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(54) **Low voltage circuit breaker**

(57) A low voltage circuit breaker (1) comprising a case which contains at least one fixed contact (2) electrically connected to a terminal which is suitable for connection with an electric circuit (3), a movable conductive arm (4) provided with at least one contact piece (5), and actuating means (10) which are operatively connected to the movable conductive arm (4) and supply the ener-

gy for moving it, characterized in that said actuating means (10) comprise a piezoelectric motor (11) which is mechanically linked to said movable conductive arm (4); and a command and control unit (30) which, following an intervention command, drives said piezoelectric motor (11) so that it actuates the movable conductive arm (4) and allows electrical coupling/uncoupling of said contact piece (5) with respect to said fixed contact (2).

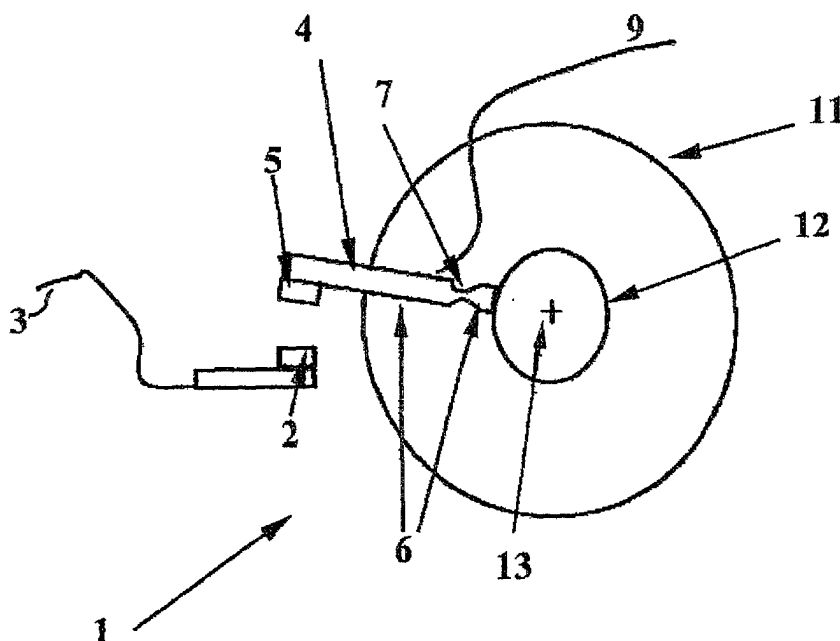


Figure 2

EP 1 280 177 A1

Description

[0001] The present invention relates to a low-voltage circuit breaker, i.e. a circuit breaker for applications with operating voltages up to 1000 Volt.

[0002] It is well-known in the art that in industrial low-voltage electric systems in which high currents and therefore high power levels are involved, specific devices, commonly indicated as power circuit breakers, are normally used. These power circuit breakers operate with nominal currents varying over a wide range, and are devised to provide some performances which are essential for ensuring the correct operation of the electric power supply circuit that they protect, and of the loads connected thereto. For example, they protect the loads from abnormal events caused by malfunctions related to short circuits or due to overloads, by automatically opening said power supply circuit; they ensure that the nominal current for the various connected users is actually equal to the required one, et cetera.

[0003] Currently, there are several constructive solutions for low-voltage power circuit breakers; among these solutions, the most commonly one foresees that coupling/uncoupling manoeuvres between movable and fixed contacts with consequent opening/closure of the circuit, occur by using appropriate actuation devices of the mechanical type. In particular, said mechanical devices exploit the energy stored in appropriate preloaded-springs for actuating a kinematic chain which is operatively connected to the moving contacts and causes their coupling/uncoupling with the corresponding fixed contacts.

[0004] At present, these known actuation devices, although they allow to perform the functions required in a quite satisfying way, still present some drawbacks and disadvantages.

[0005] In particular, the kinematic chains of the prior art have a very large number of components, are mechanically complex and inherently complicated, thus rendering the whole circuit breaker quite bulky, heavy and cumbersome, and reducing its overall reliability; in addition, the amount of mechanical energy that the actuating elements must provide is proportional to the various levels of electrical performance of the circuit breaker in which they are used, for example breaking capacity for short circuits, nominal current, et cetera, and requires long and complicated testing and calibration operations.

[0006] Moreover, in the closed position, the pressure exerted by each movable contact on the corresponding fixed contact must be adequate and strong enough in order to have a correct electrical contact between the parts, to compensate uneven ageing of the contacts, and to avoid that possible electrodynamic forces cause undesired uncoupling during functioning; as a consequence, it is usually necessary to provide the kinematic chain with a mechanical block and to use additional contact-holding springs.

[0007] These aspects are particularly important in those applications in which the short-circuit current can reach very high level. In these cases, the energy stored in the preloaded springs may result insufficient for moving the movable contacts at an adequate speed; therefore, in order to improve the interruption capacity of the circuit breaker, the solution generally adopted foresees to double the fixed and movable contacts of each phase, so as the current may be interrupted in two different parts of the pole, which are electrically connected in series to each other. With this solution, a two arm contact lever, for example of the rotary or fork type, is used; this lever is fixed to a rotary switching bar by means of an articulated connection, and requires the use of additional springs so as to give an uniform and correct distribution of the contact pressure between the contact surfaces of each phase, and to compensate non-homogeneous wear of the contact themselves. This solution clearly contributes to increase the complexity of the circuit breaker, as well as the manufacturing and assembly costs.

[0008] The aim of the present invention is to realize a low voltage circuit breaker which allows to overcome the above mentioned drawbacks and disadvantages, and in particular, which has a simplified structure in comparison with known circuit breakers and ensures, at the same time, optimised performances.

[0009] Within the scope of this aim, an object of the present invention is to realize a low-voltage circuit breaker in which the constructive architecture of the actuating system is considerably less complicated and requires a reduced number of components with respect to known circuit breakers.

[0010] Another object of the present invention is to realize a low voltage circuit breaker which allows to execute opening/closing operations in an easier and more controlled way with respect to known circuit breakers, and whose reliability is improved.

[0011] A further object of the present invention is to realize a low voltage circuit breaker which allows to reduce the manufacturing and assembling costs, as well as maintenance interventions required during its life.

[0012] Another object of the present invention is to realize a low voltage circuit breaker which is highly reliable, relatively easy to manufacture and at competitive costs.

[0013] This aim, these objects and others which will become apparent hereinafter are achieved by a low voltage circuit breaker comprising a case which contains at least one fixed contact electrically connected to a terminal which is suitable for connection with an electric circuit, a movable conductive arm provided with at least one contact piece, and actuating means which are operatively connected to the movable conductive arm and supply the energy for moving it, characterized in that said actuating means comprise:

- a piezoelectric motor which is mechanically linked

- to said movable conductive arm; and
- a command and control unit which, following an intervention command, drives said piezoelectric motor so that it actuates the movable conductive arm and allows electrical coupling/uncoupling of said contact piece with respect to said fixed contact.

[0014] In this way, the structure of the circuit breaker, and in particular of its actuating system, is drastically simplified, thus allowing the reduction of the manufacturing and assembling costs, and ensuring at the same time the execution of the electrical operations in an easier, optimised and more controlled way.

[0015] Further characteristics and advantages of the invention will become apparent from the description of preferred but not exclusive embodiments of a low voltage circuit breaker according to the invention, illustrated only by way of non-limitative example in the accompanying drawings, wherein:

figure 1 is a block diagram of the low voltage circuit breaker according to the invention;

figure 2 illustrates a schematic frontal view of the low voltage circuit breaker according to the invention, with a single-contact piece rotating arm;

figure 3 illustrates a schematic frontal view of the low voltage circuit breaker according to the invention, with a double-contact pieces rotating arm;

figure 4 is an exploded view of a rotating piezoelectric motor which can be used in the low voltage circuit breaker according to the invention;

figure 5 is a plan view of a linear piezoelectric motor used in the low voltage circuit breaker according to an alternative embodiment of the invention.

[0016] With reference to the figures, the low voltage circuit breaker according to the invention, indicated by the reference numeral 1, comprises a case (not shown), for example of the moulded type, which contains at least one fixed contact 2; the fixed contact 2 is electrically connected to a terminal of the circuit breaker which is connected to an electric circuit 3 in which the circuit breaker itself is inserted. Inside the case, there are also a movable arm 4 made of conductive material, which is provided with at least one contact piece 5, and actuating means 10 which are operatively connected to the movable conductive arm 4 and supply the energy for moving it; further the conductive arm 4 is operatively connected to the circuit 3 by means of conducting means, for example a flexible braid 9. The constructive embodiment of the case, the positioning of the fixed contact 2 and of the connecting terminal, as well as the electrical connections among the various elements, are well known in the art and therefore they will not be described in detail herein.

[0017] Advantageously, in the circuit breaker according to the invention, the actuating means 10 comprise a piezoelectric motor 11 - i.e. a motor which comprises

piezoelectric elements and whose operations are obtained by their electric excitement - which is mechanically linked to the movable conductive arm 4; further, the actuating means 10 comprise a command and control unit 30, preferably of electronic and programmable type, which, following an intervention command, drives the piezoelectric motor 11 so that it actuates the movable conductive arm 4 and allows electrical coupling/uncoupling of the contact piece 5 with respect to the corresponding contact piece of the fixed contact 2, in the way which will be described hereinafter; the intervention command can be provided for example, by a sensor which detects an electrical fault in the circuit, or by an operator who acts on a push button, or on an actuation lever of the circuit breaker.

[0018] Preferably, in the circuit breaker 1 according to the invention, the piezoelectric motor 11 is an ultrasonic self-braking motor, i.e. a motor in which braking during manoeuvre is obtained thanks to the intrinsic structure of the motor itself, without using additional braking devices, and in which the exciting signals are in the ultrasonic frequency range.

[0019] The use of a self-braking ultrasonic piezoelectric motor, allows to realize a circuit breaker whose operations are executed in an easier and more controllable way, with negligible levels of electric power consumption required for moving the movable equipment and, above all, for keeping the circuit breaker in the desired position. Further, the ultrasonic piezoelectric motor allows to have a high torque-levels/weight ratio at low speed and relatively reduced response times, and to perform substantially noise-free operations.

[0020] According to a particularly preferred embodiment, the piezoelectric motor 11 is an ultrasonic rotating self-braking motor, and the actuating means 10 further comprise a rotary switching bar 12 which is mechanically connected to the movable conductive arm 4; as illustrated in figure 2, the movable conductive arm 4 is mounted, and in particular directly fulcrumed on the rotary switching bar 12 transversal to the rotation axis 13 of the bar 12 itself, with the contact piece 5 positioned at its end portion. In this way, the use of interconnecting elements is avoided, according to a solution which is functionally effective and structurally simple.

[0021] Alternatively, if needed, it is possible to use an insulating element interposed between the bar 12 and the arm 4.

[0022] Advantageously, the body of the movable contact arm 4 can be realized with at least two substantially rigid portions 6 interconnected by means of a substantially flexible element 7, such as a flexible pivot obtainable by reducing the thickness of a portion of the arm 4 with respect to the surrounding parts; in this way, the movable conductive arm 4 is provided with a structural elasticity and, thanks also to the action of the motor which keeps the arm in position and pushes it against the fixed contact, the contact piece 5 is adequately pressed on the corresponding fixed contact 2. In this

manner, it is possible to compensate ageing and non-homogeneous wear of the contact surfaces 5 and 2, to guarantee adequate electric contact between them, and definitely to increase the useful life of the circuit breaker. Alternatively, the body of the arm 4 can be realized in a single, substantially uniform body.

[0023] Further, in addition to, or as an alternative of the solution adopted for the conductive arm 4, also the structure of the fixed contact 2 may be realized by means of two substantially rigid portions interconnected by a substantially flexible element, such as a flexible pivot obtainable as described above.

[0024] One example of a rotating self-braking piezoelectric motor, particularly suitable for application in the circuit breaker according to the invention, is shown in figure 4.

[0025] As illustrated in this figure, the piezoelectric motor 11 comprises a stator unit and a rotor unit; the rotor unit comprises a metallic disc 15 which is structurally integral with the rotary switching bar 12; in this way, the rotary switching bar 12 constitutes the shaft of the motor 11 itself, according to a solution constructively simple and functionally effective. Alternatively, it would be possible to use as a rotary switching bar, an additional bar connected to the shaft of the motor 11. Further, a bearing 16 is associated to the rotary bar 12 in order to allow its rotation.

[0026] In turn, the stator unit comprises a flange 17 to which the bearing 16 is connected, and an annular elastic disc 18 which is also connected to the flange 17 and has a base plate 19 and a teeth-shaped ring 20 which protrudes transversally, in particular in a perpendicular direction, from the base plate 19; according to the applications and/or specific needs, the teeth-shaped ring 20 can be positioned at the external edge of the base plate 19, as indicated in figure 4, or along an internal circumference. The stator unit also comprises at least one layer of piezoelectric material 21, for example of the PZT type, which is fixed, for instance glued, on the elastic disc 18; in particular, the layer of piezoelectric material 21 comprises a plurality of sectors 22 which are electrically excited by the command signals supplied by the command and control unit 30, for the purpose and in the way which will be described hereinafter.

[0027] The motor 11 further comprises friction means 23, for example constituted by a layer of rubber, which are positioned interposed between the metallic disc 15 and the teeth-shaped ring 20, and retaining means; for example, the retaining means can be constituted by a metallic elastic body 24 which is positioned on a face of the metallic disc 15 opposite to the annular elastic disc 18, and a nut 25 which is screwed to a threaded end of the bar 12 and allows keeping the various elements of the rotor packed on the stator.

[0028] Damping means 26, constituted for example by a ring-shaped layer of rubber, are interposed between the retaining means and the face of the metallic disc 15 opposite to the annular elastic disc 18, so as to

dampen undesired vibrations of the motor.

[0029] In turn, as indicated in figure 1, the command and control unit 30 comprises sensing means 31 suitable for detecting a possible fault in the electric circuit, and control means 32 which supply electric signals for driving the motor 11; further, the unit 30 comprises an auxiliary energy-accumulation unit 33, constituted for example by one or more capacitors, for the purpose which will become more apparent hereinafter.

[0030] It will be now described the operative functioning of the circuit breaker according to the invention.

[0031] Starting from the closed position, if the sensing means 31 detect a possible fault on the electric circuit 3, they output a signal to the control means 32; in turn, the control means 32 supply electric signals, i.e. voltage signals to the motor 11; the electric signals needed may be provided either by the circuit 3 or by a pre-stored power supply unit. Clearly, the intervention signal may be also sent to the control means 32 by an operator who acts on the circuit breaker remotely or directly, so as to interrupt the current flowing in the circuit, for example for performing maintenance interventions.

[0032] More precisely, the electric signals are supplied to the piezoelectric sectors 22 and cause their electrical excitation; in particular, when using a piezoelectric rotating motor, adjacent pairs of piezoelectric sectors 22 are alternatively polarised, i.e. two adjacent sectors are both polarised in a direction perpendicular to the sectors themselves and in opposite directions to each other, and are fed with ultrasonic voltage signals, which are, for instance, about 90°-phase shifted with respect to each other. As a consequence, the piezoelectric sectors 22 vibrate with a 90° phase-shift and the vibrations are transmitted to the annular elastic disc 18; in turn, the annular elastic disc 18 vibrates too and, thanks to the teeth of the ring 20, the small vibrations produced by the piezoelectric sectors are conveniently amplified. The composition of the two 90°-shifted vibrations brings to the generation of travelling waves along the ring 20; by means of the friction means 23, the movement is transmitted to the metallic disc 15 and thus, the rotor is dragged into rotation thanks to the friction action. In this manner, the rotary switching bar 12 is driven into rotation together with the movable conductive arm 4 operatively connected therewith, so as the movable contact piece 5 uncouples electrically from the corresponding fixed contact 2.

[0033] When the circuit breaker 1 has to be closed, it is sufficient to invert of 180° the phase of one of the two electric signals supplied to the piezoelectric sectors 22 which have the same polarisation; in this way, the rotor rotates in the opposite direction thus allowing the coupling of the contact piece 5 with the fixed contact 2. In this position, coupling between the contact surfaces is ensured by the holding torque of the motor, thus avoiding the need of additional brakes.

[0034] Advantageously, when re-closing the circuit breaker, if the fault detected by the sensing means 31

is still present on the circuit, the sensing means 31 output a signal to the control means 32 which, in this case, send a corresponding signal to the auxiliary energy-accumulation unit 33; in turn the unit 33 discharges and sends, in output, electric signals driving the motor 11. In this way, it is thus possible to perform the so-called "trip-free maneuver" in a simple and independent way from the main circuit.

[0035] The solutions above described can be easily implemented for different types of power low voltage circuit breakers; in particular, it is suitable for being used with circuit breakers of the current limiting type with double contacts for each phase.

[0036] An example of this type is schematically described in figure 3; as illustrated, the movable conductive arm 4 is provided with two contact pieces 5 which are positioned on opposite sides of the movable conductive arm 4 itself, at the corresponding end portions, and symmetrically to each other with respect to the rotation axis 13; correspondingly, there are two fixed contacts 2 which are also positioned substantially symmetric with respect to the rotation axis 13.

[0037] Alternatively, the double contact arm may be of the fork type.

[0038] Also in these cases, the body of the arm 4 can be advantageously realized with at least two substantially rigid portions 6 interconnected by means of a substantially flexible element 7, so as to have an elastic structure and compensate ageing and non-homogeneous wear of the contact surfaces 5 and 2, to guarantee adequate electric contact between them, and to increase the useful life of the circuit breaker.

[0039] Further, in case of multi-phase circuit breakers, inside the case there are provided, for each phase of the electric circuit 3, at least a first fixed contact 2 and a movable conductive arm 4 provided with a first contact piece 5. The arms 4 are connected to the bar 12 transversally to its rotation axis 13, and the bar 12 is actuated, together with the arms 4, by a single piezoelectric motor 11, in the manner previously described.

[0040] With this solution, by suitably programming the command unit 30, coupling/uncoupling of the contact pieces 5 with the corresponding fixed contacts 2 can be realized synchronously among the various phases.

[0041] According to an alternative embodiment, it might be possible to use a linear piezoelectric motor 11. With this solution, as schematically shown in figure 5, the piezoelectric motor 11 comprises a structural frame 29; two stacks of piezoelectric sectors 22 which are positioned in an elliptic metallic frame 27 which gives the necessary pre-stress to the stacks themselves and amplifies their displacements under excitation; a metallic mass 28 is interposed between the two stacks 22. According to this embodiment, the movable arm 4 can be directly coupled to the motor 11, or it may be mounted on the switching bar 12, as previously described, and mechanically linked to the motor by the interposition of coupling means; these coupling means, for example of

the pinion-rack type, are suitable to transform the linear movement of the motor 11 into a rotating movement of the switching bar 12.

[0042] In this configuration, adjacent layers of piezoelectric elements constituting the stacks 22, are alternatively polarised, i.e. two adjacent layers are both polarised in a direction perpendicular to the layers themselves and in opposite directions to each other, indicated by the arrows 34; during operations, the two stacks 22 are fed each with an ultrasonic voltage signal, the two signals being for instance about 45°-phase shifted with respect to each other. Thus the piezoelectric stacks 22 deform and cause the vibration of the mass 28 in the direction of the arrows 34; as a consequence, the frame 27 vibrates and the composition of its vibrations brings to the generation of an elliptic motion and definitely to a translation of its portion 35; correspondingly, the movable arm 4, directly connected to the portion 35 translates together with the frame 27; if instead coupling means are used for connecting the arm 4 to the portion 35, the translation is transformed into a rotation of the switching bar 12. Also in this case, in order to invert the movement, it is sufficient to invert of 90° the phase of one of the two electric signals supplied to the piezoelectric sectors 22.

[0043] In practice, it has been found that the low voltage circuit breaker 1 fully achieves the intended aim and objects, giving several advantages with respect to the known art.

[0044] In fact, in addition to the advantages previously mentioned, the use of the actuating means as described, and specifically of the piezoelectric motor 11, allows to simplify the structure of the whole circuit breaker, and in particular to drastically reduce the mechanical equipment, thus realizing a circuit breaker which is smaller and lighter, has a reduced number of components, and with an improved reliability. Accordingly, the manufacturing and assembling costs, the relative calibration operations, and the maintenance interventions are considerably reduced.

[0045] The low voltage circuit breaker thus conceived is susceptible of numerous modifications and variations, all of which are within the scope of the inventive concept. All the details may also be replaced with other technically equivalent elements. In practice, the materials used, so long as they are compatible with the specific use, as well as the dimensions, may be any according to the requirements and to the state of the art.

Claims

1. A low voltage circuit breaker (1) comprising a case which contains at least one fixed contact (2) electrically connected to a terminal which is suitable for connection with an electric circuit (3), a movable conductive arm (4) provided with at least one contact piece (5), and actuating means (10) which are operatively connected to the movable conductive

arm (4) and supply the energy for moving it, **characterized in that** said actuating means (10) comprise:

- a piezoelectric motor (11) which is mechanically linked to said movable conductive arm (4); and
 - a command and control unit (30) which, following an intervention command, drives said piezoelectric motor (11) so that it actuates the movable conductive arm (4) and allows electrical coupling/uncoupling of said contact piece (5) with respect to said fixed contact (2).
2. A low voltage circuit breaker (1) according to claim 1, **characterized in that** said piezoelectric motor (11) is a self-braking ultrasonic piezoelectric motor.
 3. A low voltage circuit breaker (1) according to claim 2, **characterized in that** said self-braking ultrasonic piezoelectric motor (11) is a rotating piezoelectric motor and **in that** said actuating means (10) further comprise a rotary switching bar (12) which is mechanically connected to said movable conductive arm (4) and constitutes the shaft of the rotating piezoelectric motor (11) itself.
 4. A low voltage circuit breaker (1) according to claim 3, **characterized in that** said movable conductive arm (4) is directly fulcrumed on said rotary switching bar (12), transversal to its rotation axis (13).
 5. A low voltage circuit breaker (1) according to one or more of the preceding claims **characterized in that** said movable conductive arm (4) is directly fulcrumed on said rotary switching bar (12), transversal to its rotation axis (13), and is provided with two contact pieces (5) which are positioned on opposite sides of the movable conductive arm (4) itself, at the corresponding end portions, and symmetrically to each other with respect to the rotation axis (13), said contact pieces (5) being suitable for electrically coupling with two corresponding fixed contacts (2).
 6. A low voltage circuit breaker (1) according to claim 2 **characterized in that** said self-braking ultrasonic piezoelectric motor (11) is a linear piezoelectric motor.
 7. A low voltage circuit breaker (1) according to claim 6, **characterized in that** said actuating means (10) comprise a rotary switching bar (12) which is mechanically connected to said movable conductive arm (4), and coupling means which are operatively connected to said rotary switching bar (12) and to said linear piezoelectric motor (11) respectively, said coupling means being suitable to transform the linear movement of the motor (11) into a rotating

movement of the switching bar (12).

8. A low voltage circuit breaker (1) according to one or more of the preceding claims **characterized in that** said command and control unit (30) comprises:
 - sensing means (31) suitable for detecting a fault in the electric circuit;
 - control means (32) which, following a fault detected by said sensing means (31), supply electric signals driving said motor (11).
9. A low voltage circuit breaker (1) according to claim 8 **characterized in that** said command and control unit (30) further comprises an auxiliary energy-accumulation unit (33) which, following a fault detected by said sensing means (31), receives in input a delivering signal by said control electronic means (32) and supplies, in output, electric driving signals to said motor (10).
10. A low voltage circuit breaker (1) according to one or more of the preceding claims **characterized in that** said movable contact arm (4) comprises at least two substantially rigid portions (6) which are interconnected by means of a substantially flexible element (7).

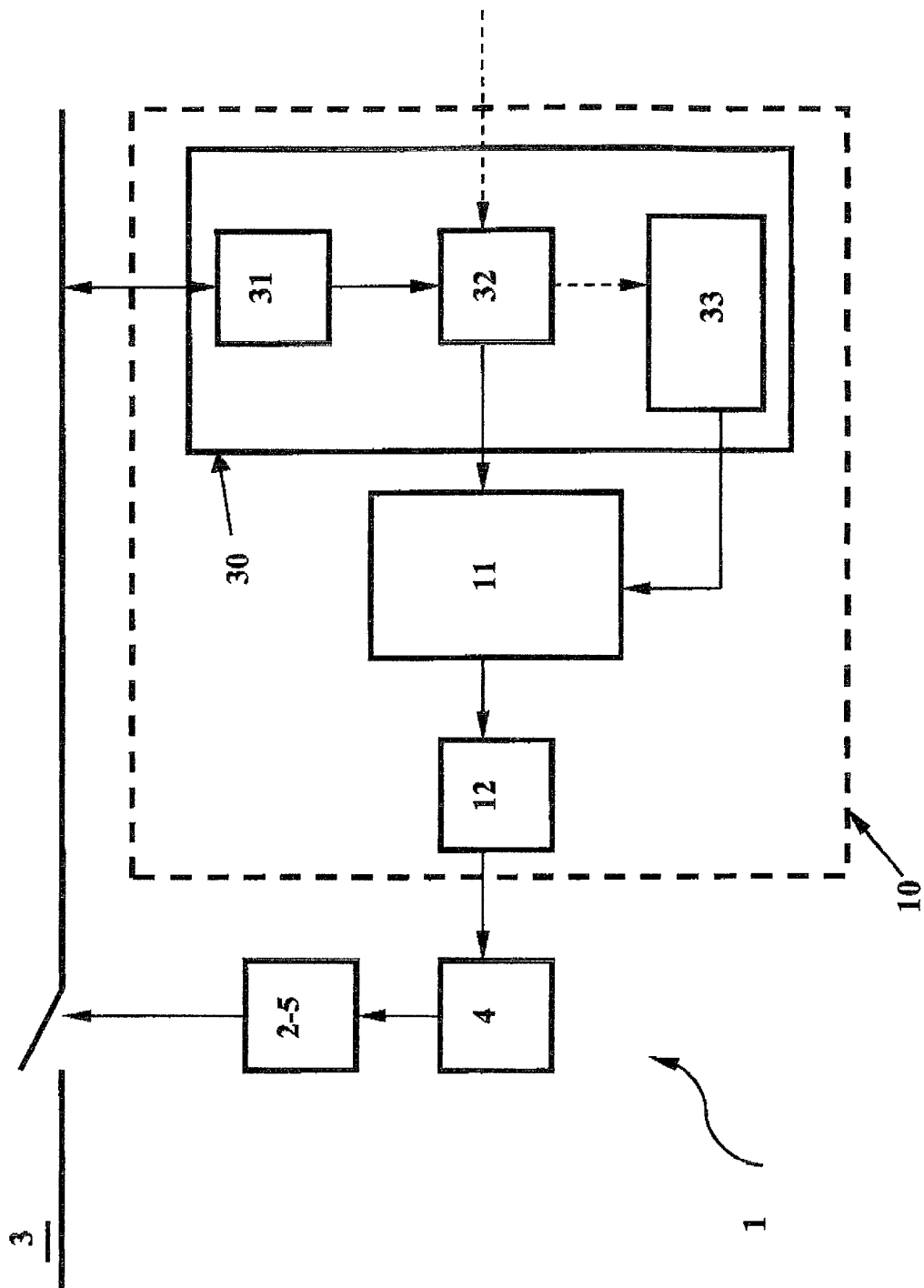


Figure 1

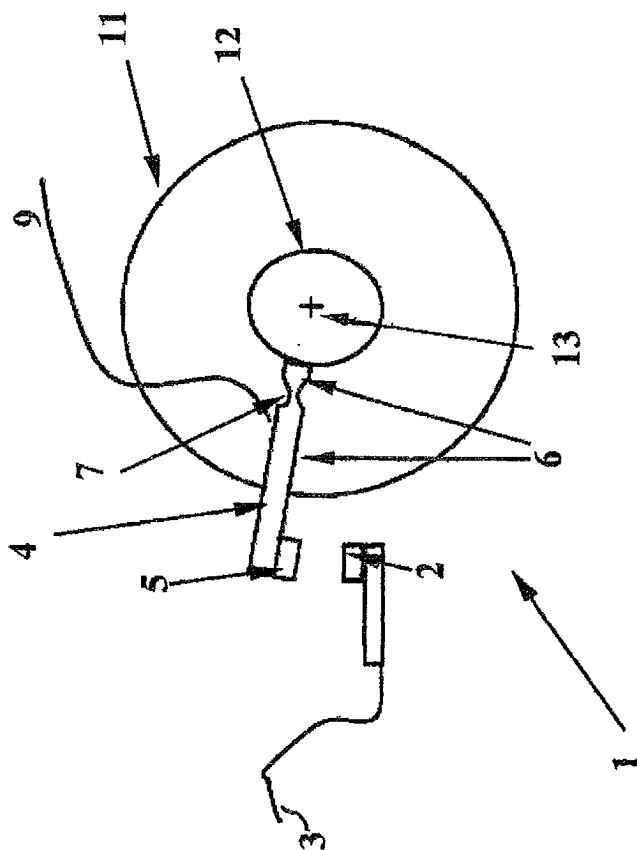


Figure 2

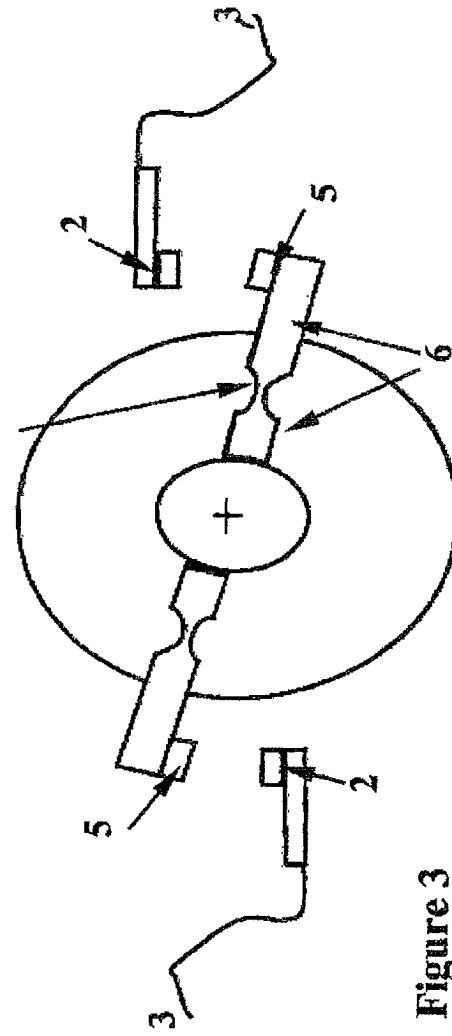


Figure 3

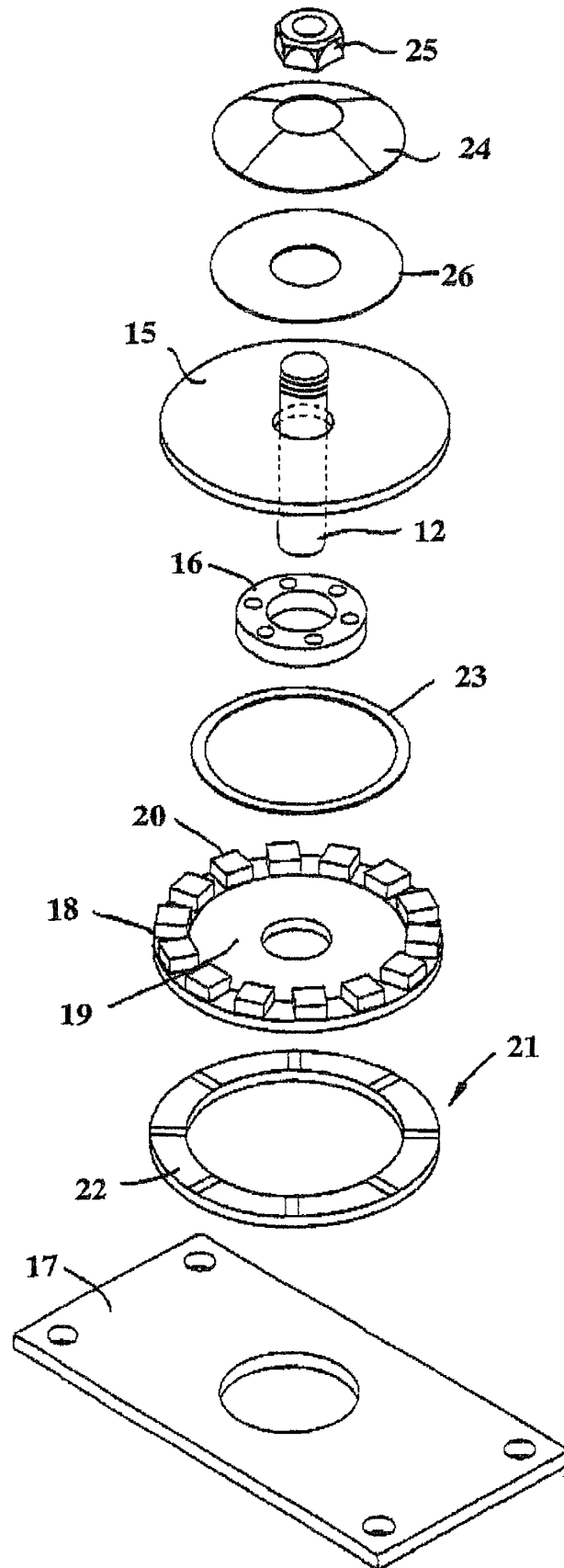


Figure 4

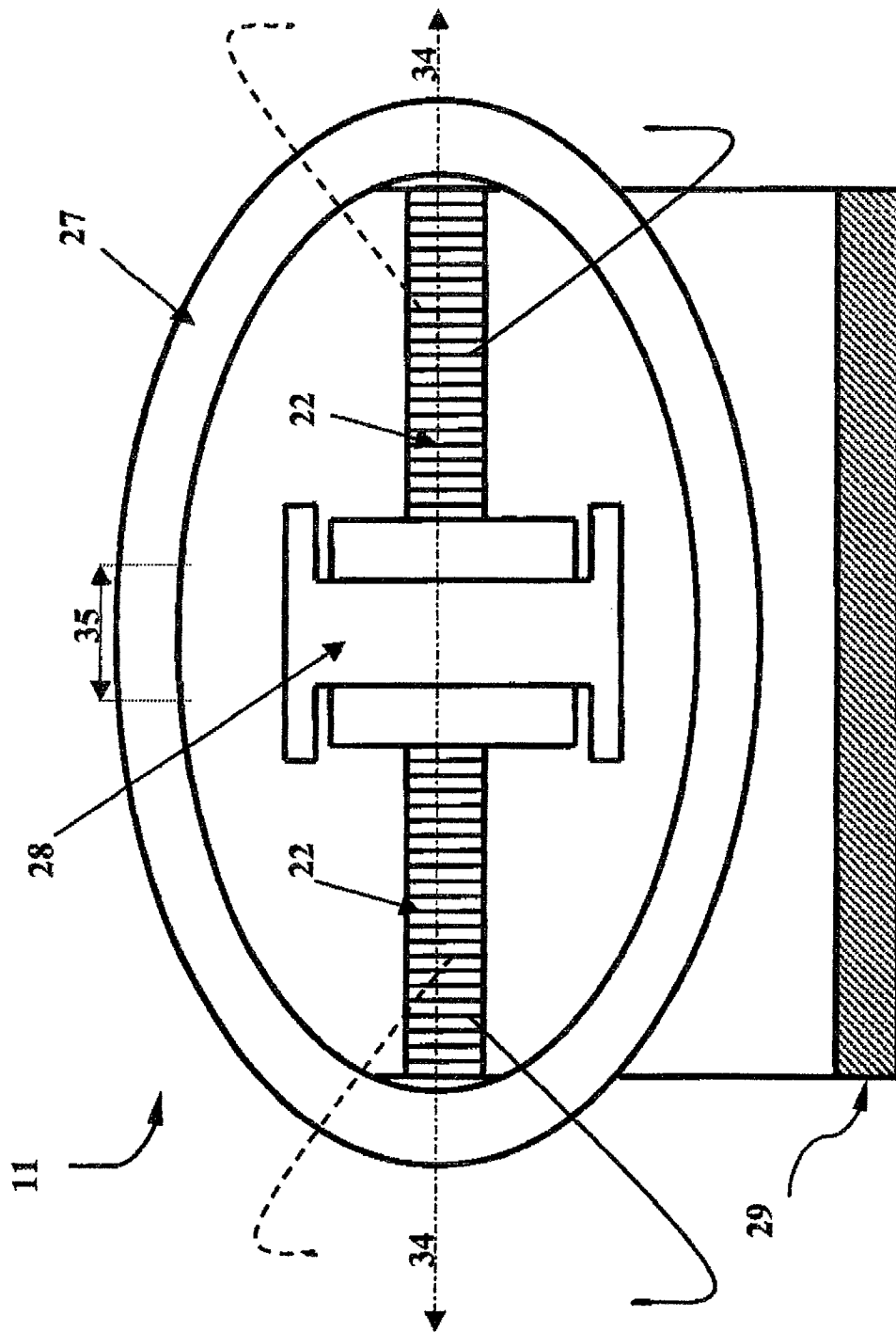


Figure 5



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EUROPEAN SEARCH REPORT

Application Number
EP 01 20 2800

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
THE HAGUE		9 January 2002	Libberecht, L
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EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 01 20 2800

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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