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(54) SHORT-CIRCUITING DEVICE

(57) A short-circuiting device (14) comprises a triggering circuit (16), an actuating element (30), a stationary electrode (20) and a moveable electrode (22), where the actuating element (30) is moveable between a first retracted position and a first extended position and joined to the moveable electrode (22) for being moved between a corresponding second retracted position, where there is gap of a first distance between the moveable and stationary electrodes (22, 20), and a second extended position, where the gap has a second lower distance, the triggering circuit (16) being configured to trigger a current to start to flow between the electrodes (20, 22) after the actuating element (30) has been actuated to move from the first retracted position and before reaching the first extended position and the current continues to flow in the gap after a first zero crossing and at least until a second zero-crossing.

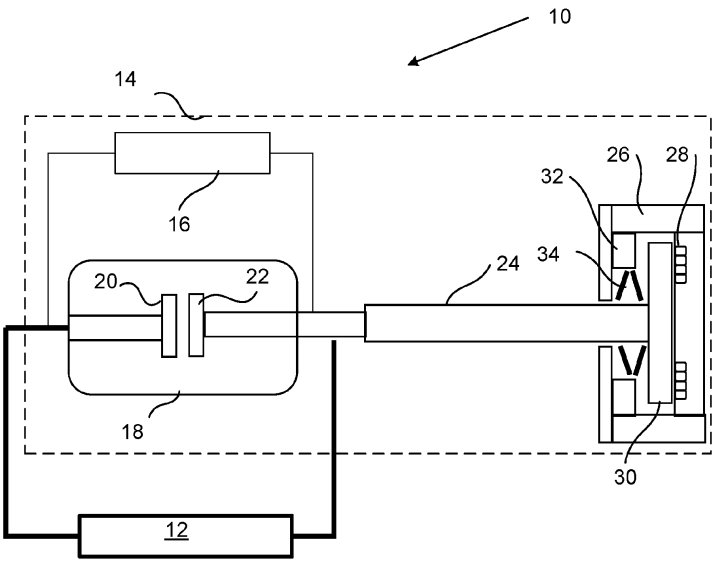

Fig. 1

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Description

Technical Field

[0001] The present disclosure generally relates to short-circuiting devices.

Background

[0002] Short-circuiting devices are of interest to use in a number of environments, where one is the use as an ultrafast closing switch in a DC circuit breaker. A short-circuiting device may be made of a stationary electrode and a moveable electrode made to move towards the stationary electrode, for instance in a vacuumized chamber.

[0003] Electrodes may be preferred compared to contact elements, because no damaging contact with force is used.

[0004] CN 106328433 discloses a device where a moveable electrode is moved from an initial position to an optimized gap position, where the electrodes are triggered and then the moving electrode is moved back to the main position.

[0005] There is, however, a need for allowing the current to continue to flow between the electrodes for a while even if a current zero is experienced, which can generally lead to the interruption of current flow, especially in a vacuumized chamber.. It may for instance be desirable to have the current flow long enough in order to allow a main breaker to be operated. This should be done at the same time as high contact making forces between the electrodes are avoided.

[0006] There is therefore a need for an improved short-circuiting device.

Summary

[0007] One object of the present disclosure is to provide a short-circuiting device that addresses at least some of the above-mentioned concerns.

[0008] This object is according to a first aspect achieved by a short-circuiting device comprising a triggering circuit, an actuating element, a stationary electrode and a moveable electrode, where the actuating element is moveable between a first retracted position and a first extended position and joined to the moveable electrode for moving the movable electrode between a corresponding second retracted position, where there is gap of a first distance between the moveable and stationary electrodes, and a second extended position, where the gap has a second lower distance between the moveable and stationary electrodes, the triggering circuit being configured to trigger a current to start to flow between the stationary electrode and the movable electrode after the actuating element has been actuated to move from the first retracted position and before reaching the first extended position and the current continues to flow in the gap between the stationary and moveable electrode after a first zero crossing and at least until a second zero-crossing. It is in some instances possible that the current continues to flow after the second zero-crossing.

[0009] The object is according to a second aspect achieved by an electrical power system arrangement comprising the short-circuiting device according to the first aspect. The electrical power system arrangement may additionally be a part of a direct current circuit breaker. The electrical power system arrangement may for instance be a current injection arrangement for a DC circuit breaker.

[0010] In a first variation of the first aspect, the moveable electrode is movable past the second extended position towards the stationary electrode after the actuating element reaches the first extended position.

[0011] In this case the triggering circuit may be configured to cause the current to flow when the movable electrode moves past the second extended position towards the stationary electrode and back to the second extended position.

[0012] In a second variation of the first aspect, the movable electrode is configured to "slightly" touch the stationary electrode in the movement past the second extended position.

[0013] The short-circuiting device may furthermore comprise an actuator mechanism and a rod.

[0014] In a third variation of the first aspect, the actuating element is joined to the moveable electrode via the rod and the length of continued movement of the moveable element is defined by the length and elasticity of the rod and the speed of the actuating element when reaching the first extended position.

[0015] It is here additionally possible that the actuating element is actuatable by the actuator mechanism and the speed may be the speed reached by the actuating element through the influence of the actuator mechanism.

[0016] In a fourth variation of the first aspect, the second distance of the gap in the second extended position is in the range of 0.8 - 1.2 mm and the movement past the second extended position towards the stationary electrode is a movement at least halfway to the stationary electrode from the second extended position

[0017] In a fifth variation of the first aspect, a half-period of the current caused to flow in the gap between the stationary and moveable electrodes is lower than the time it takes for the moveable electrode to move from a position where triggering is made, pass by the second extended position EP2 and reach a minimum distance to the stationary electrode.

[0018] In a sixth variation of the first aspect, the triggering circuit is configured to trigger the current flow between the electrodes just before the actuating element reaches the first extended position.

[0019] In a seventh variation of the first aspect, the triggering circuit is configured to apply a trigger voltage between the electrodes exceeding a gap breakdown voltage.

[0020] In an eighth variation of the first aspect, the triggering circuit is configured to cause a current to start to flow that may have a frequency in the range 1 - 10 kHz and an initial derivative at current zero crossing in the range 80 - 120 A/μs.

[0021] In a ninth variation of the first aspect, the short-circuiting device further comprises a retracting mechanism configured to force the actuating element back towards the first retracted position, which retracting mechanism may comprise at least one spring.

[0022] In a tenth variation of the first aspect, the actuating element is an armature of a Thomson actuator and the actuating mechanism is a Thomson coil of the Thomson actuator.

[0023] In an eleventh variation of the first aspect, the stationary electrode and the moveable electrode are placed in a sealed chamber, which may with advantage be a vacuumized chamber.

Brief Description of the Drawings

[0024] Further details, advantages and aspects of the present disclosure will become apparent from the following embodiments taken in conjunction with the drawings, wherein:

Fig. 1 schematically shows a power system arrangement comprising a short-circuiting device comprising a sealed chamber with a stationary electrode and a moveable electrode, where the movable electrode is joined to an actuating element in a Thomson actuator;

Fig. 2 schematically shows the sealed chamber with the moveable electrode joined to the actuating element, where the actuating element is in a first retracted position and the moveable electrode is in a second retracted position where there is a first gap size to the stationary electrode;

Fig. 3 schematically shows the sealed chamber with the moveable electrode joined to the actuating element, where the actuating element is in a first extended position and the moveable electrode is in a second extended position where there is a second gap size to the stationary electrode; and

Fig. 4 schematically shows a current used for driving an actuator mechanism, the movement of the actuating element between the first retracted position and the first extended position as well as the movement of the moveable electrode starting from the second retracted position and passing by the second extended position.

Detailed Description

[0025] In the following, a short-circuiting device will be described. The same reference numerals will be used to denote the same or similar structural features.

[0026] Fig. 1 schematically shows an exemplifying electrical power system arrangement 10 comprising a short-circuiting device 14. The electrical power system arrangement 10 is an example of current injection arrangement in a medium voltage (MV) direct current (DC) circuit breaker and in this case the short-circuiting device 14 may be an ultrafast mechanical switch for the circuit breaker. As is known in the art such a DC circuit breaker may comprise a main breaker connected in parallel with one or more surge arresters, where the main breaker may be realized as one or more series-connected electronic switches such as series-connected transistors, perhaps equipped with anti-parallel diodes. In fig. 1 the short-circuiting device 14 is connected in parallel with a circuit 12 for injecting current in such a main breaker.

[0027] It should be realized that a DC circuit breaker is merely one type of electrical power system environment in which the short-circuiting device may be included. It may as an example also be a part of a current limiter.

[0028] The short-circuiting device 14 comprises a stationary electrode 20 that is separated from a movable electrode 22 by a gap, where in this case the stationary electrode 20 and the movable electrode 22 are placed inside a sealed chamber 18, such as a vacuumized chamber. As an alternative to vacuum it is possible that different gas insulation technologies are used. The sealed chamber 18 may thus comprise a gas instead of vacuum. It is also possible to omit the chamber 18 and have the electrodes 20 and 22 surrounded by air. If air is used the dimensions are increased compared with vacuum. The moveable electrode 22 is joined to an actuating element 30 via a rod 24, which may be an insulating rod. The rod 24 may be between 15 - 30 cm long, of which 5 - 15 cm may be uninsulated.

[0029] The actuating element 30 is actuated by an actuating mechanism 28 in order to move between two positions, a first retracted position and a first extended position. The actuating element 30 is with advantage a part of a Thomson actuator 26. It may thereby be a conductive armature moved by an actuating mechanism 28, which actuating mechanism in this case is a Thomson coil. In the first retracted position the actuating element 30 rests on the coil 28. When a current runs through the coil, the actuating element is forced away from the coil towards a mechanical stop 32, and the first extended position is reached when the actuating element reaches the mechanical stop 32. At the mechanical stop 32 there is also a retracting mechanism 34, forcing the actuating element 30 back to the first retracted position. This retracting mechanism may be realized through a suitably biased spring.

[0030] As the actuating element 30 moves from the first retracted position to the first extended position, the moveable electrode 22 is also caused to be moved from a second retracted position to a second extended position. How this is done will now be described with reference also being made to fig, 2, 3 and 4, where fig. 2 schematically shows the sealed chamber 18 with the moveable electrode 22 joined to the actuating element 30 via the rod 24 when the actuating element 30 is in the first retracted position RPi and the moveable electrode 22 is in the second retracted position RP2, fig.3 schematically shows the sealed chamber with the moveable electrode joined to the actuating element 30, when the actuating element 30 is in the first extended position EP1 and the moveable electrode 22 is in the second extended position EP2 and fig. 4, shows a current used for driving the actuator mechanism, the movement of the actuating element 30 between the first retracted position RP1 and the first extended position EP1 as well as the movement of the moveable electrode 22 starting from the second retracted position RP2 and passing by the second extended position EP2.

[0031] The actuating element 30 has a stroke length, i.e. a length that it moves when moving from the first retracted position RP1 to the first extended position EPi, which stroke length is defined by the distance between the actuating mechanism 28 and the mechanical stop 32 and may be in an interval of 10-0.8 mm or 10-1.2 mm. The stroke length is translated into a movement of the same length of the movable electrode 22.

[0032] In fig. 4 the movement of the moveable electrode 22 is shown as a first curve 38 that is related to the position of the stationary electrode 20. Thereby the curve 38 also indicates the size of the gap between the stationary and the moveable electrode 20 and 22, where initially the gap has a size that corresponds to the second retracted position RP2, which is the gap size at the second extended position EP2 plus the stroke length. The gap in this case has a first distance between the moveable and stationary electrodes 20 and 22. As a non-limiting example the first distance or gap size at the second retracted position RP2 is set as 10 mm. When the moveable electrode 22 is in the second extended position EP2 that gap size is smaller. In this case the gap has a second lower distance between the moveable and stationary electrodes 20 and 22. In the present case the gap size or second distance is set as 0.8 mm although it may vary in the range of 0.8 - 1.2 mm.

[0033] The movement of the actuating element 30 is shown as a second curve 36, which second curve 36 is aligned with the first curve 38 through the first extracted position EP1 being aligned with the second extracted position EP2. Thereby also the first and second extended positions EP1 and EP2 are aligned with each other

[0034] In order to effectuate the movement of the moveable electrode 22, a current is driven through the coil 28 which current is schematically shown in a third curve 34 of fig. 4. This current causes the conductive armature 30 to be repelled by the coil 28. Thereby the armature 30 is forced away from the first retracted position RP1 at the coil 28 with high speed until it is stopped by the mechanical stop 32 at the first extended position EP1.

[0035] This movement also moves the rod 24, which in turn causes the movable contact to move from the second retracted position RP2 to the second extended position EP2.

[0036] Although the actuating element 30 stops at the first extended position EPi, it can be seen that the moveable electrode 22 does not stop at the corresponding second extended position EP2. It continues to move towards the stationary electrode 20 and in the example of fig. 4 actually even slightly touches the stationary electrode 20. The moveable electrode 22 is thus movable past the second extended position EP2 towards the stationary electrode 20 after the actuating element reaches the first extended position EP1 and may additionally be configured to touch the stationary electrode 20 in this movement past the second extended position EP2. This additional movement is due to the elasticity of the rod 24. The length of the continued movement may additionally be set based on the length and elasticity of the rod 24 and the speed of the actuating element 30 when reaching the first extended position EP2, where the speed may be the speed reached by the actuating element 30 through the influence of the actuator mechanism 28. It is here possible that the second distance of the gap in the second extended position EP2 is in the range of 0.8 - 1.2 mm and the length of movement past the second extended position EP2 is at least halfway from the second extended position EP2 to the stationary electrode 20.

[0037] After the actuating element 30 has reached the first extended position EPi, the retracting mechanism 34 acts to move the actuating element back towards the first retracted position RP1. As the actuating element 30 is joined to the moveable electrode 22 via the rod 24, also the movable electrode 22 is moved back, first to the second extracted position EP2 and then to towards the second retracted position RP2, where the elasticity of the rod also contributes to the backward movement. The current through the coil 28 is also applied for a short duration, so after a while there is no repulsion force countering the force by which the retracting mechanism 34 pulls the actuating element 30 back towards the first retracted position RP1.

[0038] According to aspects of the present disclosure, the triggering circuit 16 triggers a current to flow across the gap between the stationary and the moveable electrodes 20 and 22. The triggering may involve applying a voltage across the electrodes that exceeds a gap breakdown voltage. The current may as one example be made to flow through discharging a capacitor bank, in the circuit 12.

[0039] The triggering may take place after the actuating element 30 has been actuated to move from the first retracted position RP1 but before it reaches the first extended position EP1. The triggering may additionally be made just before the actuating element 30 reaches the first extended position EP1. It may as an example be made 0.5 - 0.1 ms before the first extended position EPi is reached.

[0040] The current typically is a decaying alternating current (AC) having a defined period obtained through discharging a capacitor bank. It is here also possible that the half period of the current is lower than the time it takes for the moveable electrode 22 to return to the second extended position EP2 after having continued to move towards the stationary electrode 20. The time it takes for the moveable electrode 22 to move from the position where triggering is made, pass by the second extended position EP2 and reach a minimum distance to the stationary electrode 20 may thus be higher than the half-period of the current flowing between the electrodes 20 and 22. It is here additionally possible that the current has a frequency in the range 1 - 10 kHz and initially a derivative at current zero crossing, in the range 80 - 120 A/μs. If the moveable electrode 22 touches the stationary electrode 20, it is also possible that the current has a first zero-crossing at the time that this touching takes place.

[0041] Through this type of operation the current starts to flow or run through the gap at the time of triggering and then continues to flow in the gap between the stationary and moveable electrode after a first zero crossing and continues to flow at least until a second zero-crossing, where a sufficiently high initial current derivative ensures that current continues to flow if there is no touch between the two electrodes and no such requirements on the current derivative is needed if there is a current zero crossing that coincides with the two electrodes touching each other. The triggering circuit thus triggers the current to flow just before the reaching of the second extended position EP2 and to continues to flow until the first zero crossing, which is controlled to occur during the movement of the movable electrode past the second extended position towards the stationary electrode and back to the second extended position. Due to the coincidence of the first zero crossing with the touching of the electrodes and/or the level of the current derivative, the current will continue to flow after this first zero crossing up until at least a second zero-crossing.

[0042] The gap is initially "large" to avoid false triggering in the retracted position. When the short-circuiting is to be made, the gap is quickly reduced by the Thomson actuator, and the current flow is triggered by the high voltage impulse breaking down the small residual vacuum gap (< 1 mm, reached after 1 ms of operation, see in fig. 4). The actuating element is reaching the first extended position, but the movable electrode moves forward past the corresponding second extended position via the elasticity of the mechanical rod, reaching almost a contact touch. The current continues to flow till the first local current zero crossing in the contact gap. If di/dt is high enough or if the zero crossing is combined with the contact touch, the current continues to flow until the next current zero crossing.

[0043] The retracting mechanism in turn pushes back the actuating element to the first retracted position, thereby the short-circuiting device is ready for a new operation.

[0044] The short-circuiting device has several advantages.

[0045] It has a high voltage withstand capability meaning only one device is needed and not several devices in series. The short-circuiting device is also capable of conducting current in both directions as well as is robust against transients in the electrical system. The electrical endurance may also be high because the current that flows between the electrodes may be produced in a small vacuum gap through an electrical arc in vacuum, leading to a small arcing voltage, and avoiding evaporating too much contact material in the sealed chamber. No contact welding is expected.

[0046] The movable electrode, at worst, only slightly touches the stationary electrode, and the travel is stopped only by the first extended position of the actuating element, not by a collision between the electrodes. No real galvanic contact is realized during the operation, protecting against welding and consequent mechanical damages from a high-speed collision. The high voltage signal will trigger the device at the desired time, improving reproducibility in time. The current flows through the vacuum electrical arc as long as the current is higher than the chopping current of the short-circuiting device (few amps). The current is interrupted in the subsequent current zero-crossing.

[0047] The short-circuiting device cannot be triggered in the second retracted position but can be easily triggered when about to reach the second extended position. The electrical endurance can be an issue where the total charge transfer per single discharge must be limited to avoid damaging the dielectric gap. When short-circuiting is desired the gap is reduced, a high voltage signal then triggers the insulation breakdown between the two electrodes, and the current can flow through the device via a vacuum arc. The short-circuiting device thereby combines the speed and the high voltage triggering system of a spark gap with the electrical endurance of a low-speed mechanical switch. The use of a Thomson actuator provides operation that is faster than a closing operation in a standard AC circuit breaker, which fast operation is required in DC breaker operations.

[0048] While the present disclosure has been described with reference to exemplary embodiments, it will be appreciated that the present invention is not limited to what has been described above. For example, it will be appreciated that the dimensions of the parts may be varied as needed.

Claims

1. A short-circuiting device (14) comprising a triggering circuit (16), an actuating element (30), a stationary electrode (20) and a moveable electrode (22), where the actuating element (30) is moveable between a first retracted position (RPi) and a first extended position (EPi) and joined to the moveable electrode (22) for moving the movable electrode between a corresponding second retracted position (RP2), where there is gap of a first distance between the moveable

and stationary electrodes (22, 20), and a second extended position (EP2), where the gap has a second lower distance between the moveable and stationary electrodes (22, 20), the triggering circuit (16) being configured to trigger a current to start to flow between the stationary electrode (20) and the movable electrode (22) after the actuating element (30) has been actuated to move from the first retracted position (RPi) and before reaching the first extended position (EP1) and the current continues to flow in the gap between the stationary and moveable electrode (20, 22) after a first zero crossing and at least until a second zero-crossing.

2. The short-circuiting device (14) according to claim 1, wherein the moveable electrode (22) is movable past the second extended position (EP2) towards the stationary electrode (20) after the actuating element (30) reaches the first extended position (EP1).

3. The short-circuiting device (14) according to claim 2, wherein the movable electrode (22) is configured to touch the stationary electrode (20) in said movement past the second extended position (EP2).

4. The short-circuiting device (14) according to claim 2 or 3, further comprising a rod (24), where the actuating element (30) is joined to the moveable electrode (22) via the rod (24), and the length of continued movement of the moveable element is defined by the length and elasticity of the rod and the speed of the actuating element when reaching the first extended position.

5. The short-circuiting device (14) according to any of claims 2 - 4, wherein the second distance of the gap in the second extended position (EP2) is in the range of 0.8 - 1.2 mm and the movement past the second extended position (EP2) is a movement at least halfway to the stationary electrode (20) from the second extended position (EP2).

6. The short-circuiting device (14) according to any of claims 2 - 5, wherein a half-period of the current caused to flow in the gap between the stationary and moveable electrodes (20, 22) is lower than a time it takes for the moveable electrode (22) to return to the second extended position (EP2) after having continued to move towards the stationary electrode (20).

7. The short-circuiting device (14) according to any previous claim, wherein the triggering circuit (16) is configured to trigger the current flow between the electrodes (20, 22) just before the actuating element (30) reaches the first extended position (EP1).

8. The short-circuiting device (14) according to any previous claim, wherein the triggering circuit (16) is configured to apply a trigger voltage between the electrodes (20, 22) exceeding a gap breakdown voltage.

9. The short-circuiting device (14) according to any previous claim. wherein the triggering circuit (16) is configured to cause a current to start to flow that has a frequency in the range of 1 - 10 kHz and an initial derivative at current zero crossing in the range 80 - 120 A/μs.

10. The short-circuiting device (14) according to any previous claim, further comprising a retracting mechanism (34) configured to force the actuating element (30) back towards the first retracted position (RPi).

11. The short-circuiting device (14) according to claim 10, wherein the retracting mechanism (34) comprises at least one spring.

12. The short-circuiting device (14) according to any previous claims, wherein the actuating element (30) is an armature of a Thomson actuator (26) and the actuating mechanism (28) is a Thomson coil of the Thomson actuator (26).

13. The short-circuiting device (14) according to any previous claims, where the stationary electrode (20) and the moveable electrode (22) are placed in a sealed chamber (18), preferably a vacuumized chamber.

14. An electrical power system arrangement (10) comprising the short-circuiting device (14) according to any previous claim.

15. The electrical power system arrangement (10) according to claim 14, wherein the arrangement is a part of a direct current circuit breaker.

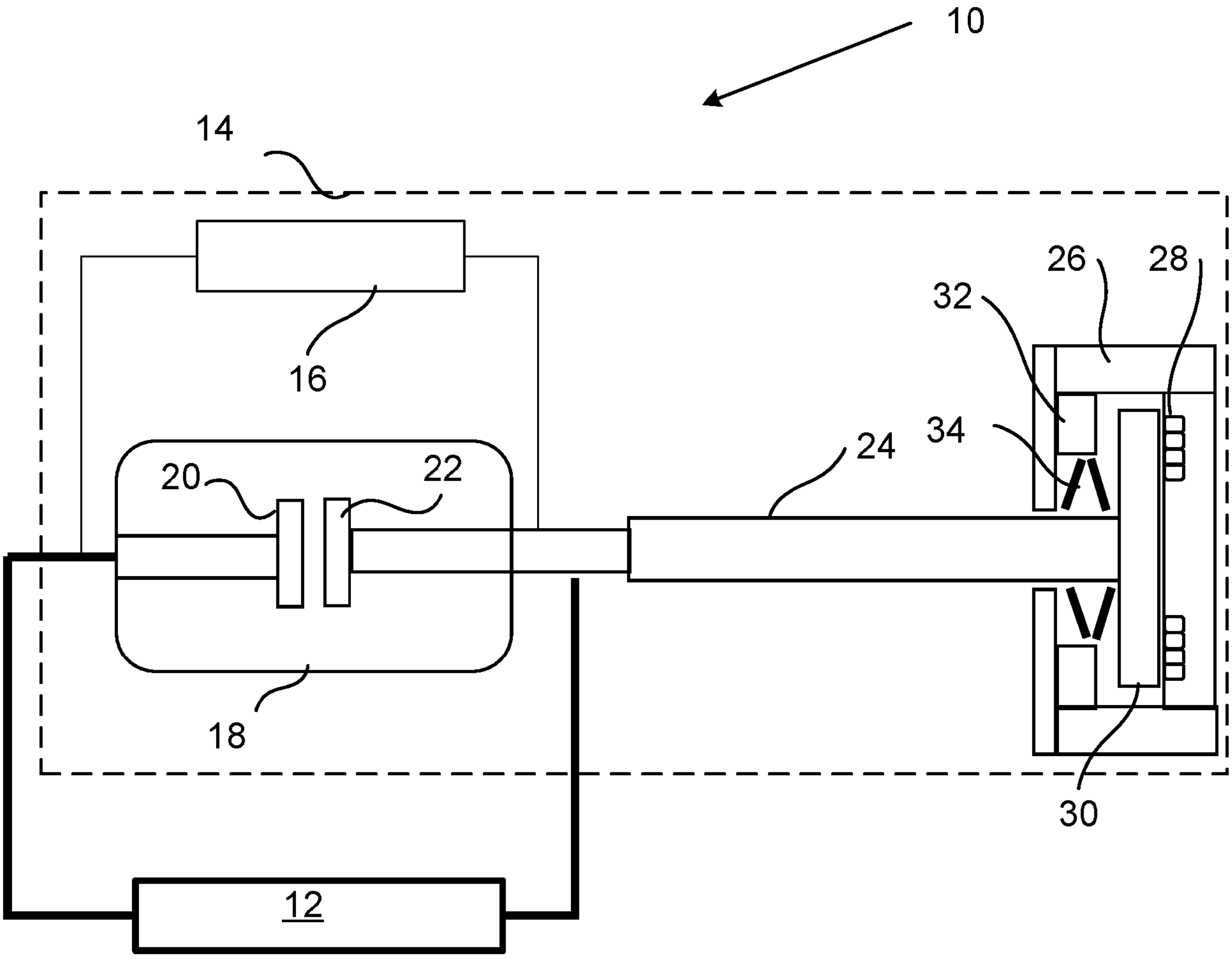


Fig. 1

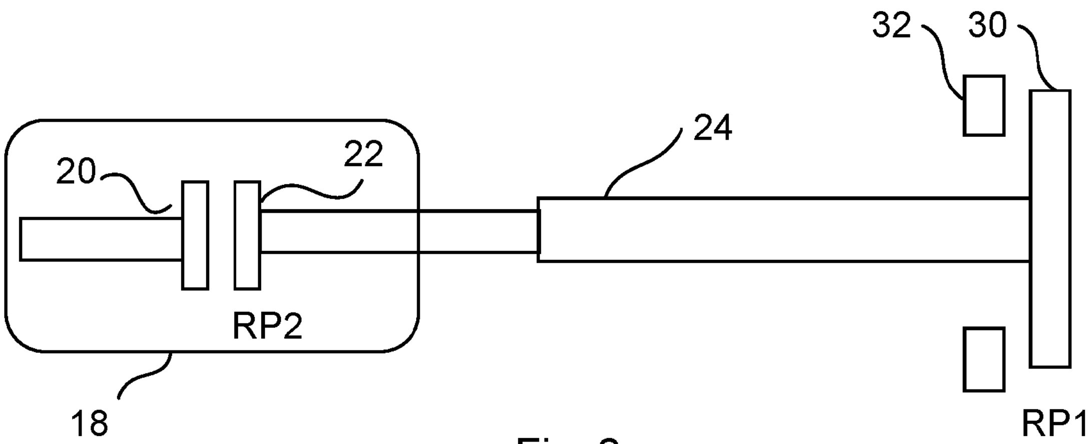


Fig. 2

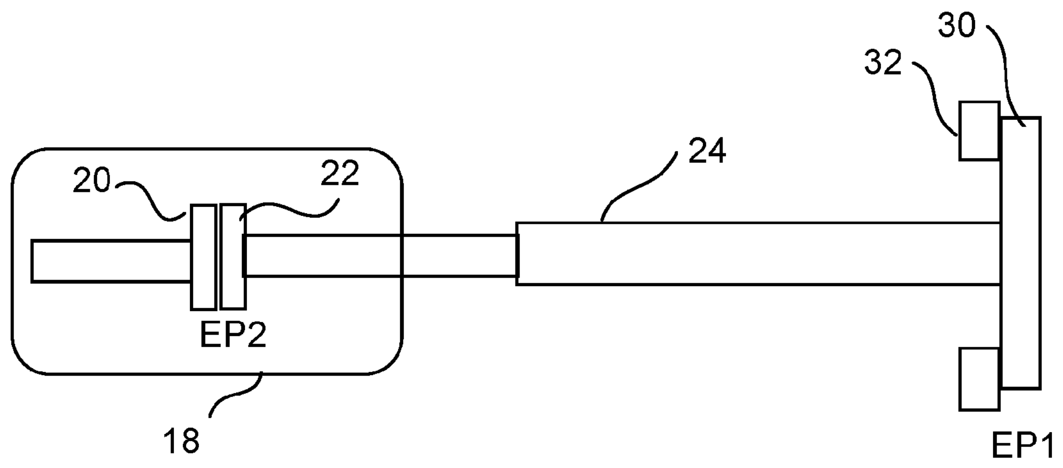
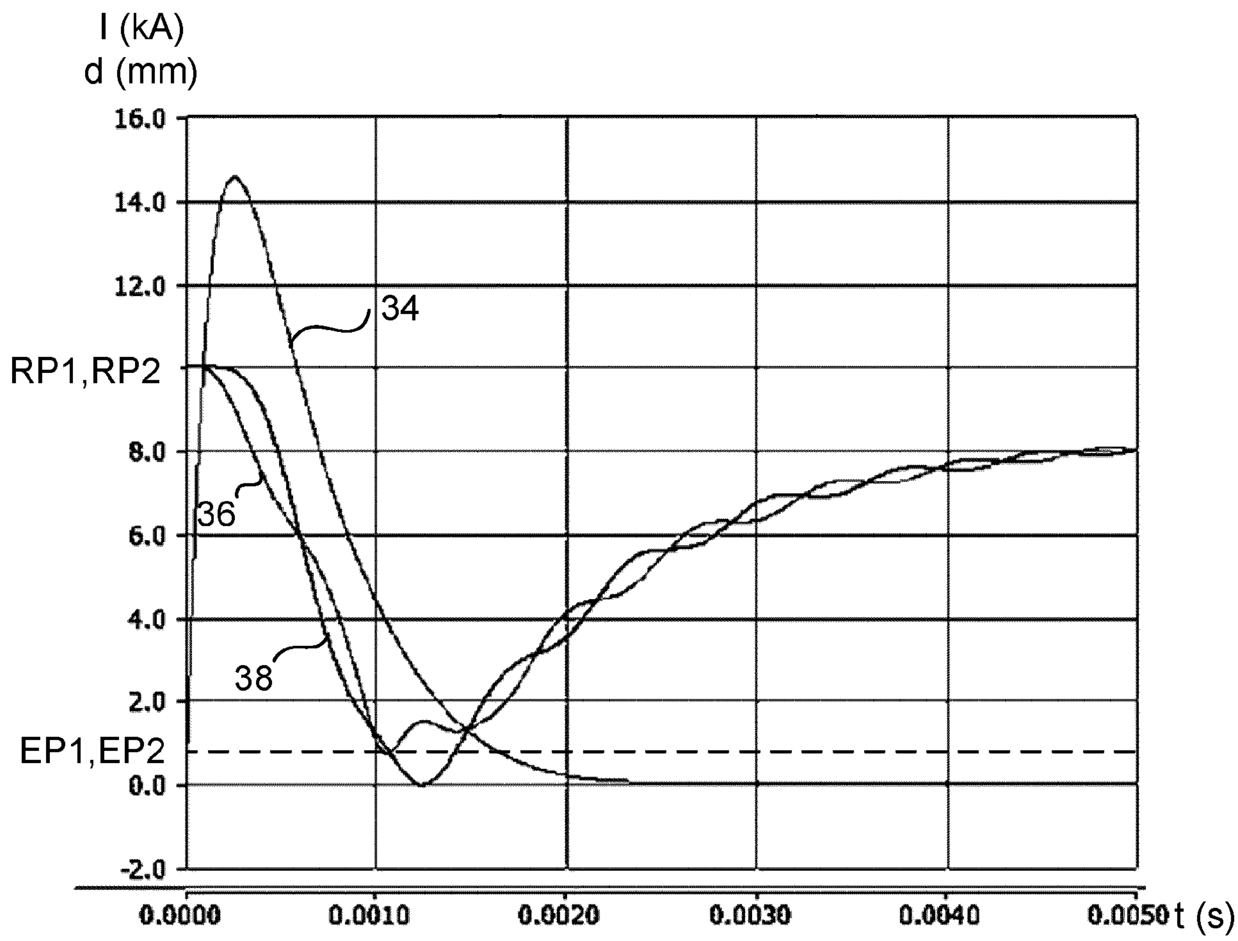

30
32
24
20
22
EP2
18
EP1

Fig. 3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t (s)

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 21 18 9115

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H01H
H01T
H05C

1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	27 January 2022	Arenz, Rainer

CATEGORY OF CITED DOCUMENTS

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