arranged between the coupling arm 13 and the output link 7.

According to the embodiment of the breaker mechanism 300 of Figure 10, the flexible joint 12 comprises a first portion 12a and a second portion 12b. The first portion 12a of the flexible joint 12 extends between the first end E12a of the flexible joint and the second portion 12b of the flexible joint. The first portion 12a of the flexible joint 12 is configured as an s-shaped structure. The second portion 12b of the flexible joint 12 extends between the second end E12b of the flexible joint and the first portion 12a of the flexible joint and is configured as a c-shaped structure.

Figure 11 shows a cross-sectional illustration of another realization of the breaker mechanism according to the embodiment shown in Figure 4. The breaker mechanism is embodied similar to the breaker mechanism shown in Figure 9 and Figure 10. The same reference signs designate the same components as explained with reference to Figure 9.

The breaker mechanism 300 shown in Figure 11 differs from the embodiments of the breaker mechanisms shown in Figures 9 and 10 in that the coupling link 4 comprises a hinge element 18. The hinge element 18 is arranged between the compliant
5 element 17 and the output link 7. The hinge element 18 has a first portion 18a and a second portion 18b which are configured as a ball and socket joint to pivotably couple the coupling link 4 to the output link 7. The output link 7 is arranged between the hinge element 18 and the moving contact
10 200.

Figure 12 shows a cross-sectional view of another realization of the breaker mechanism 300 according to the embodiment shown in Figure 4. The same reference signs used in Figure 12
15 designate the same components and their functions as described with reference to Figure 6.

The coupling link 4 comprises the coupling arm 13, the engaging element 11 and a first flexible element 19 as well
20 as a second flexible element 20. The coupling arm 13 has a first end section E13a coupled to the input link 3, not shown in Figure 12. The input link 3 may be configured as a torsional spring as shown in Figure 5. The first end section E13a of the coupling arm 4 may be coupled to the input link 3
25 by a revolute joint 5. The coupling arm 13 has a second end section E13b coupled to the engaging element 11 by the first flexible element 19. The engaging element 11 has a first end E11a being configured to be engaged in the latching element 21 and a second end E11b being coupled to the output link 7
30 by the second flexible element 20.

The first and the second flexible elements 19 and 20 may respectively be configured as a rubber strap. The flexible element 19 extends between the end section E13b of the

coupling arm 13 and a first nose of the engaging element 11. The first flexible element 19 abuts on the nose of the engaging element 11. The engaging element 11 may comprise a further nose at the second end E11b. The second flexible
5 element 20 extends between the further nose of the engaging element 11 and the output link 7 so that the flexible element 20 abuts on the output link 7.

Figures 13 to 17 show different embodiments of a breaker
10 mechanism 300 to control the movement of the moving contact 200 between an open state of the circuit breaker in which the moving contact 200 is electrically isolated from the fixed contact 100, and a closed state of a circuit breaker, in which the moving contact 200 is electrically connected to the
15 fixed contact 100. The breaker mechanism is arranged between the actuation element 10 and the moving contact 200. The breaker mechanism 300 comprises a compliant structure that is configured to transmit a force from the actuation element 10 to the moving contact 200 to move the moving contact between
20 the open and the closed state. The force is transmitted by a deformation of the compliant structure of the breaker mechanism from the actuation element 10 to the moving contact 200, when the actuation element 10 is moved between the opened and a closed position.

25 The breaker mechanism 300 comprises an input link 3, a coupling link 4 and an output link 7 being coupled to each other to provide a compliant structure that is deformed when subjected to mechanical stress, for example by moving the
30 actuation element 10, to switch the circuit breaker between the closed and the open state.

According to the embodiment shown in Figure 13, the breaker mechanism 300 comprises a first lever L1 constituted by a

single body that comprises the input link 3 and the coupling link 4 being coupled to each other by a fixed joint 6. The input link 3 is configured as a rigid portion of the first lever L1. The coupling link 4 is configured as a flexible
5 portion of the first lever L1. The input link 3 is coupled to the actuation element 10. The breaker mechanism further comprises a second lever L2 also constituted by a single body that comprises an output link 7 being configured as a rigid portion. The moving contact 200 is coupled to the output link
10 7.

The input link 3 and the actuation element 10 are pivoted around a joint 1 being configured as one of a revolute joint and a slider joint/prismatic joint. The output link 7 and the
15 moving contact 200 are pivoted around a joint 2 being configured as one of a revolute joint and a slider joint/prismatic joint. According to the embodiment of the breaker mechanism shown in Figure 13, the coupling link 4 of the first lever L1 is coupled to the output link 7 of the
20 second lever L2 by the joint 5 that may be configured as a revolute joint. According to an alternative embodiment, the revolute joint 5 may be replaced by a flexure hinge. The breaker mechanism comprises a virtual link C1 between the joint 1 and the joint 2. This fourth link is grounded.

Figure 14 shows another embodiment of the breaker mechanism 300 comprising a compliant structure between the actuation element 10 and the moving contact 200. The compliant
25 structure deforms by the movement of the actuation element 10 and causes the movement of the moving contact between the closed and open position. The breaker mechanism further comprises a first lever L1 constituted by a single body that comprises an input link 3 and a coupling link 4 being coupled to each other by a fixed joint 6. The input link 3 is
30

configured as a flexible portion of the first lever L1. The coupling link 4 is configured as a rigid portion of the first lever L1. The input link 3 is coupled to the actuation element 10. The breaker mechanism 300 further comprises a
5 second lever L2 constituted by a single body that comprises an output link 7 being configured as a rigid portion. The moving contact 200 is coupled to the output link 7.

The input link 3 and the actuation element 10 are pivoted
10 around a joint 1 that may be configured as revolute joint. The output link 7 and the moving contact 200 are pivoted around a joint 2 that may be configured as a revolute joint. The coupling link 4 of the first lever L1 is coupled to the output link 7 of the second lever L2 by a joint 5 that may be
15 configured as a revolute joint. The joint 1 of the actuation element 10 and the joint 2 of the moving contact are virtually connected by a grounded link C1. All revolute joints 1, 2 and 5 may be replaced with flexure hinges to further reduce the number of components. The revolute joints
20 1 and 2 can also be replaced with prismatic joints/slider joints.

Figure 15 shows another embodiment of the breaker mechanism 300 comprising a compliant structure that is deformed to move
25 the moving contact 200 between the open and closed position, when the actuation element 10 is moved between the opened and closed position. The breaker mechanism comprises a joint 5, a first lever L1 and a second lever L2. The first lever L1 is constituted by a single body that comprises an input link 3
30 being coupled to the actuation element 10. The input link 3 is configured as a rigid portion of the first lever L1. The second lever L2 is constituted by a single body that comprises a coupling link 4 and an output link 7 being coupled to each other by a fixed joint 6. The coupling link 4

is configured as a rigid portion of the second lever L2 and the output link 7 is configured as a flexible portion of the second lever L2.

- 5 The input link 3 and the actuation element 10 are pivoted around a joint 1 being configured as one of a revolute joint and a slider joint/prismatic joint. The output link 7 and the moving contact 200 are pivoted around a joint 2 being configured as one of a revolute joint and a slider
- 10 joint/prismatic joint. The moving contact 200 is coupled to the output link 7 of the second lever L2. The input link 3 of the first lever L1 is coupled to the output link 4 of the second lever L2 by a joint 5 that may be configured as a revolute joint. The actuation element 10 and the moving
- 15 contact 200 are virtually connected by a fourth link C1 between the joint 1 and the joint 2. All joints 1, 2 and 5 may be replaced with flexure hinges to reduce the number of components.
- 20 Figure 16 shows another embodiment of the breaker mechanism 300 to move the moving contact 200 by an appropriate movement of the actuation element 10 around a joint 1. The breaker mechanism comprises a compliant structure that is deformed in dependence on the movement of the actuation element 10. The
- 25 deformation of the compliant structure causes a movement of the moving contact 200 between the open and closed state. The breaker mechanism 300 comprises a lever L constituted by a single body that comprises an input link 3, a coupling link 4 and an output link 7. The input link 3 is configured as a
- 30 first flexible portion 3. The output link 7 is configured as a second flexible portion, and the coupling link 4 is configured as a rigid portion.

The input link 3 is coupled to the coupling link 4 by a first fixed joint 6a. The coupling link 4 is coupled to the output link 7 by a second fixed joint 6b. The input link 3 is coupled to the actuation element 10. The moving contact 200 is coupled to the output link 7. The input link 3 and the actuation element 10 are pivoted around the joint 1 that may be configured as a revolute joint. The output link 7 and the moving contact 200 are pivoted around a joint 2 that may be configured as a revolute joint. The actuation element 10 and the moving contact 200 are virtually coupled by a grounded link C1 between the joint 1 and the joint 2. The revolute joints 1 and 2 may be replaced with flexure hinges or with prismatic joints/slider joints.

Figure 17 shows another embodiment of the breaker mechanism 300 using a compliant structure between the actuation element 10 and the moving contact 200 to move the moving contact 200 between the open and closed state by a deformation of the compliant structure. The breaker mechanism 300 comprises a lever L constituted by a single body that comprises an input link 3, a coupling link 4 and an output link 7. Each of the input link 3 and the coupling link and the output link is configured as a flexible portion. The input link 3 is coupled to the actuation element 10 by a joint 1. The input link 3 is further coupled to the coupling link 4 by a first fixed joint 6a. The coupling link 4 is coupled to the output link 7 by a second fixed joint 6b. The moving contact 200 is coupled to the output link 7 via a joint 2. The input link 3 and the actuation element 10 are pivoted around the joint 1 that may be configured as a revolute joint. The output link 7 and the moving contact 200 are pivoted around the joint 2 that may be configured as a revolute joint. The joint 1 and the joint 2 are virtually coupled by the grounded link C1. The revolute joints 1 and 2 may be replaced with flexure hinges to further

reduce the number of components or may be alternatively replaced with prismatic joints/slider joints.

Figure 18 shows a practical realization of the embodiment 300 of the breaker mechanism shown in Figure 17. The breaker mechanism comprises the actuation element 10 being configured as an actuation arm that may be rotationally moved around the revolute joint 1. The actuation element 10 is coupled to the input link 3 that is configured as a compliant-based torsional spring by means of the stays 3a and 3b. The input link 3 is coupled by a flexure hinge/fixed joint 6 to the coupling link 4. The coupling link 4 comprises the coupling arm 13 that is coupled to the engaging element 11 of the coupling link 4 by another fixed joint/flexure hinge 6. The flexure hinges at the positions P1 and P2 provide rotational and translation degrees of freedom.

The engaging element 11 is coupled to the latching element 21 at the latch point P3. The engaging element 11 is further coupled to the output link 7 by means of a pre-compression mechanism 8 that provides pre-compression force and helps in locking. The output link 7 and the latching element 21 are coupled to the revolute joint 2 by means of stays 9. The stays 9 provide displacement amplification and also rotational degrees of freedom. The moving contact not shown in Figure 18 may be connected to the output link 7, for example by riveting at location P4.

List of Reference Signs

	1, 2	joint
	3	input link
5	4	coupling link
	5	revolute joint
	6	fixed joint/flexure hinge
	7	output link
	8	pre-compression mechanism
10	9	stay
	10	actuation element
	11	engaging element
	12	flexible joint
	13	coupling arm
15	14	revolute joint
	15	flexible beam/flexure hinge
	16	guiding element
	17	compliant element
	18	hinge element
20	19	flexible element
	20	flexible element
	21	engaging element
	100	fixed contact
	200	moving contact
25	300	breaker mechanism
	400	knob
	500	arc shoot
	600	bi-metallic strip
	700	arc runner
30	800, 900	end terminal
	1000	solenoid
	1100	thermal trip actuator
	CB	circuit breaker

Claims

1. A circuit breaker with reduced number of components, comprising:

- 5 - a fixed contact (100),
 - a moving contact (200),
 - a breaker mechanism (300) to move the moving contact (200) between an open state and a closed state of the circuit breaker, wherein, in the open state, the moving contact (200)
10 is isolated from the fixed contact (100), and, in the closed state, the moving contact (200) is electrically connected to the fixed contact (100),
 - wherein the breaker mechanism (300) comprises an actuation element (10) to manually switch the circuit breaker between
15 the open and the closed state,
 - wherein the breaker mechanism (300) comprises a plurality of elements (3, 4, 7) being coupled to each other to provide a compliant structure,
 - wherein the compliant structure of the breaker mechanism
20 (300) is arranged between the actuation element (10) and the moving contact (200),
 - wherein the compliant structure of the breaker mechanism (300) is configured to transmit a force from the actuation element (10) to the moving contact (200) to move the moving
25 contact (200) between the open and the closed state.

2. The circuit breaker of claim 1,
wherein the compliant structure of the breaker mechanism (300) is configured such that at least one of the plurality
30 of elements (3, 4, 7) of the breaker mechanism (300) is deformed when subjected to mechanical stress to switch the circuit breaker between the closed and the open state.

3. The circuit breaker of any of the claims 1 or 2, comprising:

- wherein the breaker mechanism (300) comprises a first lever (L1) constituted by a single body that comprises an input link (3) being coupled to the actuation element (10), wherein the input link (3) is configured as a rigid portion of the first lever (L1),
- wherein the breaker mechanism (300) comprises a second lever (L2) constituted by a single body that comprises a coupling link (4) and an output link (7) being coupled to each other by a fixed joint (6), wherein the coupling link (4) comprises at least a flexible portion (11, 12, 17) and the output link (7) is configured as a rigid portion of the second lever (L2),
- wherein the output link (7) of the second lever (L2) is coupled to the moving contact (200),
- wherein the input link (3) and the actuation element (10) are pivoted around a first joint (1) being configured as one of a revolute joint and a slider joint,
- wherein the output link (7) and the moving contact (200) are pivoted around a second joint (2) being configured as one of a revolute joint and a slider joint,
- wherein the input link (3) of the first lever (L1) is coupled to the coupling link (4) of the second lever (L2) by a third joint (5) being configured as one of a revolute joint and a flexure hinge.

4. The circuit breaker of claim 3, comprising:

- a latching element (21),
- wherein the coupling link (4) of the breaker mechanism (300) comprises an engaging element (11) and a flexible joint (12) and a coupling arm (13),
- wherein the coupling arm (13) has a first end section (E13a) coupled to the input link (3) and a second end section

(E13b) coupled to the engaging element (11) and the flexible joint (12),

- wherein the engaging element (11) has a first end (E11a) being configured to be engaged in the latching element (21),

5 - wherein the engaging element (11) has a second end (E11b) being connected to a first end (E12a) of the flexible joint (12),

- wherein the flexible joint (12) has a second end (E12b) connected to the output link (7),

10 - wherein the moving contact (200) is connected to the output link (7),

- wherein the flexible joint (12) is configured as a c-shaped structure.

15 5. The circuit breaker of any of the claims 1 to 3, comprising:

- a latching element (21),

- wherein the coupling link (4) of the breaker mechanism (300) comprises an engaging element (11) and a flexible joint (12) and a coupling arm (13) and a compliant element (17),

20 - wherein the coupling arm (4) has a first end section (E13a) coupled to the input link (3) and a second end section (E13b) coupled to the compliant element (17),

- wherein the compliant element (17) couples the engaging element (11) and the flexible joint (12) to the coupling arm (13),

25 - wherein the engaging element (11) is configured to be engaged in the latching element (21),

- wherein the flexible joint (12) has a first end (E12a) connected to the compliant element (17) and a second end (E12b) connected to the output link (7),

30 - wherein the moving contact (200) is connected to the output link (7).

6. The circuit breaker of claim 5,
wherein the flexible joint (12) is configured as a c-shaped
structure between its first and second end (E12a, E12b).

5 7. The circuit breaker of claim 5,
- wherein the flexible joint (12) comprises a first portion
(12a) and a second portion (12b),
- wherein the first portion (12a) of the flexible joint (12)
extends between the first end (E12a) of the flexible joint
10 (12) and the second portion (12b) of the flexible joint (12)
and is configured as a s-shaped structure,
- wherein the second portion (12b) of the flexible joint (12)
extends between the second end (E12b) of the flexible joint
(12) and the first portion (12a) of the flexible joint (12)
15 is configured as a c-shaped structure.

8. The circuit breaker of claim 3, comprising:
- a latching element (21),
- wherein the breaker mechanism (300) comprises an engaging
20 element (11) and a coupling arm (13) and a compliant element
(17) and a hinge element (18),
- wherein the coupling arm (13) has a first end section
(E13a) coupled to the input link (3) and a second end section
(E13b) coupled to the compliant element (17),
25 - wherein the compliant element (17) couples the engaging
element (11) and the hinge element (18) to the coupling arm
(13),
- wherein the engaging element (11) is configured to be
engaged in the latching element (21),
30 - wherein the hinge element (18) has a first portion (18a)
and a second portion (18b), wherein the first and second
portion (18a, 18b) of the hinge element (18) are configured
as a ball and socket joint,

- wherein the output link (7) is arranged between the hinge element (18) and the moving contact (200).

9. The circuit breaker of claim 3, comprising:

- 5 - a latching element (21),
 - wherein the breaker mechanism (300) comprises an engaging element (11) and a coupling arm (13) and a first flexible element (19) and a second flexible element (20),
 - wherein the coupling arm (13) has a first end section
10 (E13a) coupled to the input link (3) and a second end section (E13b) coupled to the engaging element (11) by the first flexible element (19),
 - wherein the engaging element (11) has a first end (E11a) being configured to be engaged in the latching element (21)
15 and a second end (E11b) being coupled to the output link (7) by the second flexible element (20),
 - wherein the moving contact (200) is coupled to the output link (7).

- 20 10. The circuit breaker of claim 9,
 wherein the first and the second flexible element (19, 20) are respectively configured as a rubber strap.

11. The circuit breaker of the claims 1 or 2,

- 25 - wherein the breaker mechanism (300) comprises a first lever (L1) constituted by a single body that comprises an input link (3) and a coupling link (4) being coupled to each other by a fixed joint (6), wherein the input link (3) is configured as a rigid portion of the first lever (L1) and the
30 coupling link (4) is configured as a flexible portion of the first lever (L1),
 - wherein the input link (3) is coupled to the actuation element (10),

- wherein the breaker mechanism (300) comprises a second lever (L2) constituted by a single body that comprises an output link (7) being configured as a rigid portion,
- wherein the moving contact (200) is coupled to the output link (7),
- wherein the input link (3) and the actuation element (10) are pivoted around a first joint (1) being configured as one of a revolute joint and a slider joint,
- wherein the output link (7) and the moving contact (200) are pivoted around a second joint (2) being configured as one of a revolute joint and a slider joint,
- wherein the coupling link (4) of the first lever (L1) is coupled to the output link (7) of the second lever (L2) by a third joint (5) being configured as one of a revolute joint and a flexure hinge.

12. The circuit breaker of the claims 1 or 2,
- wherein the breaker mechanism (300) comprises a first lever (L1) constituted by a single body that comprises an input link (3) and a coupling link (4) being coupled to each other by a fixed joint (6), wherein the input link (3) is configured as a flexible portion of the first lever (L1) and the coupling link (4) is configured as a rigid portion of the first lever (L1),
 - wherein the input link (3) is coupled to the actuation element (10),
 - wherein the breaker mechanism (300) comprises a second lever (L2) constituted by a single body that comprises an output link (7) being configured as a rigid portion,
 - wherein the moving contact (200) is coupled to the output link (7),
 - wherein the input link (3) and the actuation element (10) are pivoted around a first joint (1) being configured as one of a revolute joint and a slider joint,

- wherein the output link (7) and the moving contact (200) are pivoted around a second joint (2) being configured as one of a revolute joint and a slider joint,
- wherein the coupling link (4) of the first lever (L1) is
5 coupled to the output link (7) of the second lever (L2) by a third joint (5) being configured as one of a revolute joint and a flexure hinge.

13. The circuit breaker of the claims 1 or 2,

10 - wherein the breaker mechanism (300) comprises a first lever (L1) constituted by a single body that comprises an input link (3) being coupled to the actuation element (10), wherein the input link (3) is configured as a rigid portion of the first lever (L1),

15 - wherein the breaker mechanism (300) comprises a second lever (L2) constituted by a single body that comprises a coupling link (4) and an output link (7) being coupled to each other by a fixed joint (6), wherein the coupling link (4) is configured as a rigid portion of the second lever (L2)
20 and the output link (7) is configured as a flexible portion of the second lever (L2),

- wherein the moving contact (200) is coupled to the output link (7) of the second lever (L2),

- wherein the input link (3) and the actuation element (10)
25 are pivoted around a first joint (1) being configured as one of a revolute joint and a slider joint,

- wherein the output link (7) and the moving contact (200) are pivoted around a second joint (2) being configured as one of a revolute joint and a slider joint,

30 - wherein the input link (3) of the first lever (L1) is coupled to the coupling link (4) of the second lever (L2) by a third joint (5) being configured as one of a revolute joint and a flexure hinge.

14. The circuit breaker of the claims 1 or 2,

- wherein the breaker mechanism (300) comprises a lever (L)

constituted by a single body that comprises an input link

(3), a coupling link (4) and an output link (7), wherein the

5 input link (3) is configured as a first flexible portion (3),

wherein the output link (7) is configured as a second

flexible portion and wherein the coupling link (4) is

configured as a rigid portion,

- wherein the input link (3) is coupled to the coupling link

10 (4) by a first fixed joint (6a),

- wherein the coupling link (4) is coupled to the output link

(7) by a second fixed joint (6b),

- wherein the input link (3) is coupled to the actuation

element (10),

15 - wherein the moving contact (200) is coupled to the output

link (7),

- wherein the input link (3) and the actuation element (10)

are pivoted around a first joint (1) being configured as one

of a revolute joint and a slider joint,

20 - wherein the output link (7) and the moving contact (200)

are pivoted around a second joint (2) being configured as one

of a revolute joint and a slider joint.

15. The circuit breaker of the claims 1 or 2,

25 - wherein the breaker mechanism (300) comprises a lever (L)

constituted by a single body that comprises an input link

(3), a coupling link (4) and an output link (7), wherein each

of the input link (3) and the coupling link (4) and the

output link (7) is configured as a flexible portion,

30 - wherein the input link (3) is coupled to the coupling link

(4) by a first fixed joint (6a),

- wherein the input link (3) is coupled to the actuation

element (10),

- wherein the coupling link (4) is coupled to the output link (7) by a second fixed joint (6b),
- wherein the moving contact (200) is coupled to the output link (7),
- 5 - wherein the input link (3) and the actuation element (10) are pivoted around a first joint (1) being configured as one of a revolute joint and a slider joint,
- wherein the output link (7) and the moving contact (200) are pivoted around a second joint (2) being configured as one
- 10 of a revolute joint and a slider joint.

FIG 1

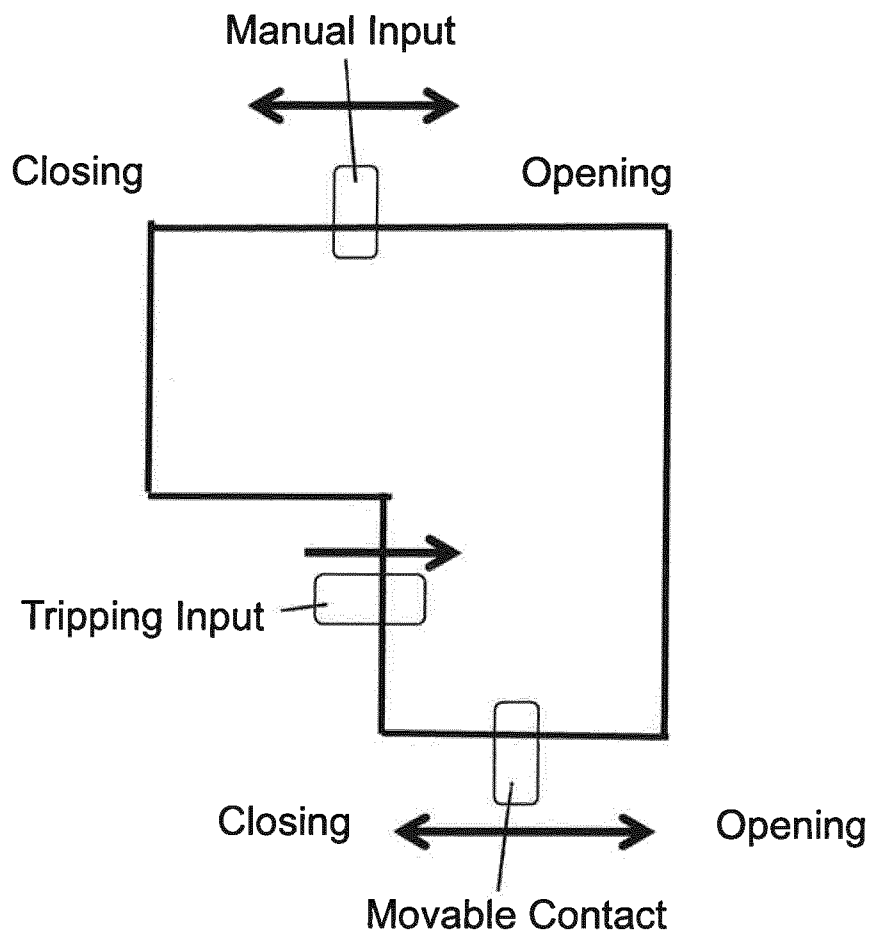


FIG 2A

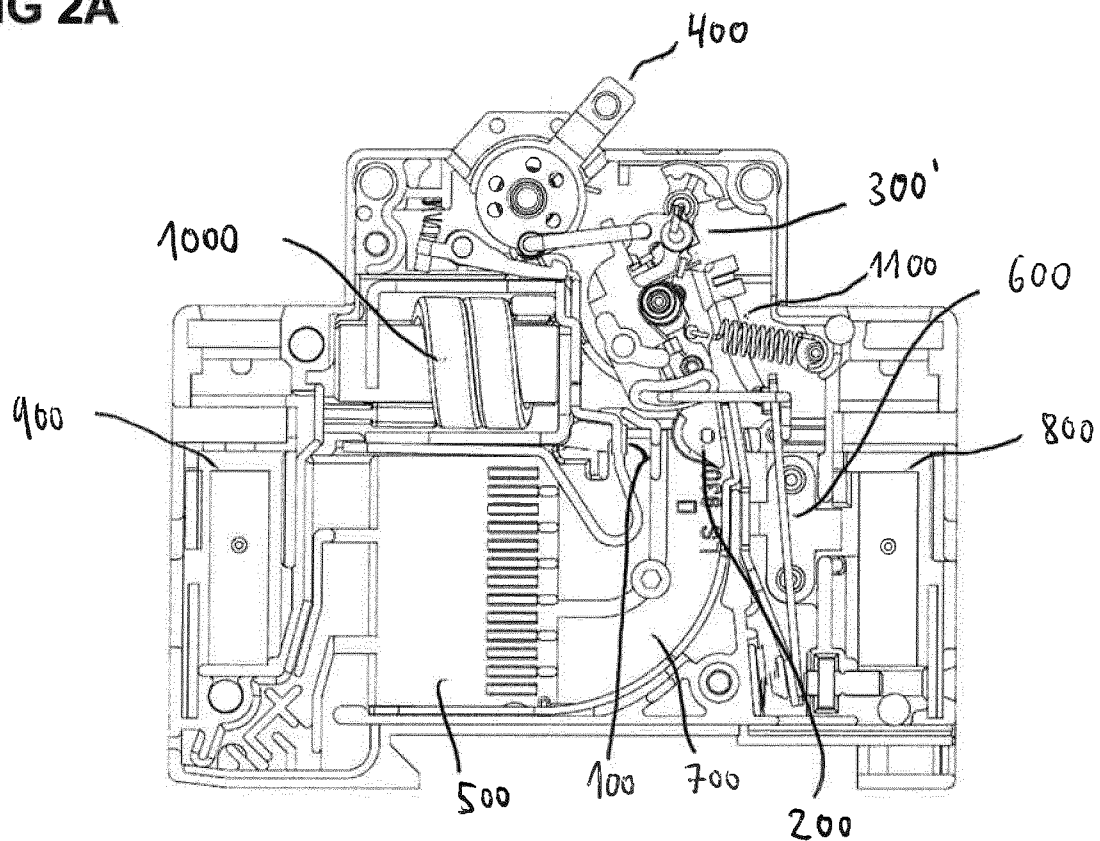


FIG 2B

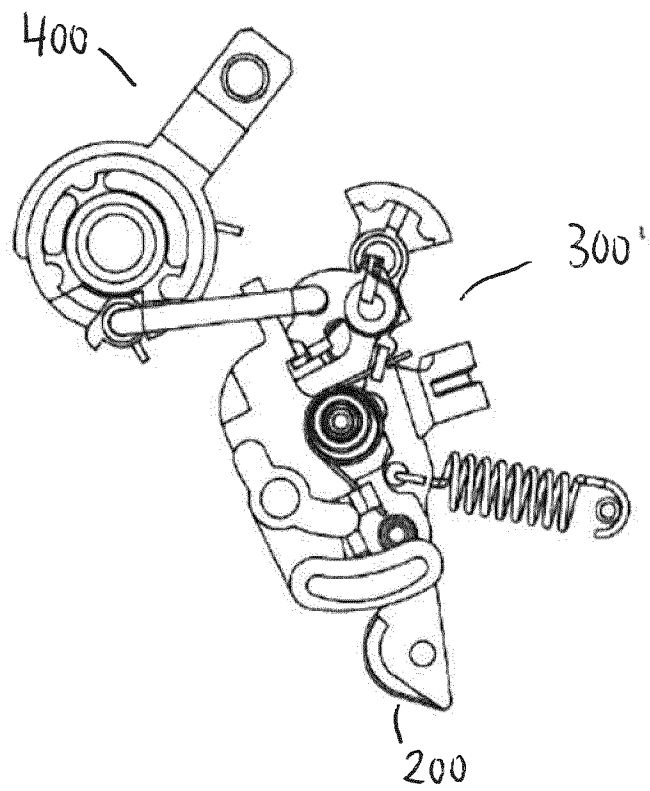


FIG 2C

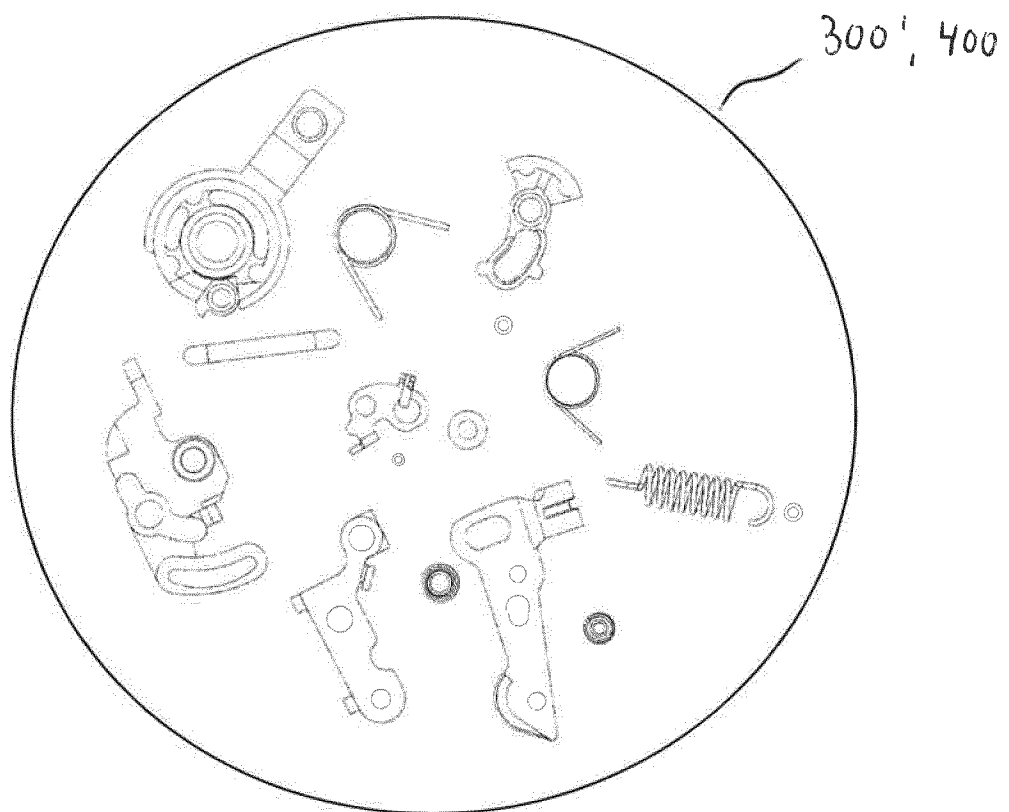


FIG 3

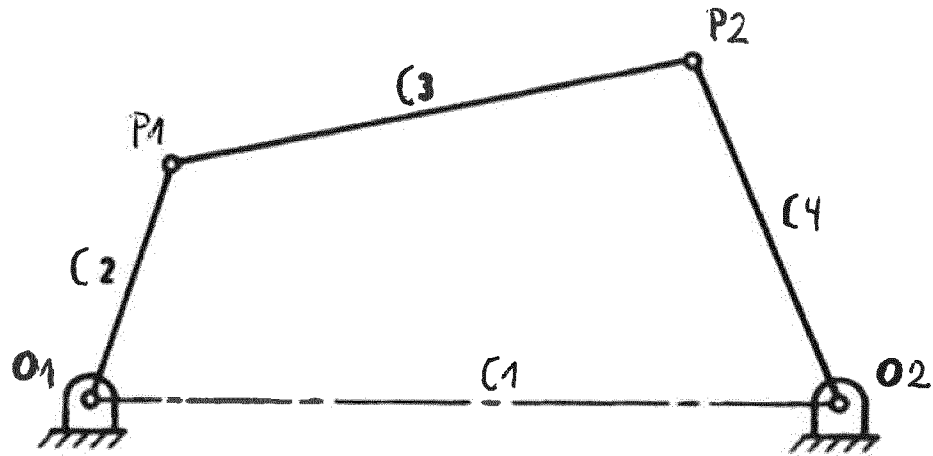


FIG 4

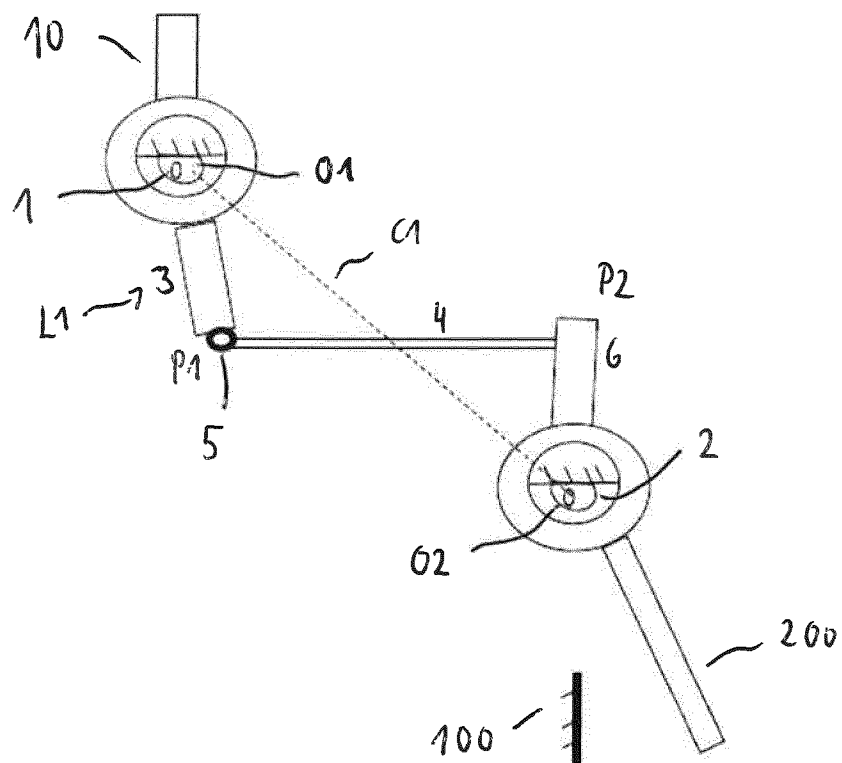


FIG 5

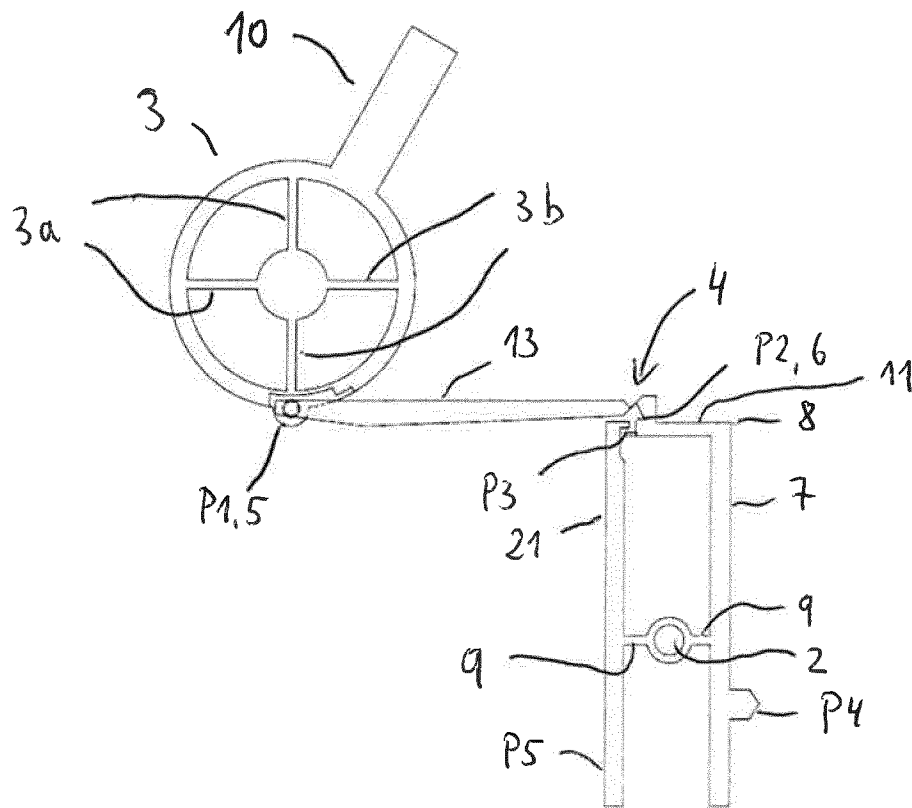
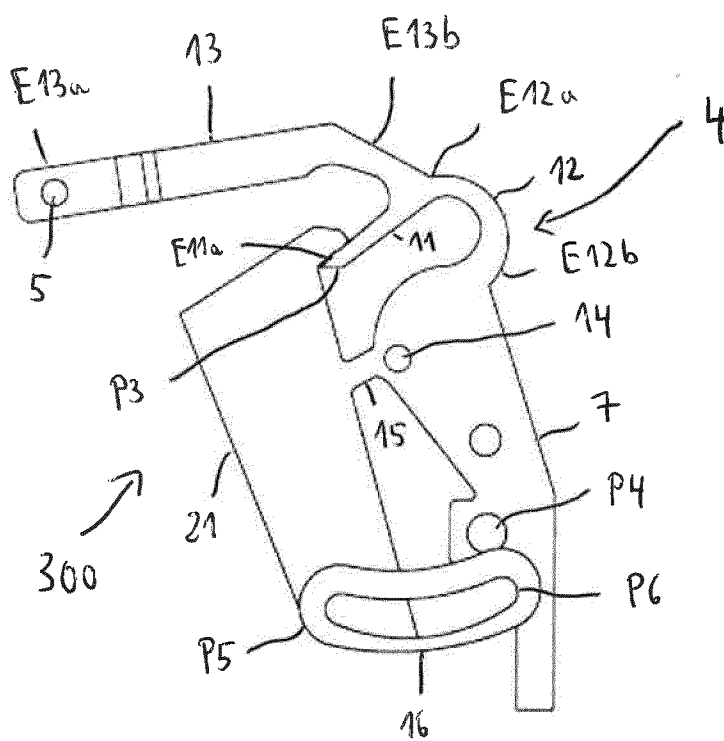


FIG 6



5/11

FIG 7

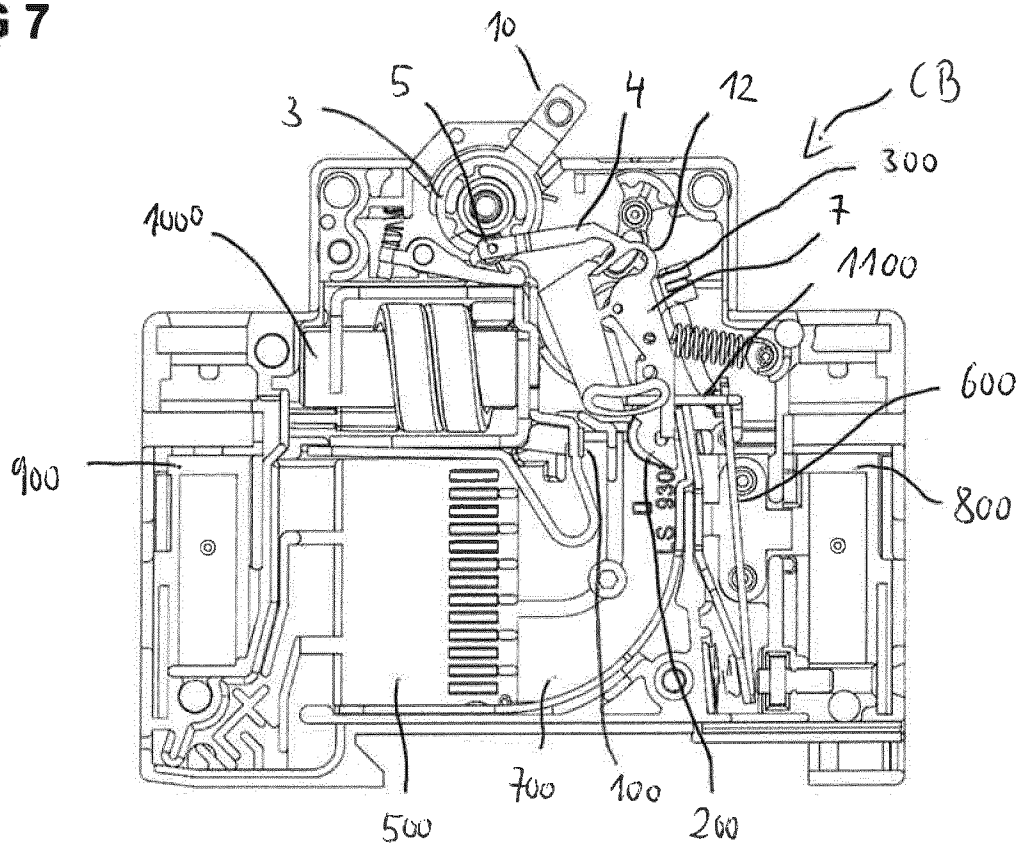


FIG 8A

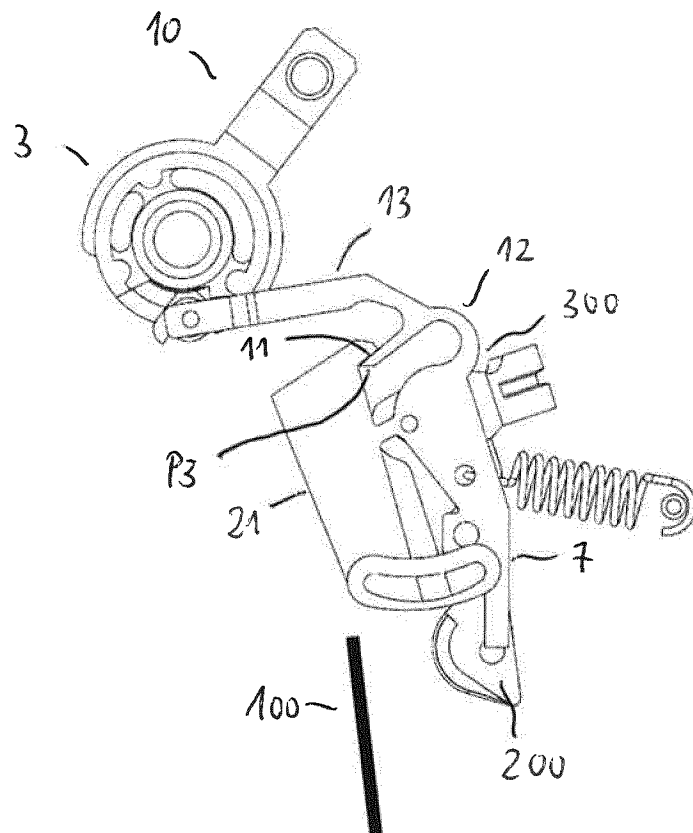


FIG 8B

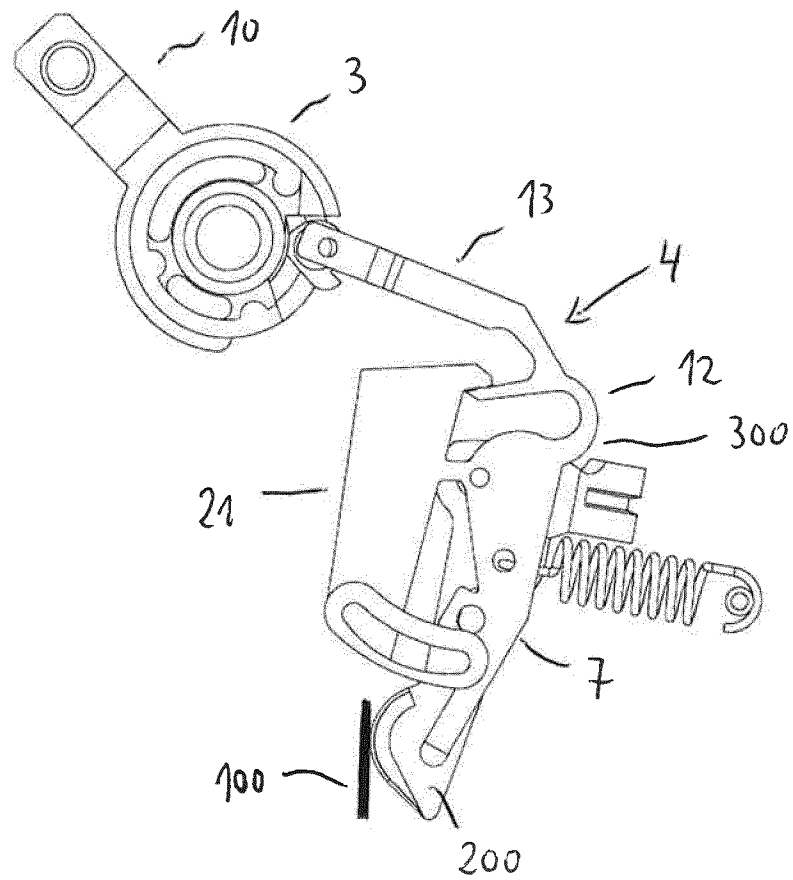


FIG 9

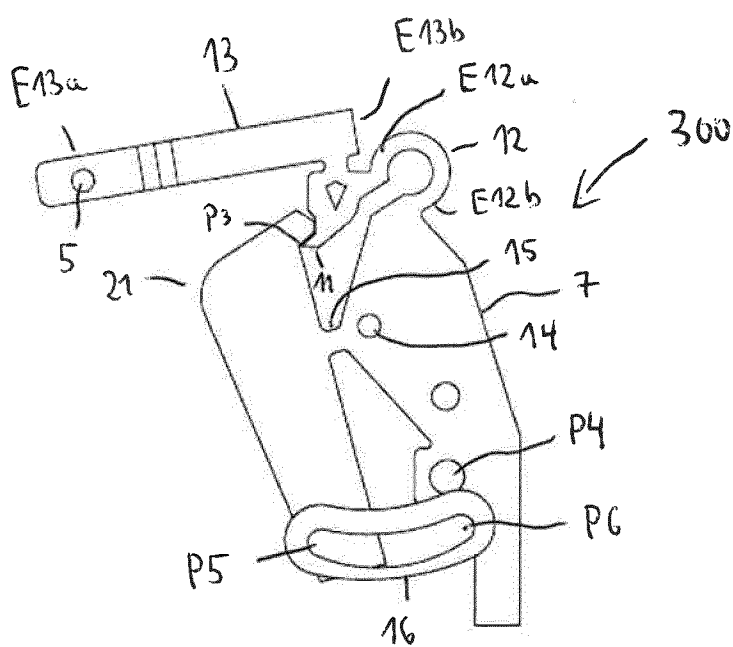


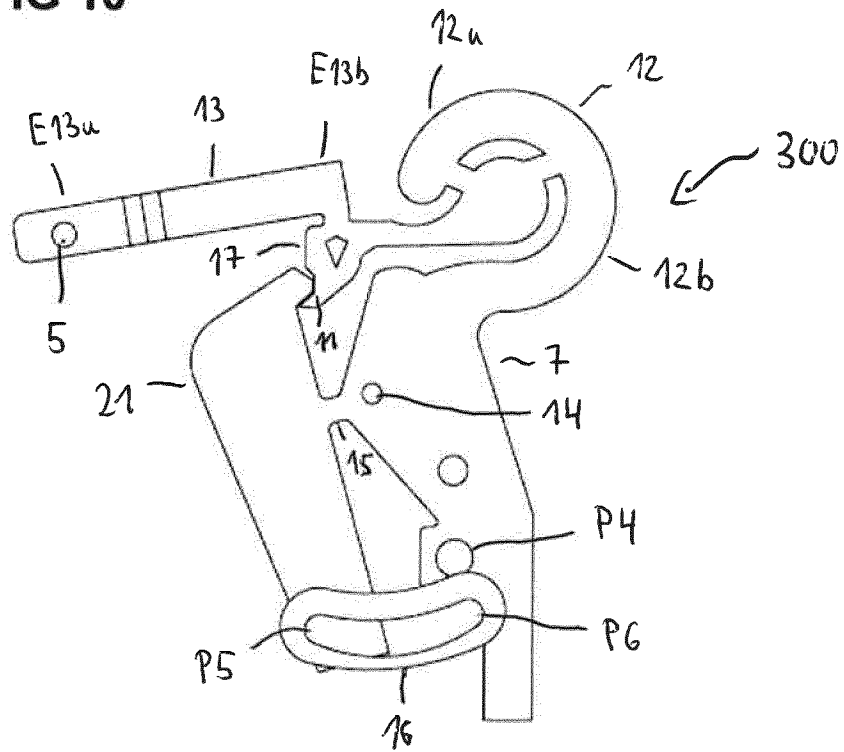
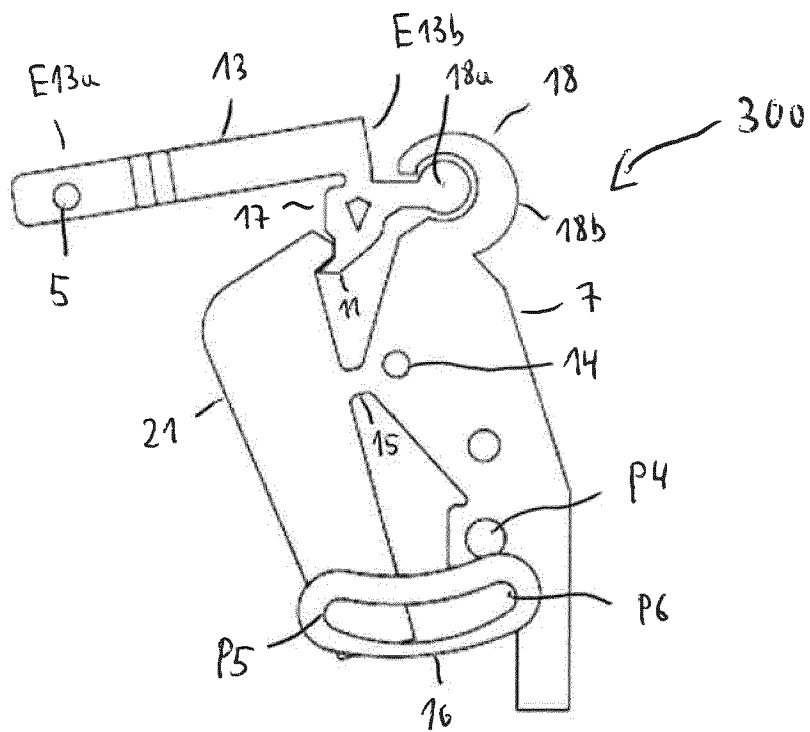
FIG 10**FIG 11**

FIG 12

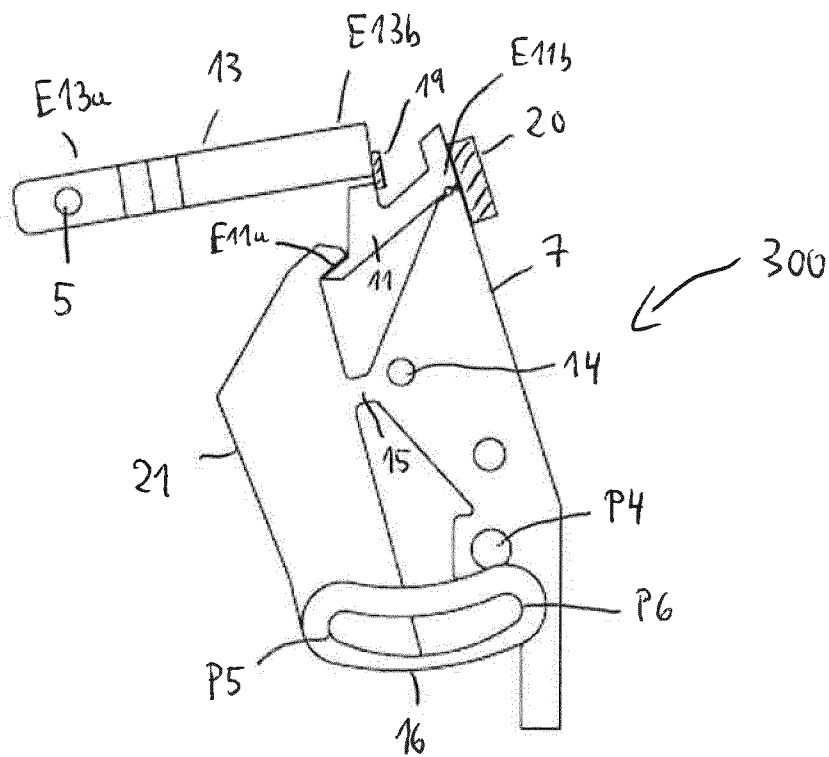


FIG 13

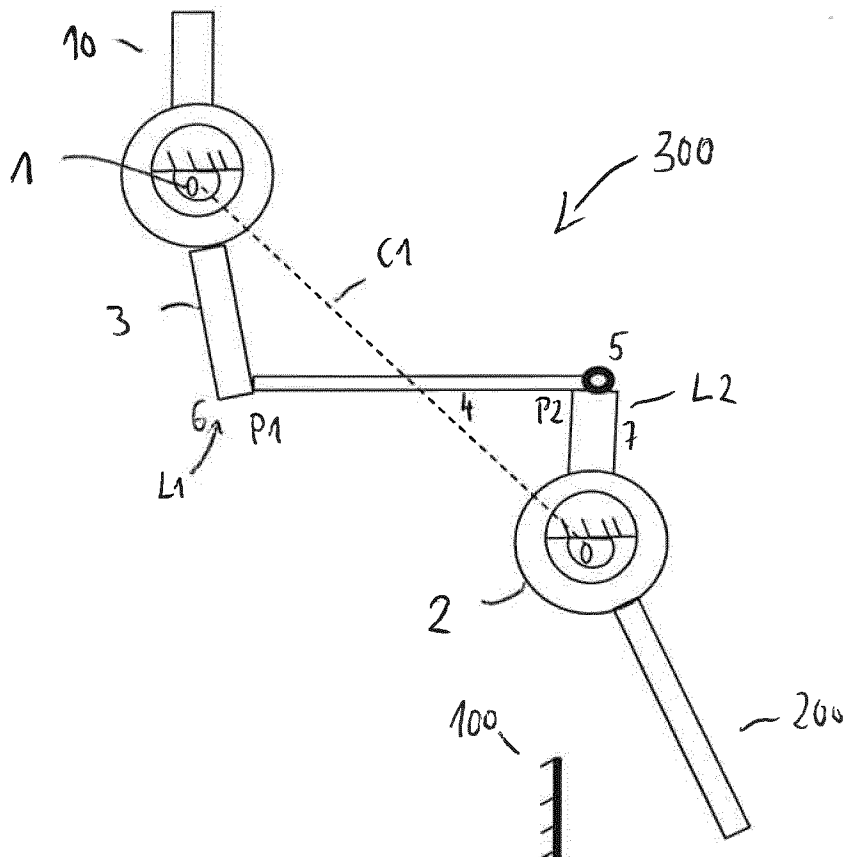


FIG 14

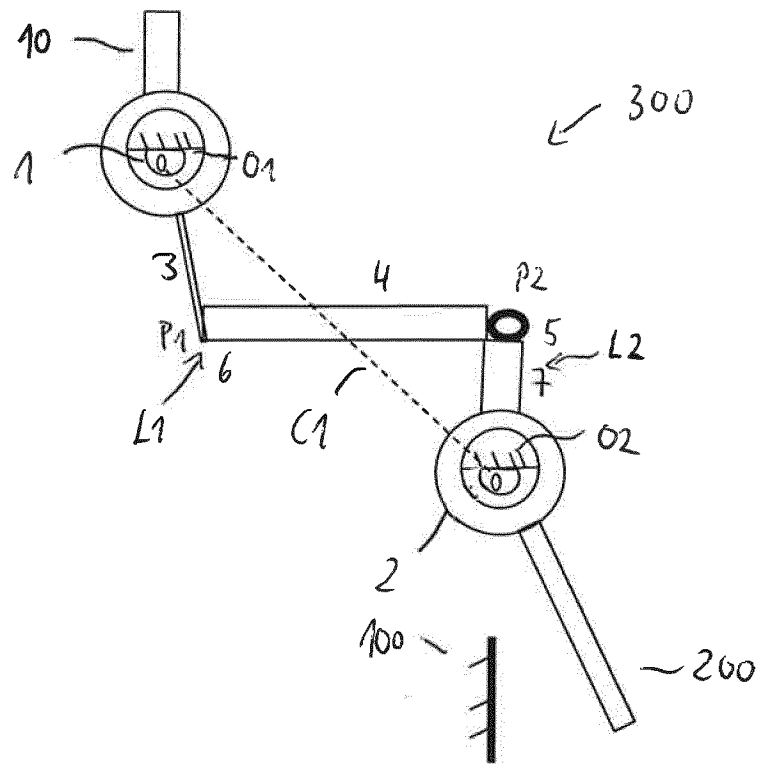


FIG 15

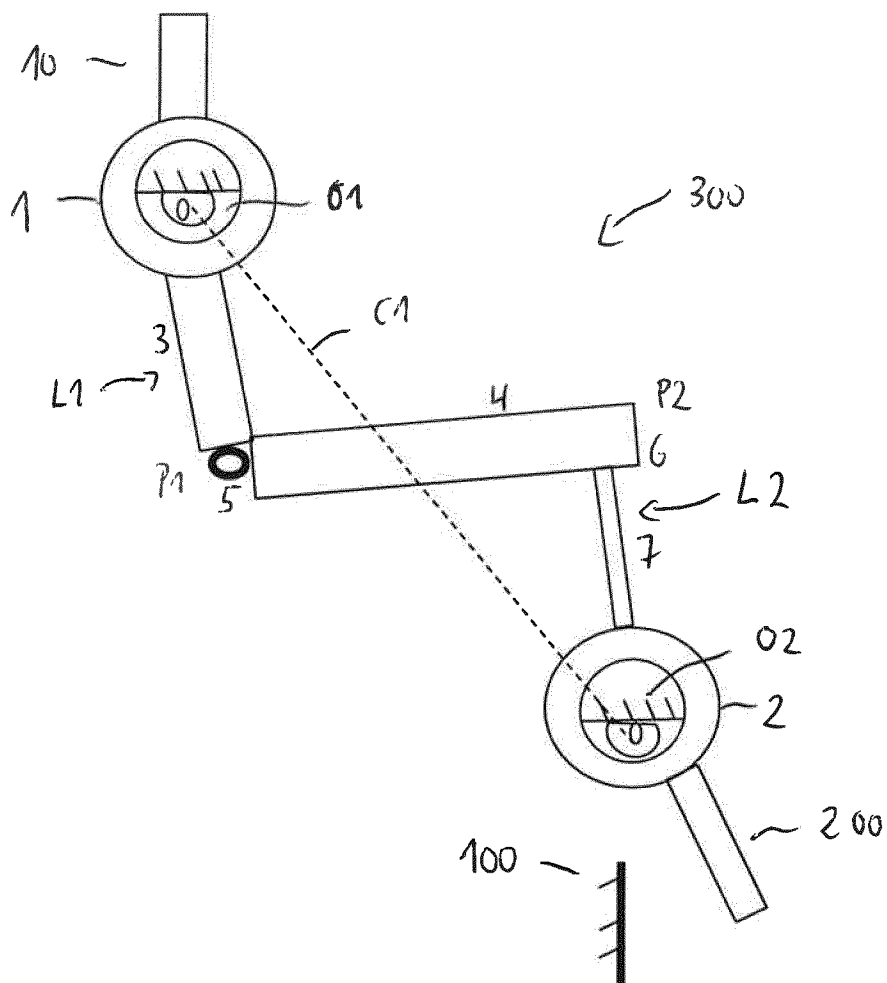


FIG 16

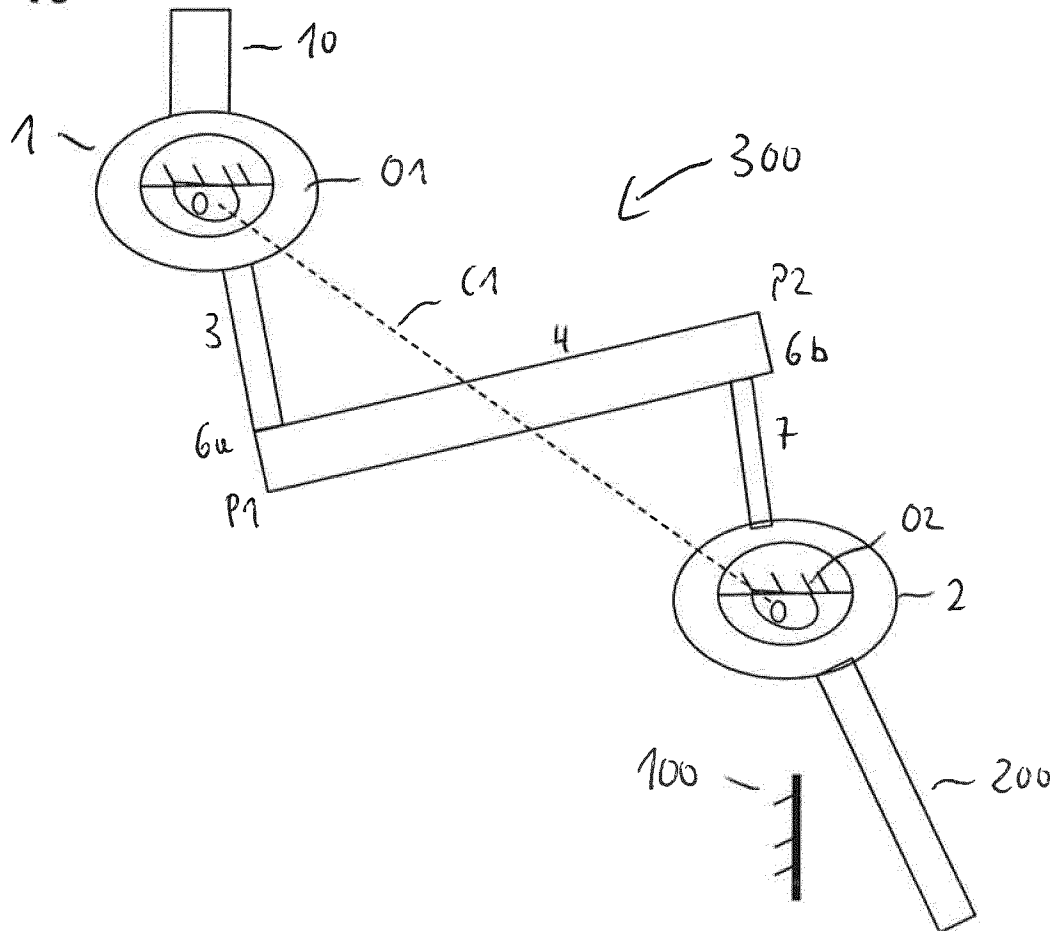


FIG 17

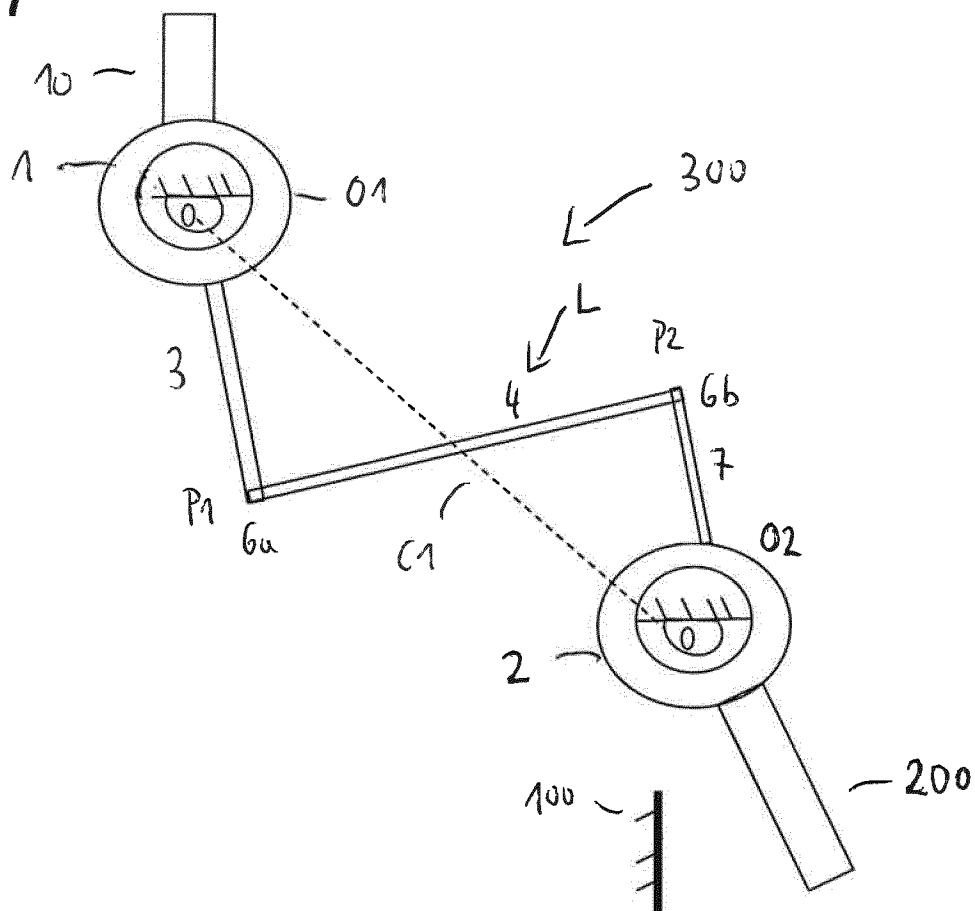
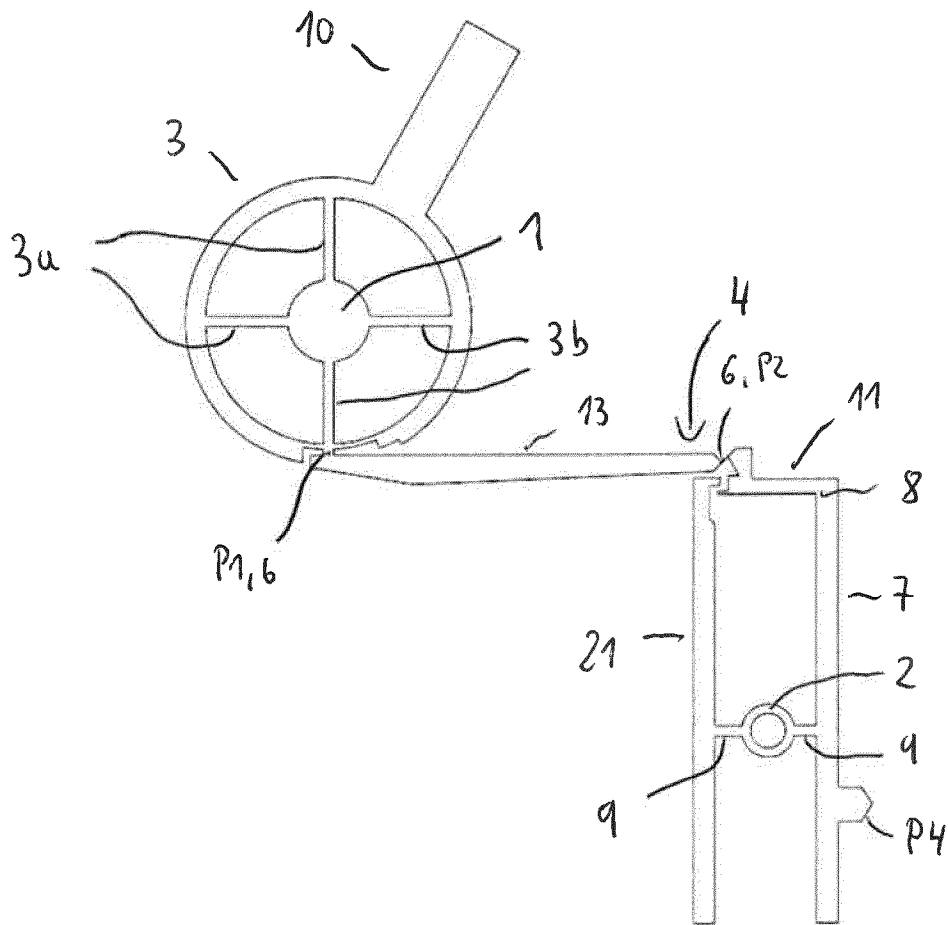


FIG 18



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/075412

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01H71/52

ADD. H01H71/50 H01H71/24

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.
X	US 2015/235794 A1 (RAKUFF STEFAN [US] ET AL) 20 August 2015 (2015-08-20)	1,2
A	figures 1-7	3-15
X	WO 2015/162508 A1 (CIRCUIT BREAKER IND [ZA]) 29 October 2015 (2015-10-29)	1,2
A	figure 1	3-15
A	WO 96/30924 A1 (DELTA CIRCUITS PROTECTION [GB]; STEVENS JOHN [GB]) 3 October 1996 (1996-10-03)	1-15
	figures 1,2,9-12	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

10 January 2018

Date of mailing of the international search report

23/01/2018

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Authorized officer

Ernst, Uwe

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/075412

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
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			DE 102015102331 A1	20-08-2015
			US 2015235794 A1	20-08-2015

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			WO 9630924 A1	03-10-1996
