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(54) SYSTEMS OF SWITCHING CONTACTS WITH SELF-COMPENSATION OF HOLM'S REPULSION AND SWITCHING DEVICES COMPRISING SAME

(57) A contact system for a switching device, comprising: a first contact adapted to receive an input current from an input terminal; and a second contact adapted to receive the input current from the first contact; wherein the first contact comprises an input conductive section configured to provide an incoming current path for transporting the input current, wherein the second contact comprises a plurality of second conductive sections configured to provide an outgoing current path for transporting the current received from the first contact towards an output terminal, and wherein one of the plurality of second conductive sections is arranged adjacent to the input conductive section to provide an output conductive section in which current received from the first contact is transported in the same direction as the current direction along the incoming current path in the input conductive section. It is also provided a switching device comprising the contact system.

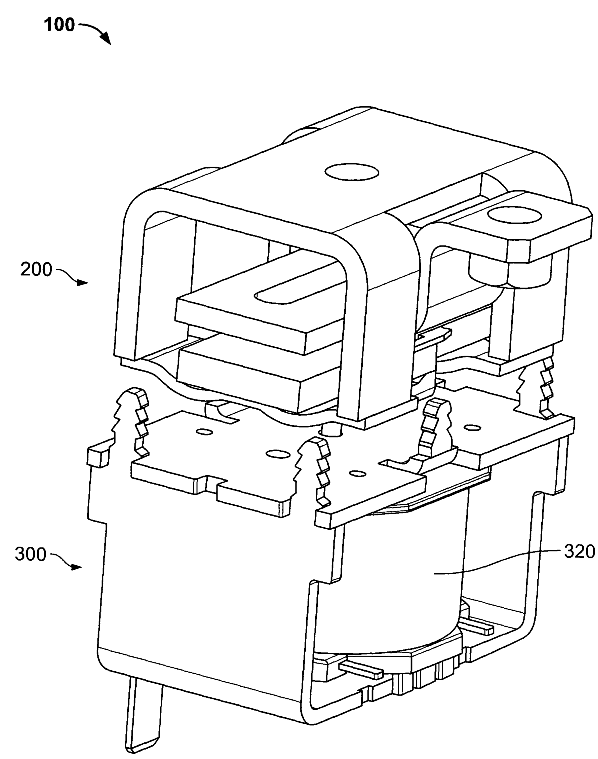

Fig. 1

EP 4 177 918 A1

Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates to contacts for switching devices used in the protection of electrical equipment against high current discharges and/or overload events, such as electromagnetic contactors and relays, and more specifically, to a system of contacts that compensates for the repulsive Holm forces generated between contacts and to switching devices comprising the contact system.

BACKGROUND OF THE INVENTION

[0002] Electromagnetic switching devices, such as relays and contactors, are commonly used in association with power equipment and circuits of industrial plants for protecting such equipment from overloads and/or high current discharges. In particular, recent developments towards more powerful power equipment, such as batteries for electrical vehicles, led to a demand for relays and/or contactors capable of providing reliable protection against high current discharges, for e.g. in the order of 15000 Ampere (15 kA) or higher.

[0003] Conventional relays and contactors are commonly switched between closed and open states via contact systems that are operated to connect/disconnect a load to/from a power source. Therefore, the switching reliability of such relays and contactors is closely related with the underlying system of switching contacts. In general, common contact systems include a stationary contact, which is fixed to the relay or contactor body, and a movable contact which can be moved with respect to the stationary contact for switching the contact system (and the relay or contactor) between open and closed states. Under normal operating conditions (i.e. in the absence of overloads and/or high discharge currents) the stationary and movable contacts are maintained in mechanical contact by the contact forces generated with an internal magnet or electromagnetic coil of a magnetic driving system included in the relay or contactor. In case of an overcurrent event, the internal magnet or electromagnetic coil is de-energized and the contact system opens.

[0004] However, it is a well-known phenomenon that the current across the stationary and movable contacts generates repulsive forces, often referred to as Holm forces, which tend to pull the contacts apart. At currents above a certain level, the repulsive Holm forces become stronger than the total contact force that keeps the contact system closed and will force the contact system to open. Thus, the current level above which the contact system opens depends on the interplay between the total attractive contact force, which includes the force applied by the internal magnetic coil, and the intensity of the repulsive forces generated by the intensity of the discharge current across the contacts.

[0005] In addition, as the generated repulsive forces increase with the intensity of the current flowing across the closed contacts, the speed with which the moving and stationary contacts are pulled apart also increases with the discharge current. This effect increases the contact system responsivity but may result in the moving and stationary contacts being so strongly pulled apart at high discharge currents that the contact system will be partially or totally destroyed. As a result, the relay or contactor will become inoperable for interrupting future overload events and require replacement. In particular, the Holms force can be very strong at high current discharges of 15 kA or higher. This problem requires that contact forces need to be increased to prevent that the contact system and respective relay or contact collapses under high overcurrent conditions.

[0006] The negative effect of the repulsive Holm forces on the contact system reliability could be counteracted by increasing the coil of the internal magnetic driving system so as to generate contact forces sufficiently strong to compensate the repulsive Holm forces at high currents. However, stronger coil motors are expensive and occupy a large volume. Furthermore, the power consumed by the internal coil would increase significantly in order to produce a contact force capable of compensating the repulsive forces generated at discharge currents of 15 kA or higher. Thus, the compensation of repulsive forces via an increase of the contact force generated by the internal coil is not an adequate solution for many applications which require contactors and/or relays of compact size and reduced energy consumption.

[0007] Consequently, there is a need for contact systems and switching devices capable of providing protection against high current discharges, in particular at currents of the order of 15 kA or higher, in a reliable manner and without compromising the compactness of the switching devices.

SUMMARY OF THE INVENTION

[0008] The present invention has been made in view of the shortcomings and disadvantages of the prior art, and an object thereof is to provide contact systems, and switching devices comprising the same, that are capable of withstanding high current discharges and having a compact size.

[0009] This object is solved by the subject matter of the independent claims. Particular embodiments of the present invention are subject matter of the dependent claims.

[0010] The present invention follows from recognizing that, in order for an electromagnetic contactor and/or relay to survive the pulling effect of the repulsive Holm forces generated at high current discharge events, e.g. of 15 kA or higher, additional attractive forces between contacts needs to be generated, i.e. aside from the attractive contact force generated by the internal magnetic driving system for maintaining the contacts closed under normal operating conditions.

[0011] The concept underlying the solution provided by the present invention lies in counteracting the repulsive Holm forces generated with an attractive Lorenz force which is produced between the stationary and movable contacts using the overcurrent itself. More specifically, the contact system provided by the present invention is so configured that the current received by one of the contacts is made to recirculate in the other contact along a specific path that makes the circulated current to be transported in a final section, at close proximity and in the same direction, as in the receiving contact. As a result, an attractive Lorentz force can be generated between contacts using the overcurrent itself and which is proportional to the intensity of the recirculated current. This attractive force supplements the contact force produced by the internal magnetic coil and allows to achieve an effective balance between the Holm repulsive force and the total attractive forces applied to the contacts.

[0012] As a result, the present invention allows producing smaller relays that can withstand a very high current discharge without collapsing. Namely, the present invention allows to fulfil the technical requirement of relays capable of providing a reliable overcurrent protection for current discharges of 15kA and able to meet future increases in overcurrent specifications.

[0013] Furthermore, the present invention also allows to counter-act the repulsive Holm forces based on a self-compensating effect that is produced by an unbalance of the currents that flow across the contact points between the stationary and movable contacts when the contact system is closed and which becomes particularly important for stationary and movable contacts having a compact size and a three-contact points geometry.

[0014] According to the present invention, it is provided a contact system for a switching device, comprising: a first contact adapted to receive an input current supplied to an input terminal of the contact system; and a second contact adapted to receive the input current from the first contact; wherein the first contact comprises an input conductive section configured to provide an incoming current path for transporting the input current, wherein the second contact comprises a plurality of second conductive sections configured to provide an outgoing current path for transporting the current received from the first contact towards an output terminal when the contact system is in a closed state, and wherein one of the plurality of second conductive sections is arranged adjacent to the input conductive section to provide an output conductive section in which current received by the second contact from the first contact is transported in the same direction as the current direction along the incoming current path in the input conductive section.

[0015] According to a further development, the output conductive section is substantially parallel to the input conductive section, and/or the plurality of second conductive sections are arranged in a same plane which is substantially parallel to the input conductive section.

[0016] According to a further development, the output conductive section is disposed adjacent the input conductive section in a direction of a relative linear movement between the first and second contacts.

[0017] According to a further development, the input conductive section and the output conductive section are configured such that a section of the incoming current path defined by the input conductive section and a section of the outgoing current path defined by the output conductive section are substantially orthogonal or non-parallel to a direction of a relative linear movement between the first and second contacts.

[0018] According to a further development, the input conductive section and the output conductive section have respective shapes that extend in a longitudinal direction of the incoming current path by at least a predetermined length at which an attractive Lorentz force between the input and output conductive sections compensates the repulsive Holm's force generated between the first and second contacts at a given intensity of input current, and preferably for an input current density of 15 kA or higher, wherein said longitudinal direction is substantially orthogonal or at least non-parallel to a direction of a relative linear movement between the first and second contacts.

[0019] According to a further development, the first contact further includes one or more interconnection branches which extend away from the input conductive section by a predetermined length so as to pass at least part of the input current from the input conductive section to one of the second conductive sections of the second contact other than the output conductive section, and wherein said second conductive section other than the output conductive section forms a recirculation conductive section configured to define a portion of the outgoing current path along which the current received from the one or more interconnection branches of the first contact is recirculated towards the output conductive section.

[0020] According to a further development, the recirculation conductive section is shaped with an extended section that is arranged substantially parallel to and opposed to the output conductive section.

[0021] According to a further development, the second contact includes a plurality of second contact islands arranged thereon in number and positions corresponding to a plurality of first contact islands arranged on the first contact the first and second contact islands providing a plurality of contact pairs via which electrical contact between the first and second contacts is established when the contact assembly is in the closed state; wherein at least one of the second contact islands is provided on said recirculation conductive section of the second contact at a respective position for electrically contacting to a corresponding first contact island provided in the interconnection branch of the first contact when the contact system is in the closed state; and/or wherein at least one of the second contact islands is provided on said output conductive section at a respective position for electrically contacting a corresponding first contact island provided on a central region of the input conductive section of the first contact when the contact system is in the closed state.

[0022] According to a further development, the second contact islands are provided in a number of three and each arranged in a position corresponding a position of a respective one of three first contact islands provided in the first contact,

> wherein a single second contact island is arranged on said output conductive section at a respective position for electrically contacting to a first contact island provided in the input conductive section of the first contact, and
>
> wherein a pair of the second contact islands is arranged at a central area of said recirculation conductive section of the second contact, a corresponding first contact island being arranged at an end portion of said one or more interconnection branches of the first contact so that the outgoing current paths for currents received by the recirculation conductive section of the second contact via said pair of second contact islands includes two half-loops that direct the received current towards the output conductive section.

[0023] According to a further development, the single first contact island is arranged on said input conductive section and positioned with its center at a first predetermined distance (d) from a center axis (C) of the first contact, the pair of first contact islands is arranged on an end portion of the interconnection branch, each first contact island of the pair being positioned in a symmetric manner with respect to a mirror plane, which contains the center axis (C) and the center of the first contact island arranged on said input conductive section, and such that a projection of their respective centers onto said mirror plane is distant by a second predetermined distance (d_B) from the center axis (C), and wherein the first and second predetermined distances (d_A, d_B) are the same and/or selected based on a width of the input conductive section and a width of the interconnection branch in a direction transverse to the center axis (C) so as to achieve an asymmetry on the distribution of currents paths along the first contact that results in a current imbalance of up to a predetermined imbalance threshold between the current passing from the first contact to the second contact across the single first contact island on the input conductive section and the currents passing from the first contact to the second contact across each of the first contact islands arranged on the interconnection branch, respectively.

[0024] According to a further development, the plurality of second conductive sections are configured to form the second contact with a closed loop geometry. The geometries of the first and second contacts are configured such that the interconnection branch of the first contact extends from a central region of the input conductive section along a direction transverse to a longitudinal length of the input conductive section and the center axis (C) to overlap said recirculation conductive section of the second contact, wherein the geometry of the first contact further includes two input end sections at respective end portions of the input conductive section to feed the input current to said input conductive section and which extend in a direction transverse to the longitudinal length of the input conductive section and the center axis (C), and wherein the input conductive section further includes two intermediate sections, one at each side of said central region and through which the current received from the input end section at the respective side is passed to the central region and/or the interconnection branch of the first contact, wherein the width and the position of each of said intermediate sections in the direction transverse to the longitudinal length of the input conductive section and the center axis is selected in combination with the position of the first contact islands arranged on the first contact so as to achieve an asymmetry on the distribution of currents paths along the first contact that results in said current imbalance of up to the predetermined imbalance threshold between the current passing from the first contact to the second contact across the first contact island on the input conductive section and the currents passing from the first contact to the second contact across each of the first contact islands arranged on the interconnection branch, respectively.

[0025] According to a further development, the predetermined imbalance threshold is 80% or below.

[0026] According to a further development, the plurality of second conductive sections is configured to form the second contact with a closed loop geometry, the geometries of the first and the second contacts being configured such that said interconnection branch of the first contact is provided as a pair of protrusions that respectively extend from a central region of the input conductive section in a direction transverse to a longitudinal length of the input conductive section to make electrical contact with the intermediate section of the second contact (220) and split the outgoing current paths in two half-loops between the intermediate section and the output terminal of the second contact.

[0027] According to a further development, the plurality of second conductive sections are configured to form the second contact with an open loop shape, the first and second contacts being configured such that the interconnection branch of the first contact is provided at an end section of the input conductive section to make electrical contact with said second conductive section other than the output conductive section at an end section of the open loop shape by a gap.

[0028] The present invention also provides a switching device for high current discharges, comprising the contact system and a magnetic driving system adapted to operate switching of the contact system between a closed state, at which the first and second contacts contact each other, and an open state at which the second contact is separated from the first contact.

[0029] According to a further development, the switching device is one of a electromagnetic relay and an electromagnetic contactor.

[0030] Thus, the present invention lies makes possible dealing with overcurrent protection without increasing the power consumed by the magnetic driving system. Further, as the additional attractive Lorentz forces are produced proportionally to the overcurrent intensity, an effective compensation of the repulsive forces can be reached at all times.

[0031] Further technical advantages of the present invention are an increase of shock resistance due to the additional attraction between contacts. This also results in an increased contact force and consequently, reduced contact resistance.

[0032] The accompanying drawings are incorporated into and form a part of the specification for the purpose of explaining the principles of the invention. The drawings are not to be construed as limiting the invention to only the illustrated and described examples of how the invention can be made and used.

BRIEF DESCRIPTION OF THE FIGURES

[0033] Further features and advantages will become apparent from the following and more detailed description of the invention as illustrated in the accompanying drawings, in which:

Fig. 1 is a schematic view of a switching device with a contact system according to the first embodiment of the present invention;

Fig. 2 is a schematic view of the contact system according to the first embodiment;

Fig. 3 is a further schematic view of the contact system shown in Fig. 2;

Fig. 4 is a schematic view showing first and second contacts of the contact system shown in Fig. 2, in an open state;

Fig. 5 is a schematic view of the first and second contacts of the contact system shown in Fig. 2, in a closed state, and showing the direction of current circulation in the first and second contacts as indicated by the arrows, in which the solid arrows and the dashed arrows illustrate the direction of the current circulation in the first contact and in the second contact, respectively;

Fig. 6 is a schematic view of a contact system according to a second embodiment of the present invention and where the direction of the current circulation in the first and second contacts of the contact system are illustrated by solid and dashed arrows, respectively;

Fig. 7 is a perspective view of a switching device having a contact system according to the third embodiment of the present invention (viewed from a top side which is the side of the input and output terminals of the contact system);

Fig. 8 is another perspective view of the switching device shown in Fig. 8 (viewed from a bottom side which the side of the terminals of an actuation coil of the contact system);

Fig. 9 is a perspective view (partially see-through) of the contact system according the third embodiment (viewed from a side of a driving shaft coupled to the contact system);

Fig. 10 is a simplified perspective view of the contact system shown in Fig. 9 in an open state;

Fig. 11 is a simplified side view of the contact system shown in Fig. 10 in the open state;

Fig. 12 is a simplified side view of the contact system shown in Fig. 10 in the closed state;

Fig. 13 is a perspective view of the contact system having a stationary contact and a movable contact according to the third embodiment (showing a top side of the contact system);

Fig. 14 is a bottom view of the movable contact and stationary contact shown in Fig. 13;

Fig. 15 is a top view of the stationary contact and movable contact shown in Fig. 13;

Fig. 16 is a perspective (see-through) view of the contact system shown in Fig. 13 that depicts the arrangement of contact islands on the stationary and movable contacts;

Fig. 17 is a perspective view of the movable contact shown in Fig. 16 (viewed from a side that faces the stationary contact in Fig. 16) and depicts in a simplified manner the direction of current flow in the movable contact;

Fig. 18 is a perspective view of the stationary contact shown in Fig. 16 (viewed from a side that faces the movable contact in Fig. 16) and depicts in a simplified manner the direction of current flow in the stationary contact;

Fig. 19 is a simplified side view of the contact system shown in Fig. 13 in the closed state and showing schematically the forces applied to the movable contact at a first stage where the contact island at side A is crossed by a higher current than each of the contact islands at side B, thereby causing an imbalance of the repulsive Holm's forces generated at sides A and B which is responsible for a stronger levitating effect at side A than at side B (without opening the contact system), and consequently, leads to a decrease of the contacts resistance at side B and an increase of the contact resistance of the contact island at side A; and

Fig. 20 shows the contact system at a second stage, subsequent to the first stage shown in Fig. 19, and in which the currents crossing each contact island at side B having increased due to the decrease of the contacts resistance at side B during the first stage, thereby causing an imbalance of the repulsive Holm's forces generated at sides A and B which is responsible for a stronger levitating effect at side B than at side A (without opening the contact system).

DETAILED DESCRIPTION OF THE INVENTION

[0034] The present invention will now be more fully described hereinafter with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown. The present invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that the disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

[0035] Fig. 1 shows a switching device 100 having a contact system 200 according to a first embodiment and a magnetic driving system 300 for driving the contact system 200.

[0036] The contact system 200 comprises first and second contacts 210, 220 which function as power contacts for connecting to a load (not shown), such as an electrical equipment (e.g. an automobile battery) or industrial equipment to be protected from high current discharges. The first and second contacts 210, 220 have a configuration that makes possible to generate an add-on Lorentz force between contacts by making the current input to the first contact 210 to flow over a circulating current path in the second contact 220, as it will be described below. The magnetic system 300 carries energizing terminals and an electromagnetic coil 320 which provides a contact force for maintaining the first and second contacts 210, 220 closed under normal operating conditions. In the present configuration, the contacts 210, 220 are of a normally-open contact type, so that they supply power to the load when the electromagnetic coil 320 is energized (closed state) and shut off the power supply to the load when the electromagnetic coil 320 is de-energized (open state).

[0037] The switching between open and closed states of the contact system 220 is associated with the first and second contacts 210, 220 being moved away from and towards each other, respectively, along a linear movement direction, for e.g. parallel to the Y-axis indicated in Fig. 2. In particular, the contact system 200 is so designed that, in operation, the second contact 220 remains fixed to an output terminal of the load (not shown) via a conductive protrusion 221 provided for this effect in the second contact 220 (stationary contact). On the other hand, the first contact 210 is configured to move towards to and away from the stationary contact 220 in the direction parallel to the Y-axis to close and open the contact system 200. For this purpose, the first contact 210 (hereinafter referred to as movable contact 210) is mounted on a support structure 230 which allows the linear displacement of the movable contact 210 along the Y-axis direction. More specifically, the support structure 230 includes a rigid shell 232 configured to accommodate both the stationary and the movable contacts 220, 210 inside. The rigid shell 232 is preferably made of an electrically conductive material and may be provided with a throughhole 234, for e.g. on a top side 236, for connecting a screw or plug of an input terminal of a load (not shown). The rigid shell 232 may also serve the function of protecting the stationary and the movable contacts 220, 210 from the external environment and of preventing obstructions to the displacement of the movable contact 210. The rigid shell 232 is preferably provided with appropriate openings for connecting the terminal protrusion 221 of the stationary contact 220 to an output terminal of the load. Additional openings may also be provided on the rigid shell, e.g. for facilitating heat dissipation from all sides, such as shown in Fig. 2.

[0038] In the configuration shown in Figs. 1 - 4, the support structure 230 is designed to be mounted with a bottom side 237 (opposed to the top side 236) onto the magnetic coil system 300. The electrical connection of the movable contact 220 to the support structure 230 is also preferably provided on the bottom side 237. For instance, a pair of flexible terminals 238, 239, such as conductive braids, may be arranged on opposed locations of the structure bottom side 237 for electrically connecting the two opposite end sections 212, 214 of the movable contact 210 to the support structure 230. The current entry points at opposed locations of the movable contact 210 helps to reduce the current resistance and the sectional size. Further, the flexibility of the conductive braids 238, 239 allows a vertical displacement of the movable contact 210 within the shell 232 for switching the contact system 200 between closed and open states, while maintaining electrical contact of the movable contact 210 with the support structure 230 and consequently, with the input terminal of the load.

[0039] The contact system 200 is configured to recirculate the overcurrent received from one of the contacts, e.g. the movable contact 210, along an outgoing current path in the other contact, e.g. the stationary contact 220, that becomes sufficiently close and parallel to the incoming current path at a final section (close to the output terminal) such that current is transported in the same direction as in the incoming current path, and consequently, an additional attractive Lorenz forces is produced. Thus, the contact force produced by the electromagnetic coil 320 to maintain the contact system 200 closed is automatically supplemented with an additional attractive force produced by the overcurrent itself and which is proportional to the intensity of the recirculated overcurrent. Moreover, as the attractive Lorentz force arises only when current flows along nearby paths and in the same direction, the distance between the stationary and movable contacts 210, 220 and relative sizes are selected or adjusted according to the particular application for the contactor or relay so as to produce an attractive force of a suitable intensity for compensating the repulsive Holm forces generated at the overcurrent of interest. For instance, the additional Lorentz force can be increased by increasing the length of the contacts 210, 220 in the direction X. i.e. the overlapping length of the parallel current paths in the contacts 210, 220.

[0040] Thus, the contact system 200 is designed so as to achieved such a compensation of the repulsive Holm forces. More specifically, the movable and stationary contacts 210, 220 have shapes and are placed in an arrangement that allow for an effective force balance between the Holms repulsive force generated by the flow of current through the contacts, the contact force generated by the electromagnetic coil 320 and the additional Lorentz force at high discharge currents, such as 15 kA or higher.

[0041] Figs. 4-5 shows the movable and stationary contacts 210, 220 of the contact system 200 shown in Figs. 2 - 3 without the support structure 230 and viewed from a lower side, which is the side facing the magnetic driving system 300. As described above, the movable contact 210 receives the input current from the braids 238, 230 at the end sections 211, 212 and comprises an input conductive section 213 (between end sections 211, 212) that defines an incoming current path for transporting the input current along the movable contact 210. The input conductive section 213 is preferably designed with the shape of a bar that extends in a longitudinal direction.

[0042] The stationary contact 220 includes a plurality of second conductive sections 222, 224, which are disposed with respect to one another such as to define an outgoing current path along the stationary contact 220, in which the current received from the movable contact 210 is recirculated towards the output terminal 226, i.e. the received current is firstly transported in a section away from the input conductive section 213 of the movable contact 210 and then directed towards a section close to the input conductive section 213. More specifically, the stationary contact 220 is shaped such that one of the plurality of second conductive sections, i.e. the conductive section 222 (output conductive section) close to the output terminal 226, is arranged adjacent to the input conductive section 213 of the movable contact 210 to transport the current received from the other second conductive sections of the stationary contact in substantially the same direction as the current direction in the incoming current path defined by the input conductive section 213. As a result, any current passing across the closed contact system 200 generates an additional attractive Lorenz between the output and input conductive sections 222, 213.

[0043] In particular, the output conductive section 222 is preferably shaped and oriented with respect to the input conductive section 213 of the movable contact 210 so that the incoming current path in the input conductive section 213 and/or the section of the outgoing current path defined by the output conductive section 222 are substantially orthogonal, or at least non-parallel, to the direction of movement of the movable contact 210 (as indicated in upward arrow in Fig. 4). This geometry and arrangement allows to achieve maximum compensation of the repulsive Holm effect for a given current intensity, since Lorenz forces are maximized for currents flowing in the same direction along parallel paths.

[0044] In addition, the output conductive section 222 is preferably disposed adjacent to the input conductive section 213 in the direction of the relative linear movement between the movable and the stationary contacts 210, 220, i.e. at a certain separation distance along the Y-direction and overlapping the input conductive section 213 so that the attractive Lorentz force generated by the currents flowing in the adjacent parallel paths (which is maximum in the direction orthogonal to the parallel paths) is predominantly oriented in the direction of the relative movement between the movable and the stationary contacts 210, 220. The stationary contact 220 is preferably shaped with a planar structure and oriented so that the remaining second conductive sections are arranged in substantially the same plane as the output conductive section 222. This planar structure and arrangement simplifies the overall geometry and increases mechanical stability of the contact system 200.

[0045] As shown in Figs. 4-5, the input and output conductive sections 213, 222 have respective shapes that extend in a longitudinal direction of the incoming current path by at least a predetermined length L.

[0046] The movable contact 210 may include an interconnection branch 216 through which the input current is transferred from the input conductive section 213 to the stationary contact 220. In this case, the interconnection branch 216 is provided with a length suitable to contact a conductive sections of the stationary contact 220 other than the output conductive section 222, preferably to an opposite conductive section 224, to ensure the desired recirculation of current along the stationary contact 220. As shown in Figs. 4-5, this opposed conductive section is shaped so as to define a recirculation conductive section 224 along which the current received from the interconnection branch 216 of the movable contact 210 is directed along a semi-loop section of the outgoing current path towards the output conductive section 222 and output terminal 226 of the stationary contact 220. The recirculation conductive section 224 is preferably shaped with an extended section substantially parallel to the output conductive section 222 and arranged at a predetermined separation therefrom.

[0047] In the configuration of the contact assembly 200 shown in Figs. 4-5, the plurality of second conductive sections forming the stationary contact 220, which include the output conductive section 222 and the recirculation conductive section 224, are shaped and arranged such that the stationary contact 220 has the shape of a closed loop. In this configuration, the interconnection branch 216 of the movable contact 210 is preferably provided at an intermediate section of the input conductive section 213 and makes electrical contact with the recirculation conductive section 224 at a respective intermediate section of the closed loop shape. In particular, the interconnection branch 216 of the movable contact 210 may be provided as a pair of parallel protrusions or branches extending from the input conductive section 213, in a direction perpendicular to the longitudinal direction, which make electrical contact with the intermediate section 227 of the stationary contact 220 at adjacent positions for splitting the outgoing current path in the stationary contact 220 into two half-loops between the intermediate section 227 and the output terminal 226.

[0048] As mentioned above, the additional Lorentz force can be increased by increasing the length of the contacts 210, 220 in the longitudinal direction (X-axis in Fig. 4), and therefore, increase the overlapping length of the parallel current paths in the input and output conductive sections 213, 222. In order to generate an attractive Lorentz force capable of compensating the repulsive Holm force between the contacts 210, 220 at a given intensity of discharge current, the shape and dimensions of the contacts 210, 220, including the dimensions of input and output conductive sections 213, 222, may be determined by experimentation and/or using simulation methods known in the technical field and based on parameters required for an intended application of the contact system 200 and switching device 100, such as discharge current to be withstand by the contacts 210, 220, contact force generated by the internal coil 320, materials and overall dimensions of the contact system 200 and switching device 100, including the geometry and cross-section of the contacts 210, 220 which has impact in the contact resistance. For instance, the magnetic flux density generated between input and output conductive sections 213, 222 may be calculated for different values of arm length, cross-section and air gap between input and output conductive sections 213, 222. As a specific example of implementation of the contact system 200 for withstanding overcurrent of 15 KA, the stationary contact 220 may have a rectangular loop shape dimensioned with a predetermined length L of 15 mm by a width W of 19 mm, and with a separation gap between movable and stationary contacts of 3.9 mm. At these dimensions, the movable contact 210 may be dimensioned with a width W2 for the input conductive section 213 of 7 mm and an overall width W1 of 16 mm (which includes W2 and the length of the intermediate branches 216). The length of the movable contact 210 is preferably the same or close to the overall length of the stationary contact 220 in order to maximize the attractive Lorentz force. For instance, the attractive force generated with such a dimensioned contact system 200 can reach up to 40 N when a discharge current of 15kA passes contacts 210, 220.

[0049] As shown in Fig. 4, the electrical contact between the stationary 220 and the movable contact 210 is preferably established via one or more second contact islands 228, which are provided in number and positions corresponding to one or more first contact islands provided in the movable contact 210 (not shown). The first and second contact islands 218, 228 provide the single electrical contact points between the movable and stationary contacts 210, 220, and consequently, define the locations at which current can entry from the movable contact 210 into the stationary contact 220. This ensures that the current received from the movable contact 210 is transported along the recirculation conductive section 224 and the output conductive section 222 before exiting the output terminal 226. The second contact islands 228 may be provided as islands of electrical conductive material which is deposited on facing sides of the movable and stationary contacts 210, 220. The contact islands may be provided on either the movable or stationary contacts 210, 220, which then establish direct electrical contact with the opposed contact of the contact assembly 220. An additional contact island may be provided to establish electrical contact between the input and output conductive sections 213, 222, as illustrated in Fig. 4, to improve stability.

[0050] In illustrated configuration, the contact system 200 is provided with two contact islands 228 disposed on an intermediate section 227 of the stationary contact 220, respectively, and a contact island 219 an intermediate position of the output conductive section 222. The contact resistance of the island 219 may be higher than offered by the contact islands 218 for avoiding the input current to exit directly through the contact island 219 and the output terminal 226. Thus, the current flow across the contact system 200 is divided in three branches that pass through each of the contact islands 218, 219. The solution can yield low resistance due to the double sided current path in the stationary contact 220 and produce very high attractive forces to counter the repulsive Holm force. Furthermore, the contact system 200 allows a symmetrical force effect and is extendable to low proportional force generation or high proportional force generation.

[0051] Fig. 6 shows a contact system 400 according to a second embodiment. The contact system 400 comprises first and second contacts 410, 420 for connecting to a load (not shown). Similarly to the contact system 200 described above, the first and second contacts 410, 420 can be moved relative to each other along the Y-direction indicated in Fig. 6 so as to switch between closed and open states, for e.g. under operation of the magnetic driving system 300 shown in Fig. 1. For instance, the first contact 410 can function as the movable contact which moves with respect to a stationary, second contact 420.

[0052] In the present configuration, the first and second contacts 410, 420 have a configuration in which the current input to the first contact 410 is transported along an input conductive section 413 and recirculated along an outgoing current path in the second contact 420 towards the output terminal 426.

[0053] More specifically, the second contact 420 has a plurality of second conductive sections arranged in the form of a single, open loop shape, such as to achieve a recirculating outgoing current path in the second contact 420. One of the second conductive sections. The output conductive section 422, is arranged adjacent and in parallel to the input conductive section 413 so that an attractive Lorentz force is generated by the currents transported in the same direction in the input and output conductive sections 413, 422. In the present configuration, the first contact 410 also includes an interconnection branch 416 to make electrical contact with an end section of an recirculation conductive section 424 of the second contact 420. The current received from the stationary contact 420 is then recirculated along the recirculation conductive section 424 so as to enter in the output conductive section 422 with the same direction as the current direction in the input conductive section 413 before exiting through the output terminal 426. Thus, the contact system 400 also allows to achieve a compensation of repulsion Holm forces based on the same principle of recirculation of the overcurrent of the present invention to produce additional attractive forces between the stationary and movable contacts 420, 410.

[0054] As explained above with reference to Fig. 4, the additional Lorentz force self-generated by the recirculation of current on the stationary contact 220 allows to counter-act the levitation effect produced by the Holm's force at high current discharges and may be increased by increasing the length of the movable and stationary contacts 210, 220 in the longitudinal direction (X-axis in Fig. 4) as well as the distance between the input conductive section 213 and the recirculation conductive section 224. However, such an increase of the counter-acting effect is upper-limited by the size constraints imposed on contactors and relay for certain real-life applications. In particular, a reduction of the length L and width of the stationary contact 220 for accommodating into a contactor of smaller size will reduce the attractive Lorenz force self-produced by current recirculation.

[0055] A switching device and a contact system according to a third embodiment of the present invention allows to effectively counter-act the levitating effect caused by repulsive Holm's forces generated at discharge currents of the order of 15kA or more while meeting the requirements of compactness desired for several applications, such as batteries for electrical vehicles, as it will be described with reference to figures 7 to 19.

[0056] Figs. 7 and 8 show perspective views of a switching device 100' having a contact system 500 according to the third embodiment. The contact system 500 comprises a first contact 510 and a second contact 520 for connecting the switching device 100' between terminals of a load (not shown), such as an external electrical equipment, an electrical circuit, an automobile battery and the like. Similarly to the first embodiment, the contact system 500 is configured to switch between a closed circuit configuration and an open circuit configuration under the actuation of a magnetic driving system, such as the magnetic driving system 300 described with reference to Fig. 1. For instance, as shown in Fig. 9, the movable contact 510 may be coupled to a driving shaft 540 which can be moved back and forth along the central axis C under the electromagnetically actuation produced by the coil 320 of the magnetic driving system 300, as it will be described later.

[0057] Fig. 10 shows a simplified perspective view of the contact system 500 in an open circuit configuration ("open state"), in which the movable contact 510 and the stationary contact 520 are separated by a gap that interrupts the flow of electric current through the contact system 500. The movable contact 510 ("first contact") is intended to receive a current (I_{in}) input to the contact system 500 and can move towards to and away from the stationary contact 520 ("second contact") in a direction of relative movement, which is parallel to the central axis C of the contact system 500 shown in Fig. 7. The stationary contact 520 is intended to remain fixed with respect to the switching device 100' when the contact system 500 is coupled to the magnetic driving system 300 and is generally used to output the current (Iout) that passes through the contact system 500 to another load terminal via an output terminal 525.

[0058] The contact system 500 also includes a support structure or frame 530 within which both the stationary and movable contacts 510 and 520 are arranged. An input terminal 535 is provided on a top side 536 of the frame 530 for connecting the contact system 500 to the load terminal (not shown) that supplies the input current I_{in} to the contact system 500. The electrical contact between the movable contact 510 and the frame 530 is made via flexible stripes or braids 534 arranged on support frame legs at the lower side 537. The support frame 530, including the flexible stripes 534, comprise good electrical conductor material(s) so that the support frame 530 transports the electrical current received from the input terminal 535 towards the flexible stripes 534, which feed the input current I_{in} into the movable contact 510. The flexible stripes 534 are made of a resilient material designed to exert a suitable pressure against the movable contact 510 and to allow the displacement of the movable contact 510 between the open and closed states. The flexible stripes 534 are preferably soldered or welded to input end sections 511, 512 of the movable contact 510 to ensure good electrical contact in the closed state.

The connection of the contact system 500 to the other load terminal (not shown) is made via an output branch or output terminal 525 directly connected to the stationary contact 520 and that protrudes to outside the frame 530. The stationary and movable contacts 520 and 510 comprise good electrically conductive materials that can support the current transport function of the contact system 500 at currents of the order of 15 kA and higher, such as copper or any good electrical conductive material known in the art. The stationary contact 520 may be mounted/fixed to the support frame 530, for e.g. on a bar (not shown) passing transversally across the support frame 530, and is electrically insulated from the support frame 530 by insulating elements arranged between the support frame 530 and the stationary contact 520 as needed to ensure that the stationary contact 520 receives the input current I_{in} fed to the contact system 500 from the movable contact 510 only.

[0059] As mentioned above, the movement of the movable contact 510 towards the stationary contact 520 to close the contact system 500 may be operated by the magnetic driving system 300, which also generates the contact force that holds the movable contact 510 in the closed position against the stationary contact 520. Specifically, the magnetic driving system 300 inductively actuates the driving shaft 540 which is coupled/attached to the movable contact 510 via an over-travel spring 550 arranged on a central region 555 of a bottom side surface of the movable contact 510 (which is the side facing the magnetic driving system 300 in the switching device 100'). The driving shaft 540 extends at a right angle from the bottom side surface of the movable contact 510 and is configured to plunge in the inner core of the coil 320 (i.e. along the central axis C) when the contact system 500 is mounted onto the magnetic driving system 300. Thus, when the coil 320 of the magnetic driving system 300 is energized with a suitable current, the driving shaft 540 moves linearly along the central axis C towards the top side 536 of the contact system 500, pressing the movable contact 510 against the stationary contact 520. In the closed state, the electric current I_{in} supplied to the input terminal 535 of the contact system 500 flows from the movable contact 510 to the stationary contact 520 to be output at the output terminal 525 (output current lout), as depicted by the direction of the arrows in Fig. 12.

[0060] When the actuation coil 320 of the magnetic driving system 300 is de-energized, the driving shaft 540 plunges back to the coil 320, thereby separating the movable contact 510 from the stationary contact 520, as shown in Fig. 11. Further, the over-travel spring 550 allows to bias the movable contact 510 towards the open position when the coil 320 of the magnetic driving system 300 is not actuating on the driving shaft 540. The resultant of these forces ($F_{coil+spring}$) should be sufficient to maintain the contact system 500 closed during normal operation and until the contact system 500 is crossed by a high discharge current at which the repulsive Holm's forces generated between the movable and stationary contacts 510, 520 begin to play a major role in the closed state of the contact system 500.

[0061] As discussed above, the repulsive Holm's force generated between the movable and stationary contacts at high-intensity currents, such as 15 kA and above, can cause negative effects to the operation and reliability of the contact system and switching device. In particular, the reduced size of the contact system 500 in comparison to the contact system 200 of the first embodiment leads to the counter-effect achieved by the self-generated Lorentz forces having less impact in keeping the contact system 500 closed. Thus, the generated repulsive Holm's forces may cause an abrupt separation of the movable and stationary contacts 510 and 520 against the contact force generated by the magnetic driving system 300 and therefore, lead to an undesired interruption of the electrical path connected to the switching device 100'. The abrupt separation of the movable and stationary contacts 510 and 520 at high currents may also result in welding of contacts due to the heat generated by arc currents. Due to their relative larger dimensions, the contact systems 200 and 400 described above can counter-act the negative effects caused by the repulsive Holm's force by mainly relying on the self-generated Lorenz forces to attract the stationary and movable contacts to each other under high current discharges.

[0062] The contact system 500 of the present embodiment is specifically designed to create an additional self-compensation effect of the repulsive Holm's forces generated between the movable and stationary contacts 510 and 520 and that helps to maintain the contact system 500 closed at current discharges higher than usually expected at typical contact forces (for e.g. at currents above 15 kA and contact forces between 40 N and 60 N), although the size of the stationary and movable contacts 520 and 510 has been decreased to be accommodated in a more compact contactor or relay.

[0063] Similarly to the first embodiment, the electrical contact between the movable and stationary contacts 510 and 520 is established via pairs of contact islands which are arranged on the side surfaces of the movable and stationary contacts 510 and 520 that face each other, i.e. an upper side surface 519 of the movable contact 510 shown in Fig. 17 and a bottom side surface 529 of the stationary contact 520 shown in Fig. 18. For instance, as shown in Fig. 16, three contact pairs are provided, where each of the contact pairs has one contact island arranged onto the upper side surface 519 of the movable contact 510 (i.e. the first contact islands 518a, 518b, 518c shown in Fig. 17) and another contact island arranged onto the bottom side surface 529 of the stationary contact 520 (i.e. the second contact islands 528a, 528b, 528c shown in Fig. 18). Each contact island of a contact pair is relatively positioned so as to contact with the corresponding contact island of the same contact pair when the contact system 500 is in the closed state. Preferably, three contact pairs are provided to establish the electrical contact between the movable and stationary contacts

510 and 520 at three distinct contact points which are positioned relative to each other so as to achieve an asymmetry in the current paths generated in the movable contact 510 and the stationary contact 520, respectively. Further, they also ensure that the input current received by the movable contact 510 is passed to the stationary contact 520 only at the specific contact regions and that it is transported along determined current paths in the stationary contact 520 before exiting via the output terminal 525. Thus, the three contact pairs (518a, 528a), (518b, 528b) and (518c, 528c) define the sole points (or regions) of electrical contact between the stationary and movable contacts 520 and 510, and consequently, influence the current paths along which electric current passes from the movable contact 510 into the stationary contact 220. The contact system 500 in the present embodiment is provided with a single contact pair (518a, 528a) on side A and two contact pairs (518b, 528c) and (518b, 528c) on side B, opposed to side A, of the contact system 500. However, other configurations in which only one contact is provided on side B may be envisaged.

[0064] In addition, the shape of the movable and stationary contacts 510 and 520 and relative position of the contact pairs leads to a specific current distribution along the movable and stationary contacts 510 and 520, which is responsible for producing an imbalance between the current that passes across the contact pair (518a, 528a) at a side A of the contact assembly 500 and the currents that pass across each of the contact pairs (518b, 528b) and (518c, 528c) at a side B of the contact assembly 500, as it will be described in the following.

[0065] Similarly to the previous embodiments, the movable and stationary contacts 510 and 520 of the contact system 500 have respective geometries which impose specific current paths for passing the current across the movable contact 510 (incoming current paths) and across the stationary contact 520 (outgoing current paths) and which result in a re-circulation of the current along the stationary contact 520, so that parallel currents flow in the same direction over respective, parallel sections of the stationary and movable contacts 520 and 510 to produce Lorenz forces that counteract (at least partially) the repulsive effect generated by the Holm's force. As shown in Fig. 14, the movable contact 510 is designed with a planar geometry that includes two end sections 511, 512, each configured to receive current from the frame 530 via the flexible stripes 534, and a main, input conductive section 513 (or branch) configured to transport the current received via the input end sections 511, 512 towards a center region 515 of the movable contact 510. The input conductive section 513 extends longitudinally (i.e. along the direction of the X axis which is transverse to the central axis C as shown in Fig. 13) over a length L', preferably having a symmetric length to the left and right sides of the central axis C and the central region 515. The end sections 511, 512 are disposed at respective ends of the input conductive section 513, on left and right sides of the central region 515, and both extend in a direction transverse to the longitudinal direction X of the input conductive section 513 and the central axis C (for e.g. parallel to the Z axis shown in Fig. 14). The end sections 511 and 512 are dimensioned with a size suitable for establishing a good electrical contact with the underlying flexible stripes 534.

[0066] The geometry of the movable contact 510 further includes an interconnection branch 516 that extends away from the central region 515 of input conductive section 513 in a direction transverse to the longitudinal axis X of the input conductive section 513. The interconnection branch 516 is disposed substantially in parallel with and between both the input end sections 511 and 512.

[0067] As shown in Fig. 17, one of the contact islands 518a is arranged at the central region 515 of the input conductive section 513, more specifically, at an intermediate position of the longitudinal length L' and width W' of the input conductive section 513, such that the current distribution paths established between the end sections 511 and 512 and the contact island 518a are substantially symmetric. Further, the contact island 528a is positioned in alignment with the center axis C of the movable contact 510 and with its the center being located at a predetermined distance d_A from the center axis C. The interconnection branch 516 serves the purpose of partially deviating the current paths established along the input conductive section 513, between the input end sections 511, 512 and the contact island 518a, towards the contact islands 518b and 518c. The contact islands 518b and 518c are disposed at an end portion of the interconnection branch 516 for contacting with the conducting islands 528b and 528c disposed on the opposed stationary contact 520, as shown in Fig. 17. In particular, the contact islands 518b and 518c are disposed on the right and left sides of the interconnection branch 516 in a symmetric manner with respect to a mirror plane containing the center axis C and the center of the contact island 518a and are positioned such that the projection of their respective centers on the mirror plane are at a same predetermined distance d_B from the center axis C. The interconnection branch 516 and the adjacent contact islands 518b and 518c allow to split the current paths established on the interconnection branch 516 and provide additional current paths for passing the incoming current from the input conductive section 513 towards the stationary contact 520, which results in an unbalanced distribution of the currents between the contact pair at side A and the two contact pairs at side B of the contact system 500.

[0068] The first and second predetermined distances (d_A, d_B) are preferably the same and/or selected based on parameters of the movable contact 510, such as the width W' of the input conductive section 513 and a width of the interconnection branch 516 in a direction transverse to the center axis (C) (i.e. along the direction of the Z axis in Fig. 14) so as to achieve an asymmetry on the distribution of currents paths along the movable contact 510 that results in a current imbalance of up to a predetermined imbalance threshold (preferably up to 80% current imbalance) between the current passing from the movable contact 510 to the stationary contact 520 across the single first contact island 518a arranged on the input conductive section 513 and the currents passing from the movable contact 510 to the stationary contact 520 across each of the first contact islands 518b and 518c arranged on the interconnection branch 516, respectively.

[0069] In addition, as shown in Fig. 14, the input conductive section 513 further includes two intermediate sections 517, 518, one at each side of the central region 515 and through which the current received from the input end section 511, 512 at the respective side left and right sides is passed to the central region 515 and/or to the interconnection branch 516 of the movable contact 510. The width and the position of each of intermediate section 517 and 518 along the direction transverse to the longitudinal length of the input conductive section 513 and the center axis (C) (i.e. along the direction of the Z axis in Fig. 14) also play a major role in the distribution of the current paths along the movable contact 510. Therefore, these parameters can be selected (for e.g. based on simulation analysis) in combination with the position of the first contact islands 518a, 518b and 518c arranged on the movable contact 510 so as to achieve an asymmetry on the distribution of currents paths along the movable contact 510 that results in a current imbalance of up to a predetermined imbalance threshold being reached between the current Ia passing from the movable contact 510 to the stationary contact 520 across the contact island 518a on the input conductive section 513 and the currents Ia and Ib, which pass from the movable contact 510 to the stationary contact 520 across each of the first contact islands 518b and 518c arranged on the interconnection branch, respectively. In the configuration of Fig. 14, the intermediate sections 517 and 518 have the same width has the width W' of the input conductive section 513. However, a geometry may be envisaged in which the intermediate sections 517 and 518 have a smaller width than the width W' of the input conductive section 513 and/or which are displaced towards the end portion of the interconnection branch 516, thereby significantly modifying the current distribution along the movable contact 510 and the currents Ia, Ib and Ic across the contact pairs (518a, 528a), (518b, 528b) and (518c, 528c). In particular, the current imbalance between the currents across the contact pair (518a, 528a) at side A and the contact pairs (518b, 528b) and (518c, 528c) at side B of the movable contact 510 is expected to decrease with a displacement of the intermediate sections 517, 518 closer to the center axis C and/or with an increase of the width of the intermediate sections 517, 518. Fig. 16 depicts the relative positioning of the movable and stationary contacts 510 and 520 when arranged in the support frame 530 and the relative positioning of the respective contact islands (518a, 528a), (518b, 528b) and (518c, 528c). Fig. 17 illustrates in a simplified manner the directions of current flow (current paths) through the movable contact 510 (dashed arrows) as well as the direction of the currents Ia, Ib and Ic (solid arrows) that pass across the contact islands of the contact pairs (518a, 528a), (518b, 528b) and (518c, 528c), respectively, when the contact system 500 is closed.

[0070] The stationary contact 520 has a planar geometry comprising a plurality of conductive sections 522 - 527 which are disposed and electrically connected with respect to each other so as to form a closed-loop geometry, as shown in Fig. 15. The plurality of conductive sections 522 - 527 may form a single body or may be separate conductive sections electrically connected to the immediately adjacent conductive sections to form the closed-loop shape.

[0071] The geometry of the stationary contact 520 includes an output conductive section 522 that extends longitudinally (for e.g. parallel to the X axis shown in Fig. 15) to the left and right sides of the output terminal 525 over a length L", and a recirculation conductive section 524, arranged opposite to the output conductive section 522 and across the central hole of the closed-loop geometry. The output conductive section 522 is intended to be placed adjacent to the input conductive section 513 of the movable contact 510 such that the current paths in the input conductive section 513 and the output conductive section 522 respectively lie in parallel planes that are orthogonal, or at least non-parallel, to the direction of relative movement of the movable contact 510 (i.e. the direction of the C axis), as shown in Fig. 13. This allows to maximize the Lorenz forces self-generated by the recirculation of current in the stationary contact 520.

[0072] A contact island 528a is arranged at an intermediate position of the output conductive section 525 in correspondence with the contact island 518a of the movable contact 510. Additional contact islands 528b and 528c are positioned adjacent to each other on an central area of the recirculation conductive section 524 and in correspondence with the contact islands 518b and 518c on the movable contact 510. The narrow width of the recirculation conductive section 524 on this area ensures that the current received via each the contact islands 518b, 518c is re-circulated along the semi-looped current paths established on the right and left sides of the loop shape shown in Fig. 18, respectively, towards the output conductive section 522 and the output terminal 525. The closed-loop shape of the stationary contact 520 is completed by the second conductive sections 526, 527, adjacent recirculation conductive section 524.

[0073] The closed-looped shape of the stationary contact 520 determines the outgoing current path(s) between the output terminal 525 and each point of contact established with the movable contact 510 via the contact pairs and ensures that part of the current received by the recirculation conductive branch 524 is redirected towards the output conductive section 522 to flow in the same direction as the flow direction in the input conductive section 513 of the movable contact 510. As a result, an additional attractive Lorenz between the output and input conductive sections 522 and 513 is generated by an over-current passing across the closed contact system 500.

[0074] Fig. 18 shows a simplified representation of the currents Ia, Ib and Ic (solid arrows) that are received by the contact islands 528a, 528b and 528c, respectively, when the contact system 500 is closed and the directions of current flow (outgoing current paths) established along the closed loop of the stationary contact 520 (dashed arrows) towards the output terminal 525.

[0075] The contact islands 528a - 528c on the stationary contact 520 and the contact islands 518a - 518c on the movable contact 510 preferably have the same shape, size as well as surface roughness and hardness properties so as to have a similar contact resistance across the contact pairs. However, due to the asymmetry of the current paths imposed by the specific geometries of the stationary and movable contacts 520 and 510 and the three-point contacts, the intensities of the currents across each of the contact pairs (518a, 528a), (518b, 528b), and (518c, 528c) will not be the same. Specifically, the current across the contact pair (518a, 528a) on side A of the movable contact 510 (which is the side of the input conductive section 513) will be significantly higher than across each of the opposed contact pairs (518b, 528b) and (518c, 528c) on the opposed side B.

[0076] Experimental observation and simulation analysis have shown that the unbalanced currents across the contact pairs disposed on sides A and B play an important role in the effective Holm's force generated between the movable and stationary contacts 510 and 520, namely, it may increase the threshold value of discharge current above which the contact system 500 will open against the contact force created by the underlying magnetic driving system 300. This effect may also be present in the contact systems 200 and 400 described above, but becomes particularly important for a three-point contact geometry and asymmetric load paths, such as achieved with the geometry of the contact system 500, since it is then very difficult to obtain asymmetric load paths with the same resistance between the input and output terminals of the contact system 500.

[0077] The contact system 500 of the present embodiment exploits the effect produced by unbalanced currents on the overall repulsive Holm's force felt by the movable contact 510 and which is caused by the asymmetric load paths available for the flow of current through the contact system 500. In particular, simulation of the current distribution and current densities achieved for the specific geometry of the movable and stationary contacts 510 and 520 with three-point contact show that the current Ia across the contact island 518a is significantly higher than the intensity of the currents Ib and Ic across the contact islands 518b and 518c on the intermediate connection branch 512 at the opposed side B. Namely, the current distribution along the stationary contact 520 and the movable contact 510 is such that different current intensities across the contact pairs are achieved depending on the side A or B on which the contact pairs are located. For instance, at a contact force of 13.3N per contact pair and an input current load of 15kA, it is estimated that the current Ia across the intermediate contact pair (218a, 228a) at side A of the contact assembly 500 may reach 10560 A against current intensities Ib and Ic of 2220 A across the contact pairs (218a, 228a) and (218c, 228c) located at the opposite side B, which corresponds to a current imbalance of about 78%. In this case, a repulsive Holm's force of about 60N may be generated at side A against a repulsive Holm's force of 2.7N per contact pair on side B of the movable contact 510. Thus, even under similar roughness and hardness conditions of the contact islands, the sides A and B of the movable contact 510 initially feel an imbalance of the repulsive Holm's forces caused by the unbalanced currents across the contact pairs.

[0078] This current unbalance may be sufficient for counter-acting the Holm's force generated on sides A and B of the movable contact 510, depending on the contact force generated by the actuating coil 320 to maintain the contacts closed, the surface condition and hardness of the contact islands. For instance, it is known that the electrical contact between contact islands may be accomplished over discrete areas or spots of a much smaller size than the area of the contact islands themselves depending on the roughness and hardness of the contact island surface. The number and size of contact spots influences the current distribution close to the contact islands and may lead to the generation of Holm's forces sufficiently strong to cause levitation of the movable contact at high currents, for e.g. at 15kA and above. This effect is already visible in low voltage drop measurements of the contact resistance and is expected to increase at very high current flow and low contact forces. In case of poor contact surface conditions, the number or size of spot contacts is further reduced, leading to a significant increase of the repulsive effect and eventually total failure of the contact system and respective switching device. Calculation results performed for the geometry of the contact system 500 with an arrangement of three contact pairs at a discharge current of 15 KA and a total contact force of 41.5 N assumed to be equally distributed per contact pair (i.e. 5 kA and 13.8 N per contact pair) and a contact spot of 0.1 mm size show that the theoretical Holm's force estimated for medium hardness and surface finishing of contact islands may achieve 13.4 N against 6.3 N obtained for contacts in perfect conditions. In real conditions, a higher Holm's force of 17.5 N has been measured. Nonetheless, experimental and simulation results show that an imbalance of up to 80% between the current Ia across the intermediate contact pair (518a, 528a) at side A and the currents Ib and Ic across each of the contact pairs (518b, 528b) and (518b, 528b) at the opposed side B of the movable contact 510 may lead to a sufficient self-compensating effect of the repulsive Holm's forces for maintaining the contact system 500 closed at a total load current of 15 kA and above.

[0079] Specifically, the unbalance between the current

Ia across the contact pair (518a, 528a) at side A and the currents Ib and Ic across each of the contact pairs (518b, 528b) and (518b, 528b) on side B results in a higher repulsive Holm's force being initially generated on side A, due to a higher current passing across the contact pair (518a, 528a) when the contact assembly 500 is in the closed state and receives a high current discharge, as illustrated in Fig. 19.

[0080] Fig. 19 shows a simplified side view of the movable and stationary contacts 510 and 520 of the contact system 500 at a first stage in which the contact system 500 is in the closed state, i.e. the movable contact 510 is pressed against the stationary contact 520 by the force $F_{coil + spring}$ applied at the center of the movable contact 510, and the current Ia passing through the contact island 518a at side A is significantly higher than the currents Ib and Ic that pass through each of the contact islands 518b and 518c at side B.

[0081] The force $F_{coil + spring}$ applied onto the movable contact 510 results from the bias exerted by the over-travel spring 550 and the actuation force generated by the actuation coil 320 to move the driving shaft 540 towards the stationary contact 520 so as to maintain the contact system 500 closed for currents within a desired operation range (for e.g. at currents below 15 kA). The resilience of the over-travel spring 550 allows not only slight displacements of the movable contact 510 along the center axis C but also slight oscillations of the movable contact 510 about an axis R that passes longitudinally through the movable contact 510 at a direction transverse the central axis C (see Fig. 13). The axis R define an axis of oscillation of the movable contact 510 (real or virtual rotation) with respect to the contact assembly 500. The force $F_{coil + spring}$ causes reaction forces to be applied onto each of the contact islands 518a, 518b, and 518c by the opposed contact islands 528a, 528b and 528c of the stationary contact 520 (for e.g. see the downward reaction forces R_a and R_b onto the movable contact 510 depicted in Fig. 19 and correspondent to the contact islands 518a and 518b, respectively). Under normal operation conditions, the resultant force and resultant torque applied on the movable contact 510 should be negligible, so that the movable contact 510 is in a stable equilibrium state, i.e. with no translation and/or rotation movement with respect to the stationary contact 520. However, a discharge current Iin of the order of 15 kA and above may lead to the appearance of significant Holm's forces at each of the sides A and B of the movable contact 510.

[0082] However, due to the shape and three-point contact geometry of the movable and stationary contacts 510 and 520, at high overload currents the current I_{in} input to the contact system 500 is distributed along asymmetric current paths on the movable contact 510, leading to an initial imbalance between the current Ia across the single contact island 518a at side A and the currents Ib and Ic across the pair of contact islands 518b and 518c at side B, respectively. The current Ia can be up to a 80% higher value than each of the currents Ib and Ic (which have substantially the same intensity in the configuration of the present embodiment). As a result, the higher Holm's force generated at side A of the movable contact 510 will produce a levitation effect (repulsive force) at side A much stronger than the levitation effect produced by the lower Holm's forces on side B, mechanically unbalancing the movable contact 510 and increasing the overall contact force on side B while reducing the overall contact force on side A, thereby decreasing the contact resistance at side B and increasing the contact resistance at side A (without opening the contact system 500).. Thus, the effect of the imbalanced Holm's forces is equivalent to that of an effective torque that attempts to rotate the movable contact 510 about the axis R towards the side B (without opening the contact system 500), leading to a decrease of the contact resistance across the contact pairs (518b, 528b) and (518c, 528c) at side B and an increase of the contact resistance across the contact pair (518a, 528a) at side A.

[0083] Meanwhile, the increase of the contact pressure on side B and the associated reduction of the contact resistance across the contact pairs (518b, 528b) and (518c, 528c) is reflected in a consequent increase of the current density across these contact pairs (518b, 528b) and (518c, 528c). At the same time, the current density across the contact pair (518a, 528a) at side A becomes to decrease due to the increase of the contact resistance caused by the levitating effect produced by the Holm's force generated at this side. The repulsive Holm's force will then progressively decrease at side A, while the Holm's force at side B is increased, until a stage in time where the imbalance of the Holm's forces generated at sides A and B is equivalent to an effective torque about the axis R that attempts to rotate the movable contact 510 about axis R in the opposite direction, i.e. towards side A, thereby increasing the pressure of the contact island 518a on side A against the contact island 528a of the stationary contact 520. The oscillating variation of the contact pressure on side A and side B of the movable contact 510 against the stationary contact 520 created by the unbalanced Holm's forces is equivalent to an additional attractive force that attracts one of the respective sides A and B towards the stationary contact 520. At the same time, the oscillating contact pressure decreases the repulsive Holm's force being generated at the side of the movable contact 510 that tends to levitate, and therefore, allows to maintain the contact system 500 closed at higher discharge currents than normally expected.

[0084] Fig. 20 shows a simplified side view of the movable and the stationary contacts 510 and 520 of the contact system 500 in a closed state and at a second stage, i.e. at a time subsequent to the first stage shown in Fig. 19.

[0085] In this second stage, the currents Ib and Ic crossing each contact island 518b and 518c at side B of the movable contact 510 have increased due to the decrease of the respective contacts resistance at side B during the first stage, while the current Ia has decreased as a consequence of the contact resistance decrease caused by the higher levitating effect produced by the Holm's force at this side during the first stage. As a result, the higher Holm's forces associated with the higher currents at side B will have a stronger levitation effect on side B than on the lower Holm's force produced at side A, resulting in a reduction of the contact pressure and increase of the contact resistance at side B. The imbalance of the repulsive Holm's forces between sides A and B at the second stage is equivalent to an effective torque that attempts to rotate the movable contact 510 about the axis R towards side A (without opening the contact system 500), leading to a new increase of the contact pressure exerted by the stationary contact 520 onto the contact islands 518a at side A and a decrease of the contact pressure exerted onto the contact islands 518b and 518c at side B. The repulsive Holm's forces generated by the unbalanced currents will continue to increase/decrease in an oscillatory manner at each of sides A and B, at least for a given time interval, although the contact system 500 remains closed. The attractive Lorentz forces self-generated by the recirculation of current on the stationary contact 520 are still present (particularly on side A of the movable and stationary contacts 510, 520) but may not have sufficient intensity to fully counter-act the Holm's force due to the size of the contact system 500 (length L" and width W") being reduced in comparison with the contact systems 200 and 400 described above. However, due to the self-compensating effect of the repulsive Holm's force achieved by the geometry of the contact system 500, it is possible to achieve a contact system 500 of compact size that is capable of remaining close at currents of the order of 15 kA (or higher) while using typical contact forces (n the range between 40 N and 60 N) generated by the actuation coil 320 and over-travel spring 540. For instance, the self-compensating effect can be achieved at such operating parameters with a movable contact 510 dimensioned with a length L' of about 40 mm, a width W' of about 7 mm for the input conductive section 513 and a comparable width of about 7 mm of the interconnection branch 516 (i.e. in the direction of the axis Z shown in Fig. 14), combined with a stationary contact 520 dimensioned with a length L" of about 41 mm, a lateral width W" of 19 mm and loop hole of about 5 mm (in the direction of the Z axis shown in Fig. 15).

[0086] The movable contact 510 may continue such a virtual oscillation movement for a given time duration which is sufficient for a fuse or other disconnecting mechanism safely disconnecting the load from the path of current discharge before the contact system 500 is forced to open. Thus, this combined self-compensating effect of the unbalanced Holm's forces allows to maintain the contact system 500 and the switching device 100' closed at discharge currents well above 15kA and/or during a longer time period than usually observed for this order of discharge currents in conventional contacts systems.

[0087] An important parameter of the self-compensating Holm's effect lies in the distances d_A and d_B at which the contact pairs (518a, 528a), (518b, 528b), and (518c, 528c) are positioned with respect to the center axis C (d_A and d_B corresponding to a same distance d in the exemplary configuration illustrated in Figs. 19 and 20), since the torque generated by the unbalance Holm's force tends to increase with the distance d. On the other hand, an increase of the distance d implies a change in the geometries of the movable and stationary contacts 510 and 520 and therefore, will also affect the current distribution on the contacts 510 and 520 and the currents across the individual contact pairs (518a, 528a), (518b, 528b), and (518c, 528c). Other parameters that play a major role in the contact resistance of the individual contact pairs (518a, 528a), (518b, 528b), and (518c, 528c), and therefore, on the self-compensating Holm's effect, include the contact force generated by the actuation coil 320 and the bias pressure generated by the over-travel spring 550. In order to maximize the self-compensating Holm's effect produced by the unbalanced currents, the shape and dimensions of the contacts 510 and 520, including the dimensions of the input and output conductive sections 513 and 522, may be determined using simulation methods known in the art for the parameters required for an intended application, such as discharge current to be withstand by contact system without opening, the contact force generated by the actuating coil 320, materials and overall dimensions of the contact system 500 and switching device 100', including the geometry and cross-section of the contacts 510 and 520 as well as the condition and hardness of the contact islands.

[0088] Thus, the contact system 500 allows to effectively counter-act the negative effects produced by the repulsive Holm's force at high discharge currents, such as 15 kA or above, via a combination of the contact force generated by the actuating coil 320, the attractive Lorentz force which is self-generated by the re-circulation of current in the stationary contact 520 and, most importantly, the self-compensating effect of the Holm's force produced by the unbalance of currents across the contact pairs disposed at opposite sides of the movable contact 510 with respect to the central axis C.

[0089] The first and second contacts of the contact systems described above are preferably made of an electrical conducting material capable of withstand erosion and mechanical stress. The contact material should also provide high welding resistance and stable arc resistance so that the contacts may withstand high current discharges.

[0090] In conclusion, the present invention provides reliable contact systems and switching devices for protecting electrical equipment used in high voltage applications by using a design of the underlying contact system that allows to generate additional attractive Lorentz forces between the stationary and movable contacts using recirculation of the overcurrent itself and therefore, capable of self-compensating the repulsion caused by Holm forces generated at high discharge currents, such as in the order of 15 kA or higher. Moreover, as the attractive Lorentz force is proportional to the discharge current flowing across the contact system, a collapse of the contact system and resultant destruction of the respective switching devices can be avoided for a large range of discharge currents with the same contact system design. In addition, the contact systems of present invention also allow to counter-act the repulsion effects caused by Holm's forces at high discharge current by exploiting a mechanism of self-compensation of the effective Holm's force which is associated with unbalanced currents being produced across the contact points between the stationary and movable contacts due to the asymmetrical load paths achieved by the specific geometries of the stationary and movable contacts.

[0091] It should be noted that in the description above assumed that, in Figs. 2 - 3 and 6, the horizontal direction is a direction along the X-axis and the vertical direction is a direction parallel to the Y - axis. Further, although certain features of the above exemplary embodiments were described using terms such as "top", "bottom", "upward" or "downward", "vertical", "left" and "right", these terms were used for the purpose of facilitating the description of the respective features and their relative orientation only and should not be construed as limiting the use of the claimed invention or any of its components to a particular spatial orientation. Moreover, although the present invention has been described above with reference to switching devices for high current applications and/or high overloads, the principles of the present invention can also be advantageously applied to switching devices intended for low voltage applications.

Reference Signs

[0092]

100	switching device
200	contact system of first embodiment
210	first contact (movable contact)
211, 212	end sections of the first contact member
213	input conductive section
216	intermediate branch
220	second contact (stationary contact)
221	protrusion of stationary contact
222	output conductive section
224	recirculation conductive section
226	output terminal
227	intermediate section
228	second contact island
230	support structure
232	rigid shell
234	through-hole on support shell
236	top side of shell
237	bottom side
238, 239	pair of braids
300	magnetic driving system
320	electromagnetic coil
332, 334	terminals of electromagnetic coil
400	contact system of second embodiment
410	first contact (movable contact)
413	input conductive section
416	intermediate branch
420	second contact (stationary contact)
422	output conductive section
424	recirculation conductive section
426	output terminal
100'	switching device of third embodiment
500	contact system of third embodiment
510	first contact (movable contact)
511, 512	end sections of the first contact
513	input conductive section
515	central section
516	interconnection branch
517, 518	intermediate sections
518a - 518c	first contact islands (on movable contact)
519	upper side surface
520	second contact (stationary contact)
521	intermediate section of stationary contact
522	output conductive section
524	recirculation conductive section
526, 527	adjacent conductive section of second contact
525	output terminal
528a - 528c	second contact islands (on stationary contact)
529	bottom side surface of the second contact
530	support frame
534	pair of braids
535	input terminal
536	top side of support frame
537	bottom side of support frame
540	driving shaft
550	over-travel spring
555	central region
C	central axis of contact system, direction of relative movement

Claims

1. Contact system for a switching device, comprising:

a first contact (210; 410; 510) adapted to receive an input current supplied to an input terminal (234; 535) of the contact system; and
a second contact (220; 420; 520) adapted to receive the input current from the first contact (210; 410; 510);
wherein the first contact (210; 410; 510) comprises an input conductive section (213; 513) configured to provide an incoming current path

for transporting the input current,
wherein the second contact (220; 420; 520) comprises a plurality of second conductive sections (222, 224; 521 - 527) configured to provide an outgoing current path for transporting the current received from the first contact (210; 410; 510) towards an output terminal (226; 525) when the contact system is in a closed state, and
wherein one of the plurality of second conductive sections is arranged adjacent to the input conductive section and provides an output conductive section (222; 422; 522) in which current received by the second contact (220; 420; 520) from the first contact (210; 410; 510) is transported in the same direction as the current direction along the incoming current path in the input conductive section.

2. A contact system according to claim 1, wherein

the output conductive section (222; 422; 522) is substantially parallel to the input conductive section (213; 413; 513), and/or
the plurality of second conductive sections are arranged in a same plane which is substantially parallel to the input conductive section.

3. A contact system according to claim 1 or 2, wherein the output conductive section (222; 422; 522) is disposed adjacent the input conductive section in a direction of a relative linear movement between the first (210; 410; 510) and second contacts (220; 420; 520).

4. A contact system according to any one of claims 1 to 3, wherein
the input conductive section (213; 413; 513) and the output conductive section (222; 422; 522) are configured such that a section of the incoming current path defined by the input conductive section (213; 413; 513) and a section of the outgoing current path defined by the output conductive section (222; 422; 522) are substantially orthogonal or non-parallel to a direction of a relative linear movement between the first (210; 410; 510) and second contacts (220; 420; 520).

5. A contact system according to any one of claims 1 to 4, wherein

the input conductive section (213; 413; 513) and the output conductive section (222; 422; 522) have respective shapes that extend in a longitudinal direction of the incoming current path by at least a predetermined length at which an attractive Lorentz force between the input and output conductive sections compensates the repulsive Holm's force generated between the first (210; 410; 510) and second contacts (220; 420; 520) at a given intensity of input current, and preferably for an input current of 15 kA or higher; wherein
said longitudinal direction is substantially orthogonal or at least non-parallel to a direction of a relative linear movement between the first (210; 410; 510) and second contacts (220; 420; 520).

6. A contact system according to any one of claims 1 to 5, wherein

the first contact (210; 410; 510) further includes one or more interconnection branches (216; 416; 516) which extend away from the input conductive section by a predetermined length so as to pass at least a part of the input current from the input conductive section (213; 413; 513) to one of the second conductive sections of the second contact (220; 420; 520) other than the output conductive section (222; 422; 522), and
wherein said second conductive section other than the output conductive section (222; 422; 522) forms a recirculation conductive section (224; 424; 524) configured to define a portion of the outgoing current path along which the current received from the one or more interconnection branches (216; 416; 516) of the first contact (210; 410; 510) is recirculated towards the output conductive section (222; 422; 522).

7. A contact system according to claim 6, wherein
the recirculation conductive section (224; 524) is shaped with an extended section that is arranged substantially parallel to and opposed to the output conductive section (222; 422; 522).

8. A contact system according to claim 6 or 7, wherein

the second contact (220; 420; 520) includes a plurality of second contact islands (528a - 528c) arranged thereon in number and positions corresponding to a plurality of first contact islands (518a - 518c) arranged on the first contact (210; 410; 510), the first and second contact islands providing a plurality of contact pairs via which electrical contact between the first and second contacts is established when the contact assembly is in the closed state;
wherein at least one of the second contact islands is provided on said recirculation conductive section (224; 414; 524) of the second contact (220; 420, 520) at a respective position for electrically contacting to a corresponding first contact island provided in the interconnection branch (216; 516) of the first contact (210; 410; 510) when the contact system is in the closed

state; and/or
wherein at least one of the second contact islands is provided on said output conductive section (213; 413; 513) at a respective position for electrically contacting to a corresponding first contact island provided on a central region of the input conductive section (213; 413; 513) of the first contact (210; 410; 510) when the contact system is in the closed state.

9. A contact system according to claim 8, wherein

the second contact islands (528a - 528c) are provided in a number of three and each arranged in a position corresponding a position of a respective one of three first contact islands (518a - 518c) provided in the first contact (210; 510),
wherein a single second contact island (528a) is arranged on said output conductive section (213; 513) and at a respective position for electrically contacting to a single first contact island (518a) arranged on the central region of the input conductive section (213; 513) of the first contact (210; 510), and
wherein a pair of the second contact islands (528b, 528c) is arranged at a central area of said recirculation conductive section (224; 524) of the second contact (220; 520), a corresponding first contact island (518b, 518c) being arranged at an end portion of said one or more interconnection branches (216; 516) of the first contact (210; 510) so that the outgoing current paths for currents received by the recirculation conductive section of the second contact (220; 520) via said pair of second contact islands (528b, 528c) includes two half-loops that direct the received current towards the output conductive section (222; 522).

10. A contact system according to claim 8 or 9, wherein

the single first contact island (518a) is arranged on said input conductive section (213; 513) and positioned with its center at a first predetermined distance (d_A) from a center axis (C) of the first contact (210; 510);
the pair of first contact islands (518b, 518c) is arranged on an end portion of the interconnection branch (216; 516), each first contact island of the pair (518b, 518c) being positioned in a symmetric manner with respect to a mirror plane, which contains the center axis (C) and the center of the first contact island (518a) arranged on said input conductive section (213; 513), and such that a projection of their respective centers onto said mirror plane is distant by a second predetermined distance (d_B) from the center axis (C); and
wherein the first and second predetermined distances (d_A, d_B) are the same and/or selected based on a width of the input conductive section and a width of the interconnection branch (516) in a direction transverse to the center axis (C) so as to achieve an asymmetry on the distribution of currents paths along the first contact (510) that results in a current imbalance of up to a predetermined imbalance threshold between the current passing from the first contact to the second contact across the single first contact island on the input conductive section and the currents passing from the first contact to the second contact across each of the first contact islands arranged on the interconnection branch, respectively.

11. A contact system according to any one of claims 6 to 10, wherein

the plurality of second conductive sections are configured to form the second contact (520) with a closed loop geometry; and
wherein the geometries of the first (510) and the second contacts (520) are configured such that the interconnection branch (516) of the first contact (510) extends from a central region of the input conductive section (513) along a direction transverse to a longitudinal length of the input conductive section (513) and the center axis (C) to overlap an intermediate section of said recirculation conductive section (524) of the second contact at ,
wherein the geometry of the first contact (510) further includes two input end sections (511, 512) at respective end portions of the input conductive section (513) to feed the input current to said input conductive section (513) and which extend in a direction transverse to the longitudinal length of the input conductive section (513) and the center axis (C), and
wherein the input conductive section (513) further includes two intermediate sections (517, 518), one at each side of said central region and through which the current received from the input end section at the respective side is passed to the central region and/or the interconnection branch of the first contact,
wherein the width and the position of each of said intermediate sections in the direction transverse to the longitudinal length of the input conductive section and the center axis (C) is selected in combination with the position of the first contact islands arranged on the first contact so as to achieve an asymmetry on the distribution of currents paths along the first contact (510) that results in said current imbalance of up to the predetermined imbalance threshold be-

tween the current passing from the first contact to the second contact across the first contact island on the input conductive section and the currents passing from the first contact to the second contact across each of the first contact islands arranged on the interconnection branch, respectively.

12. A contact system according to claim 10 or 11, wherein
the predetermined imbalance threshold is 80% or below.

13. A contact system according to any one of claims 6 to 10, wherein

the plurality of second conductive sections is configured to form the second contact (520) with a closed loop geometry,
the geometries of the first (210) and the second contacts (220) being configured such that said interconnection branch (216) of the first contact (210) is provided as a pair of protrusions that respectively extend from a central region of the input conductive section (213) in a direction transverse to a longitudinal length of the input conductive section (213) to make electrical contact with the intermediate section (227) of the second contact (220) and split the outgoing current paths in two half-loops between the intermediate section and the output terminal of the second contact (220); or
wherein the plurality of second conductive sections (424; 424) are configured to form the second contact (420) with an open loop shape,
the first (410) and second contacts (420) being configured such that the interconnection branch (416) of the first contact (410) is provided at an end section of the input conductive section (413) to make electrical contact with said second conductive section (424) other than the output conductive section at an end section of the open loop shape.

14. A switching device for high current discharges, comprising:

a contact system (200; 400; 500) according to any one of claims 1 to 13; and
a magnetic driving system (300) adapted to operate switching of the contact system (200; 400; 500) between a closed state, at which the first (210; 410; 510) and second contacts (220; 420; 520) contact each other, and an open state at which the second contact (220; 420; 520) is separated from the first contact (210; 410; 510) by a gap.

15. A switching device according to claim 14, wherein the switching device is one of a electromagnetic relay and an electromagnetic contactor.

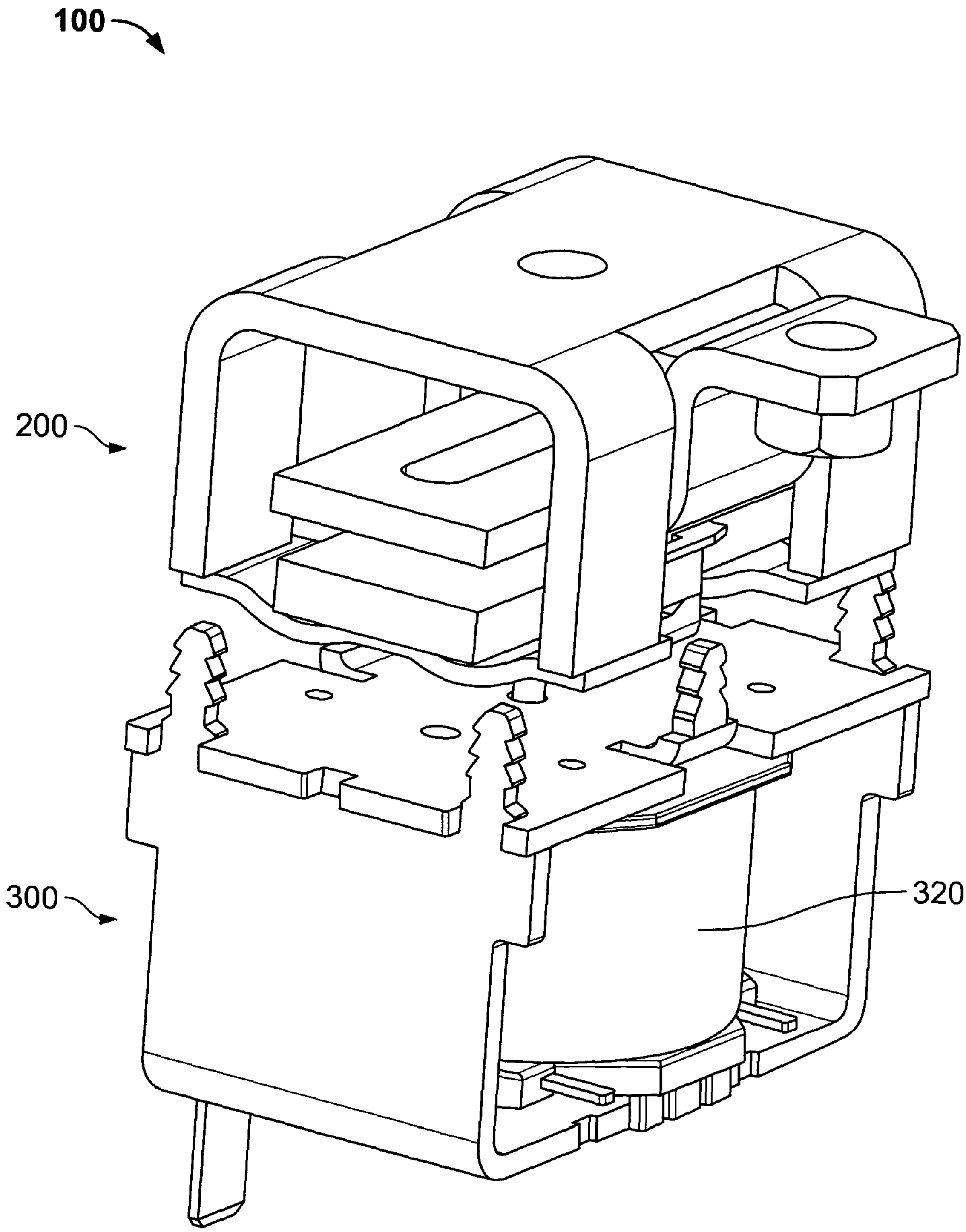

Fig. 1

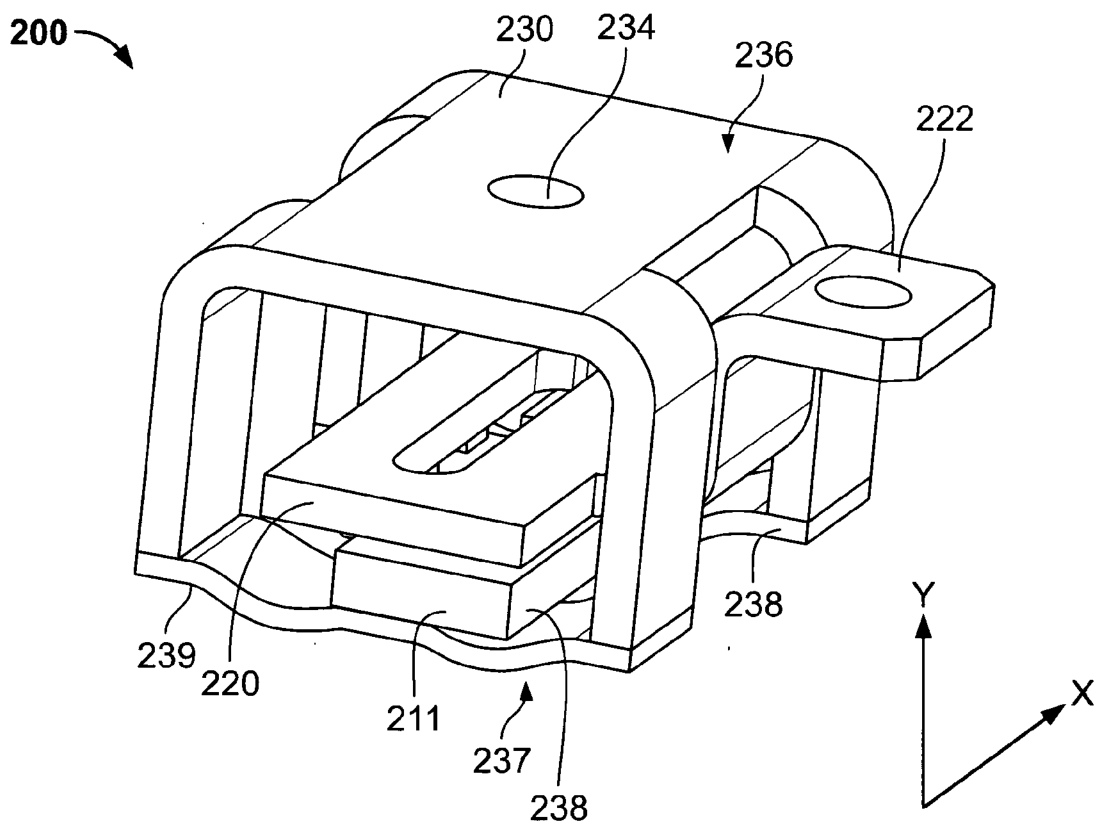
200
230
234
236
222
239
220
211
237
238
238
Y
X

Fig. 2

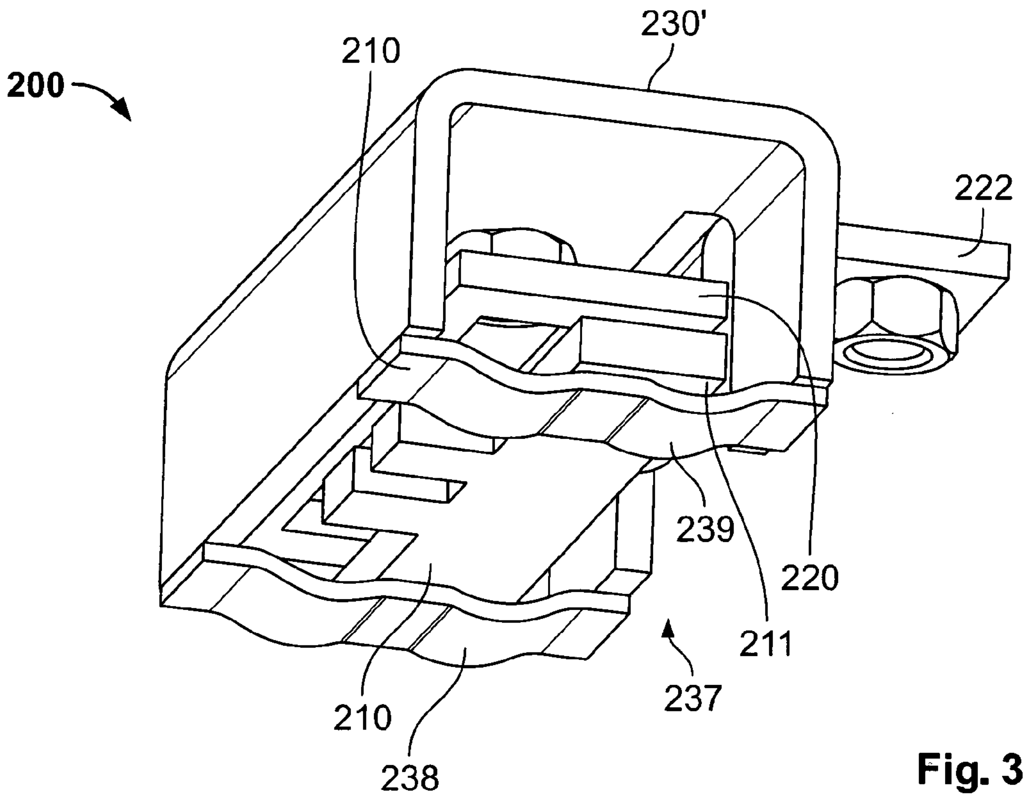
200
210
230'
222
239
220
211
237
210
238

Fig. 3

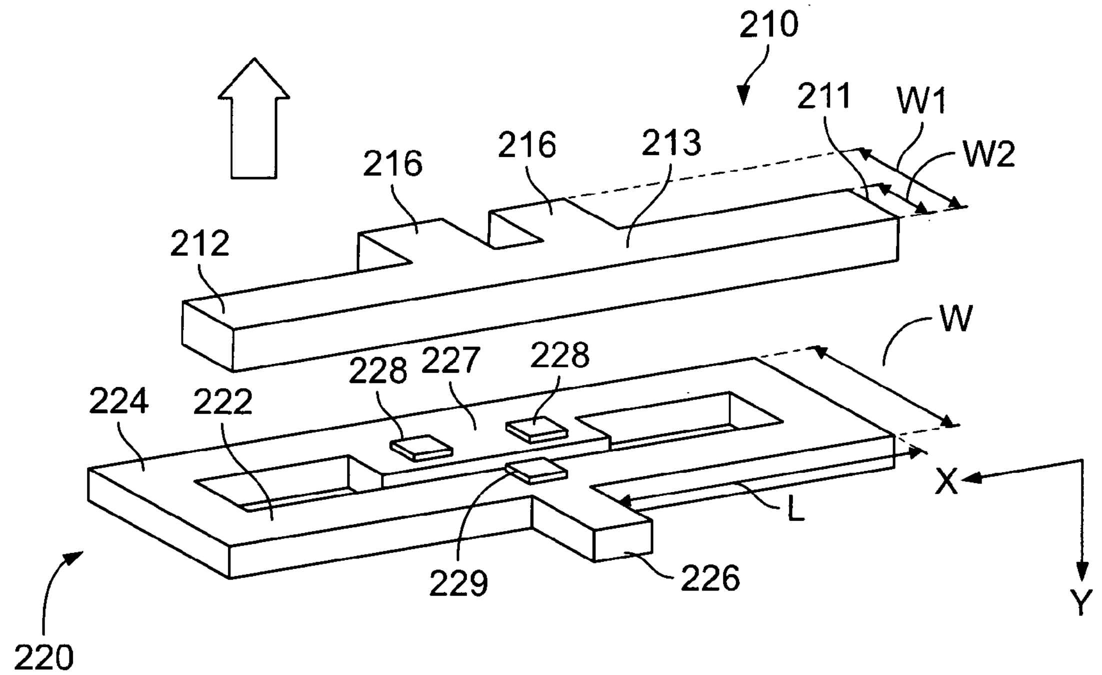
210
211
W1
W2
216
216
213
212
W
228
227
228
224
222
X
L
229
226
Y
220

Fig. 4

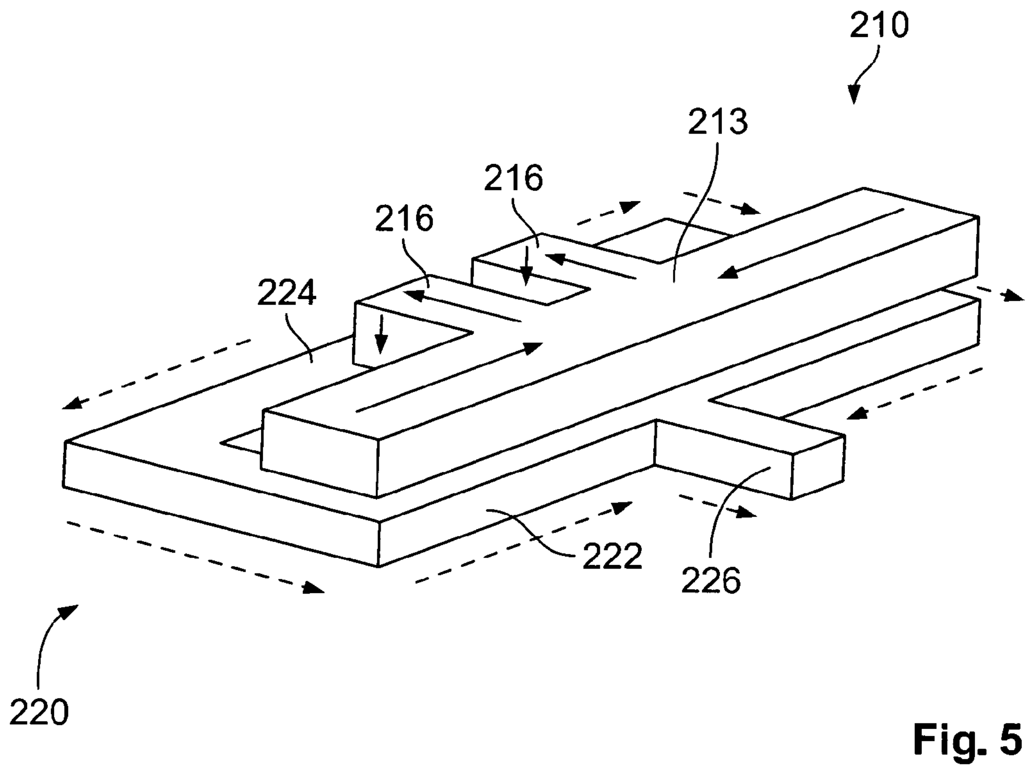
210
213
216
216
224
222
226
220

Fig. 5

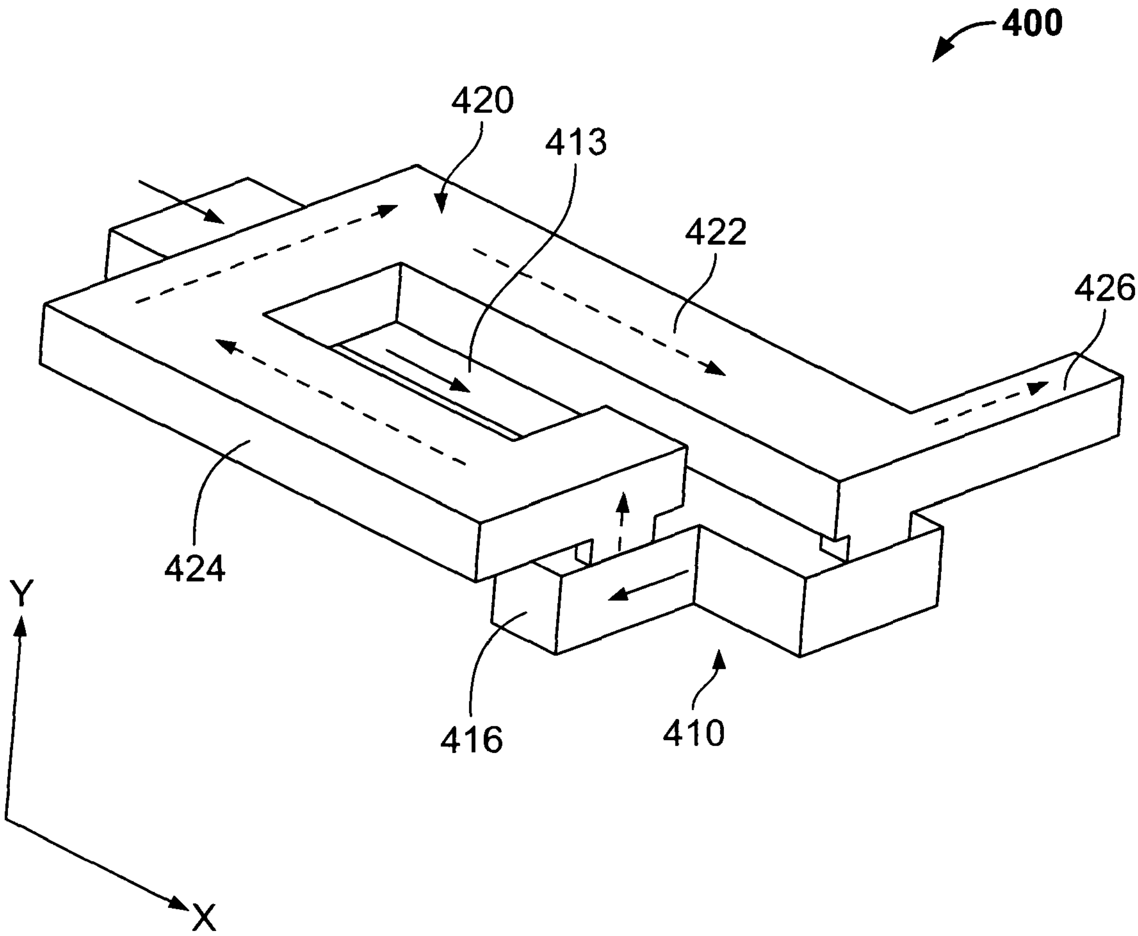

Fig. 6

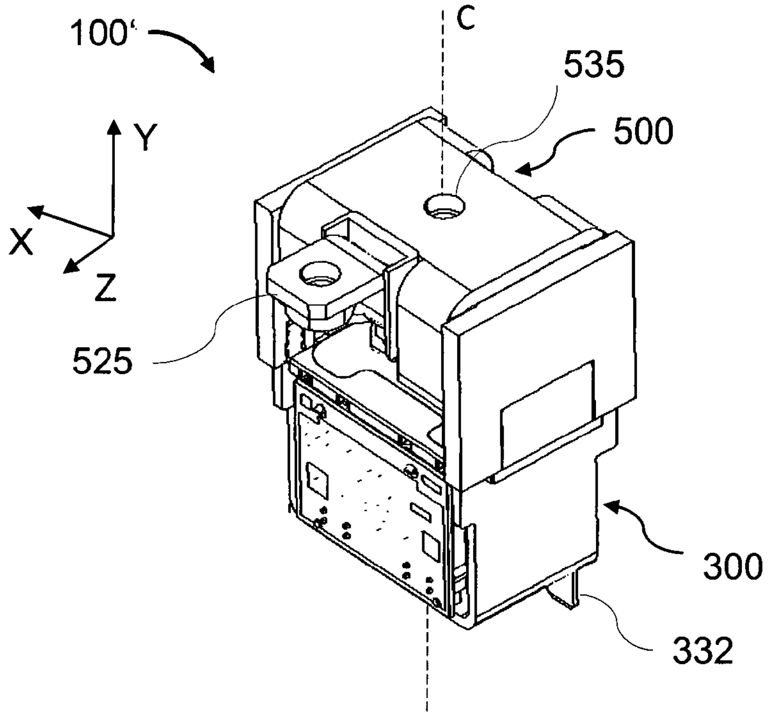

Fig. 7

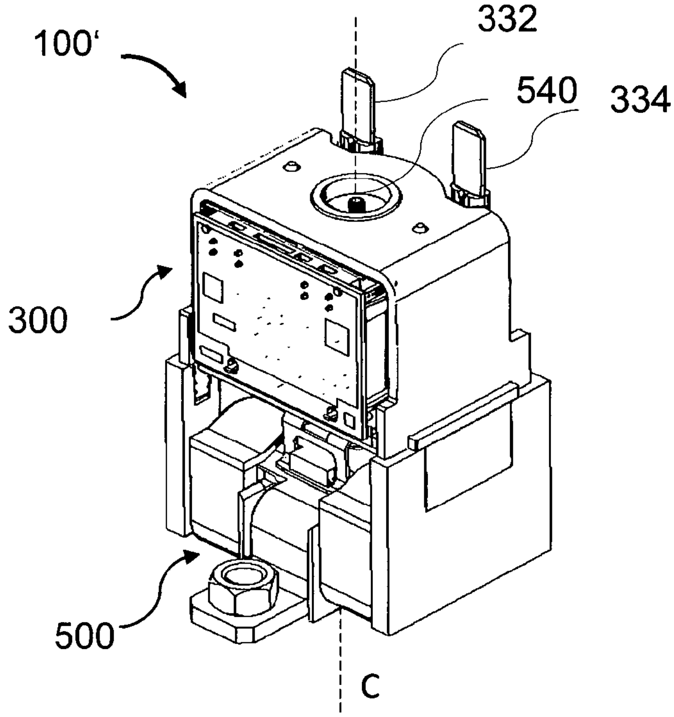

Fig. 8

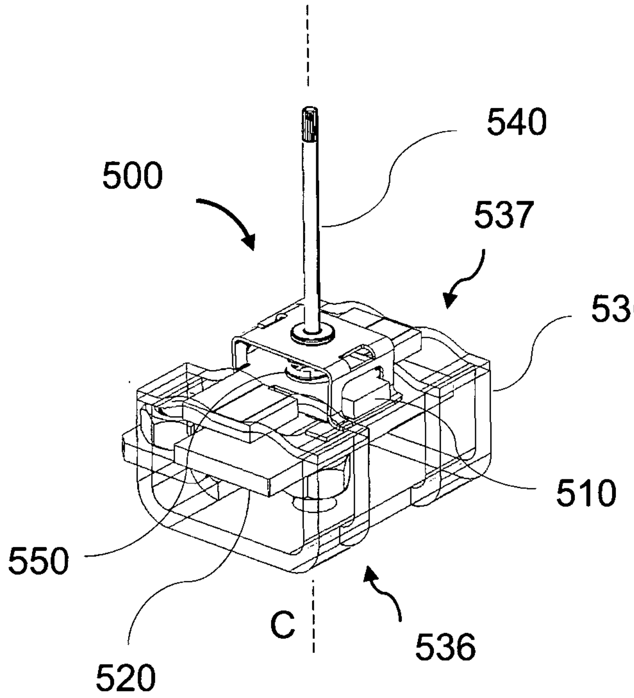
540
500
537
530
510
550
C
536
520

Fig. 9

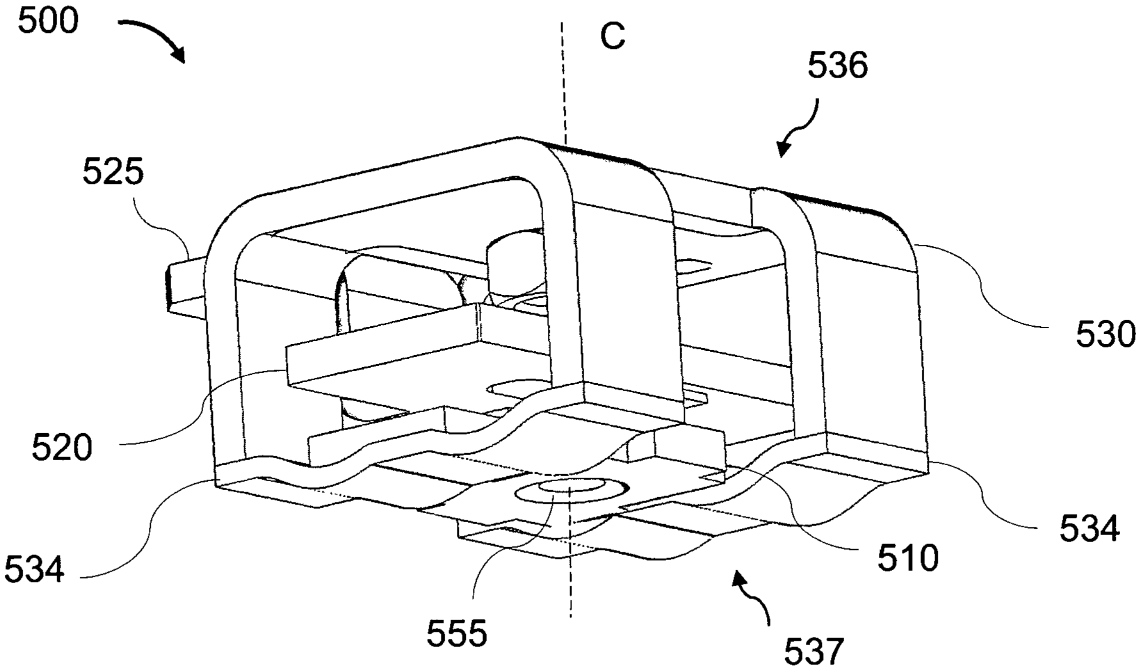
500
C
536
525
530
520
534
510
534
555
537

Fig. 10

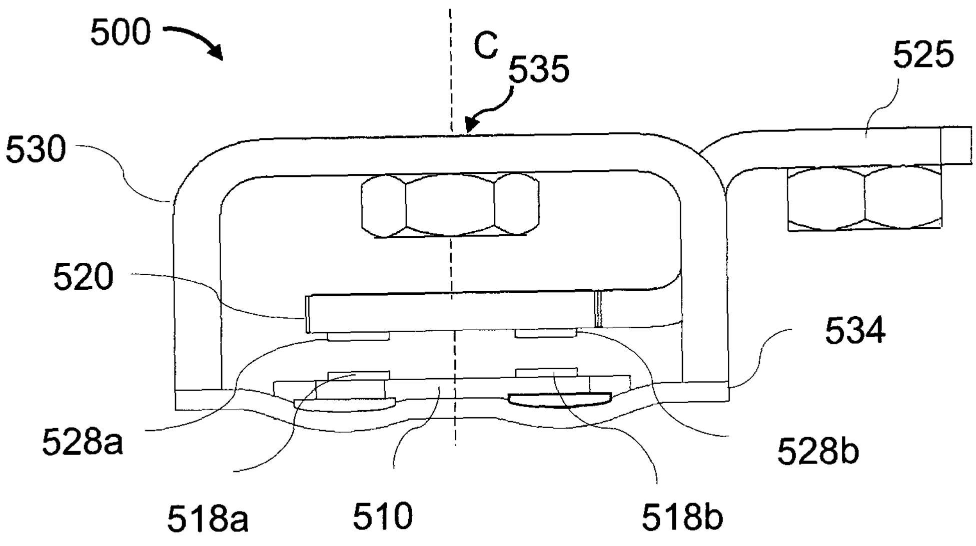
500
C
535
525
530
520
534
528a
528b
518a
510
518b

Fig. 11

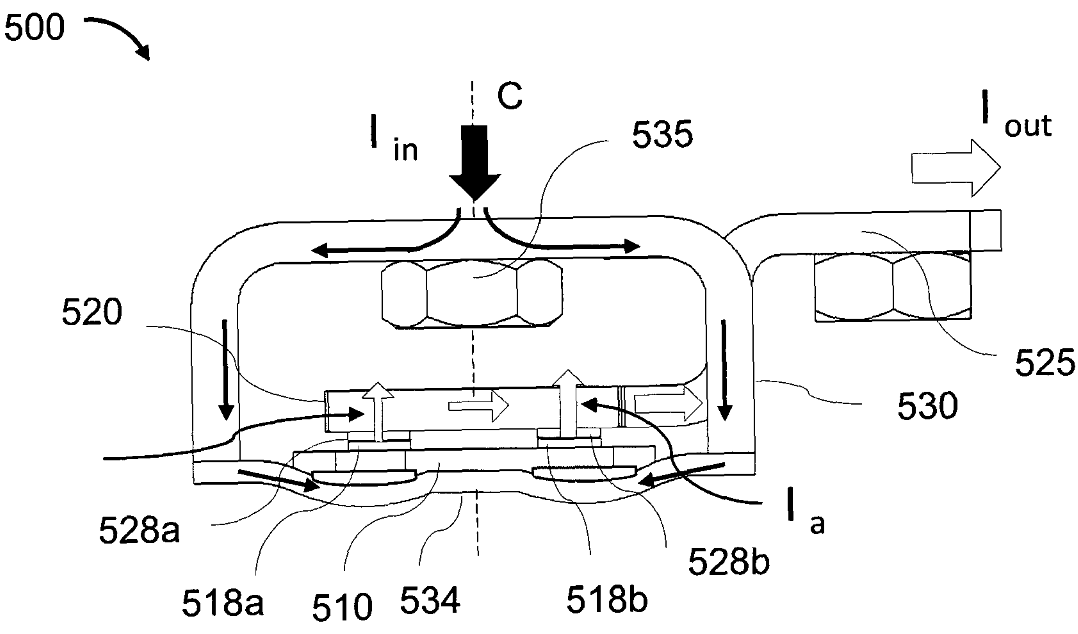
500
C
I in
535
I out
520
525
530
I a
528a
528b
518a
510
534
518b

Fig. 12

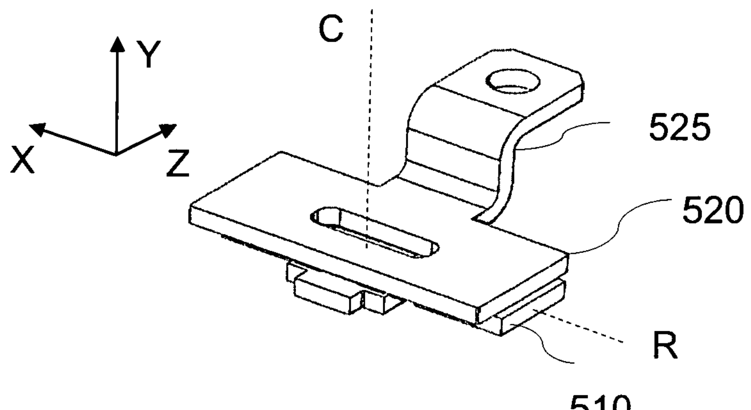

Fig. 13

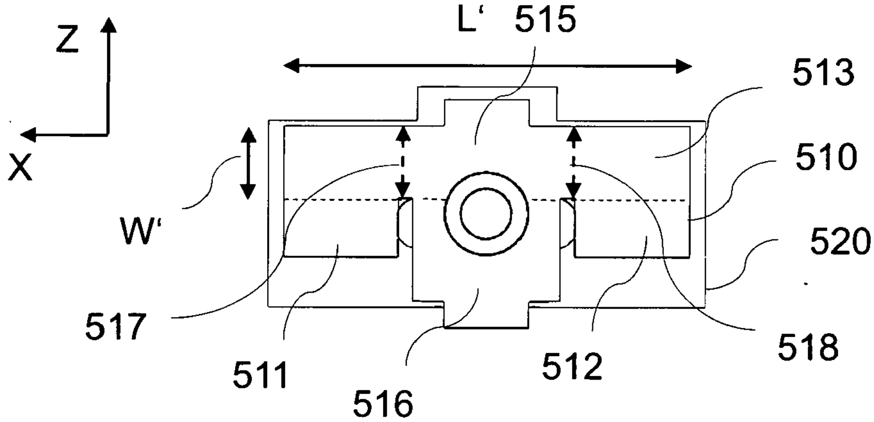

Fig. 14

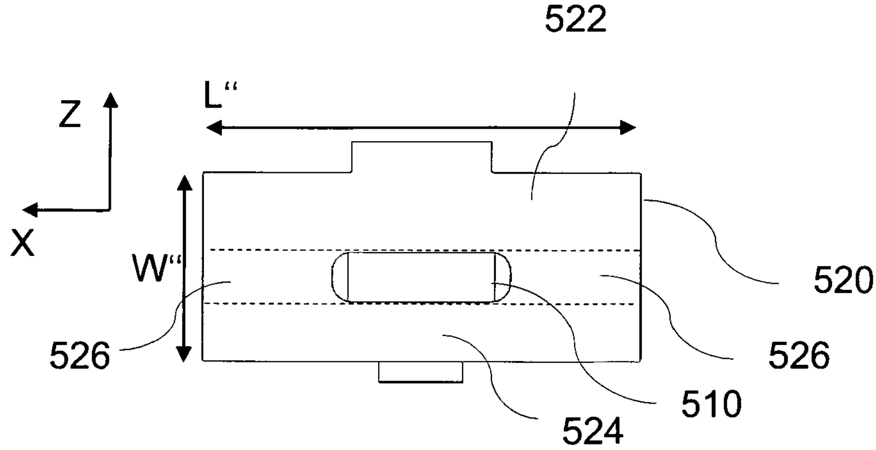

Fig. 15

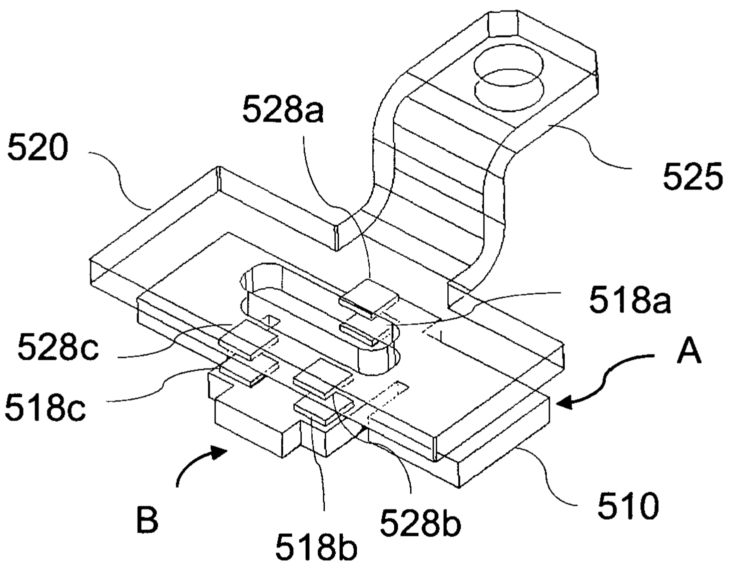
520
528a
525
518a
528c
A
518c
B
510
528b
518b

Fig. 16

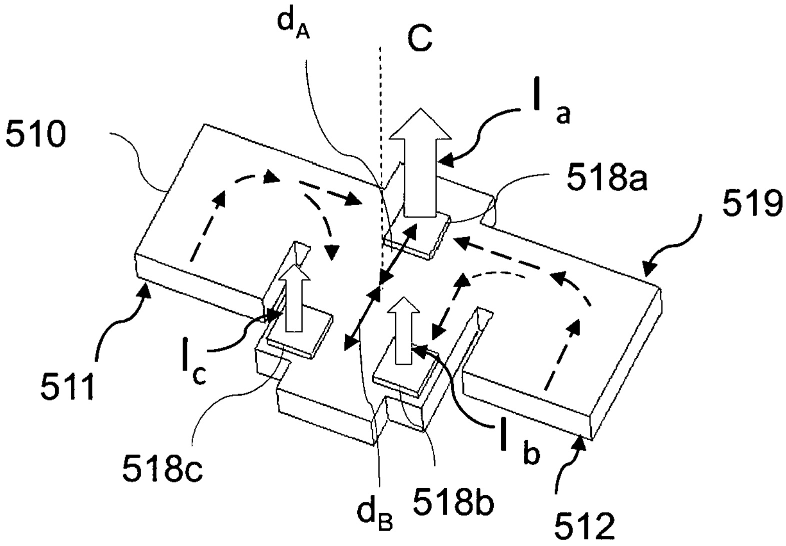
d_A
C
I_a
510
518a
519
I_c
511
I_b
518c
d_B
518b
512

Fig. 17

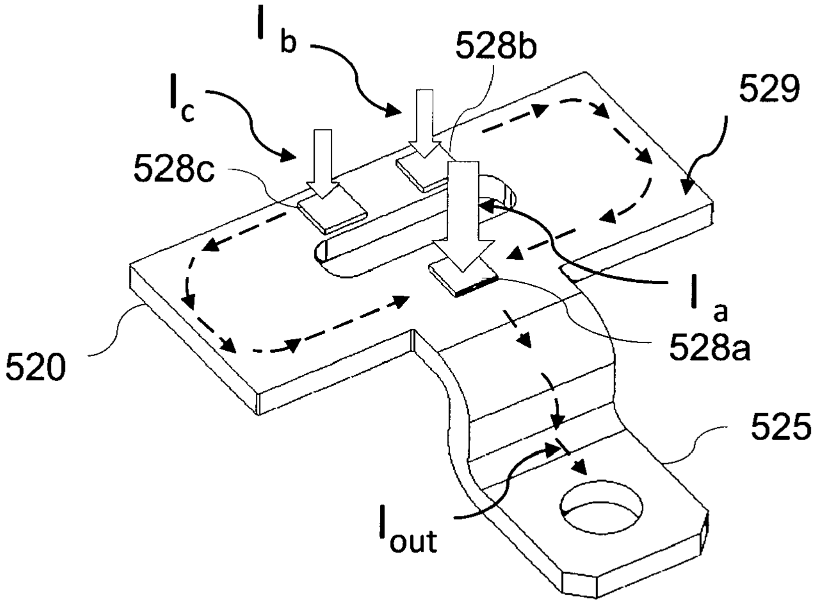

Fig. 18

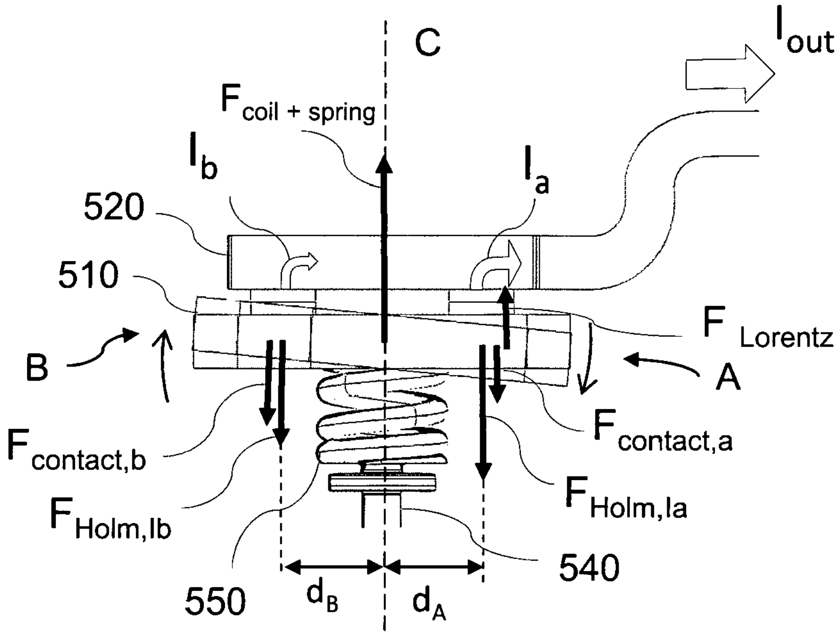
C
I_out
F_coil + spring
I_b
I_a
520
510
F Lorentz
B
A
F_contact,b
F_contact,a
F_Holm,Ib
F_Holm,Ia
540
550
d_B
d_A

Fig. 19

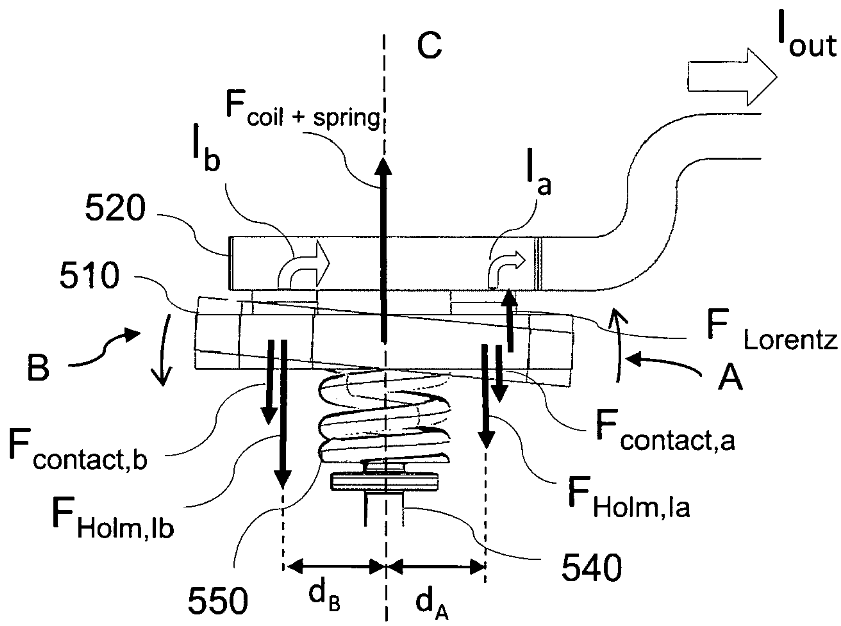
C
I_out
F_coil + spring
I_b
I_a
520
510
F Lorentz
B
A
F_contact,b
F_contact,a
F_Holm,Ib
F_Holm,Ia
540
550
d_B
d_A

Fig. 20

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EUROPEAN SEARCH REPORT

Application Number
EP 22 39 8022

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			H01H

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	20 March 2023	Fribert, Jan

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