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(54) **A SYSTEM OF SWITCHING CONTACTS WITH COMPENSATION OF HOLM REPULSION AND SWITCHING DEVICE 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.

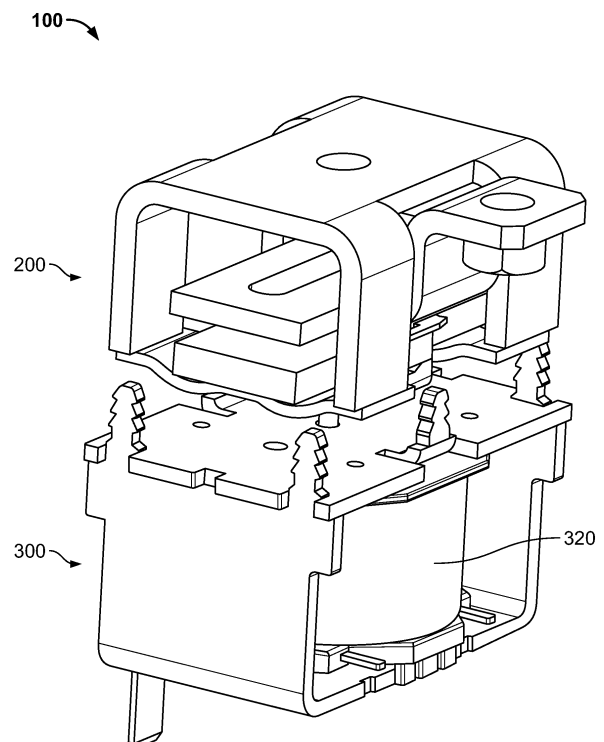


Fig. 1

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 Holm's 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 Lorentz 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] 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 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.

[0014] 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.

[0015] According to a further development, to 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.

[0016] According to a further development, the input and output conductive sections are configured such that 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.

[0017] According to a further development, the input and output conductive sections 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 force 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.

[0018] According to a further development, 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 an interconnection branch arranged to pass the input current from the input conductive section to one of the second conductive sections other than the output conductive section.

[0020] According to a further development, 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 interconnection branch of the first contact is recirculated towards the output conductive section.

[0021] 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.

[0022] According to a further development, the second contact is adapted to establish contact with the first contact via one or more second contact islands provided in number and positions corresponding to one or more first contact islands provided in the first contact, at least one second contact island is provided on said second conducting branch other than the output conducting branch for connecting to at least one corresponding contact island provided in the interconnection branch of the first contact.

[0023] According to a further development, the plurality of second conductive sections are configured to form the second contact with a closed loop, the first and second contacts being configured such that the interconnection branch of the first contact is adapted to electrically contact said second conductive section other than the output conductive section at an intermediate section of the closed loop shape.

[0024] According to a further development, said interconnection branch of the first contact is provided as a pair of protrusions configured to make electrical contact with the intermediate section of the second contact at adjacent positions so as to split the outgoing current path in two half-loops between the intermediate section and the output terminal of the second contact.

[0025] 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 intercon-

nection 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.

[0026] 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.

[0027] According to a further development, the switching device is one of a electromagnetic relay and an electromagnetic contactor.

[0028] 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.

[0029] 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.

[0030] 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

[0031] 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;

and

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.

DETAILED DESCRIPTION OF THE INVENTION

[0032] 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.

[0033] 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.

[0034] 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).

[0035] 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 through-hole 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.

[0036] 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.

[0037] 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 Lorentz forces is produced. Thus, the contact force produced by the electro-

magnetic 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.

[0038] 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.

[0039] 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.

[0040] 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.

[0041] 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.

[0042] 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.

[0043] 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.

[0044] 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.

[0045] 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.

[0046] 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 15 kA passes contacts 210, 220.

[0047] 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.

[0048] 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.

[0049] 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.

[0050] 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.

[0051] 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 a 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. 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.

[0052] 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 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.

[0053] 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. However, although certain features of the above exemplary embodiments were described using terms such as "top", "bottom", "upward" or "downward", these terms were used for the purpose of facilitating the description of the respective fea-

tures and their relative orientation only and should not be construed as limiting 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

[0054]

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
 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

Claims

1. 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.

2. A contact system according to claim 1, wherein

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.

3. A contact system according to claim 1 or 2, wherein to 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.

4. A contact system according to any one of claims 1 to 3, wherein the input and output conductive sections are configured such that 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.

5. A contact system according to any one of claims 1 to 4, wherein the input and output conductive sections 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 force 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.

6. A contact system according to claim 5, 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.

7. A contact system according to any one of claims 1 to 6, wherein the first contact further includes an interconnection branch arranged to pass the input current from the input conductive section to one of the second con-

ductive sections other than the output conductive section.

8. A contact system according to claim 7, 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 interconnection branch of the first contact is recirculated towards the output conductive section. 5
9. A contact system according to claim 8, wherein the recirculation conductive section is shaped with an extended section that is arranged substantially parallel to and opposed to the output conductive section. 10
10. A contact system according to any one of claims 7 to 9, wherein 15
the second contact is adapted to establish contact with the first contact via one or more second contact islands provided in number and positions corresponding to one or more first contact islands provided in the first contact, at least one second contact island is provided on said second conducting branch other than the output conducting branch for connecting to at least one corresponding contact island provided in the interconnection branch of the first contact. 20
11. A contact system according to any one of claims 7 to 10, wherein 25
the plurality of second conductive sections are configured to form the second contact with a closed loop, the first and second contacts being configured such that the interconnection branch of the first contact is adapted to electrically contact said second conductive section other than the output conductive section at an intermediate section of the closed loop shape. 30
12. A contact system according to claim 11, wherein said interconnection branch of the first contact is provided as a pair of protrusions configured to make electrical contact with the intermediate section of the second contact at adjacent positions so as to split the outgoing current path in two half-loops between the intermediate section and the output terminal of the second contact. 35
13. A contact system according to any one of claims 7 to 10, wherein 40
the plurality of second conductive sections are 45

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.

14. A switching device for high current discharges, comprising:
a contact system according to any one of claims 1 to 13; 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. 15
15. A switching device according to claim 14, wherein the switching device is one of a electromagnetic relay and an electromagnetic contactor. 20

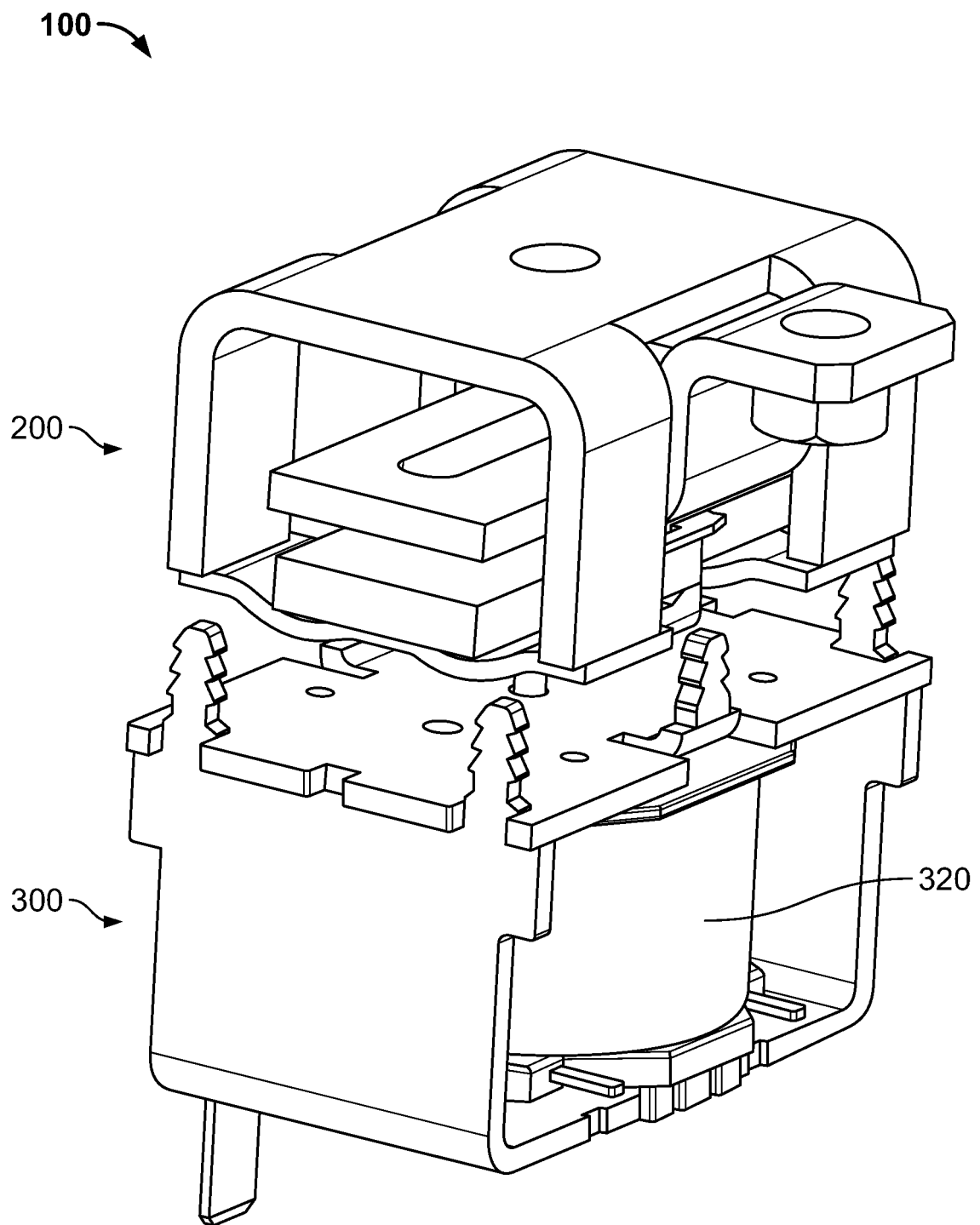


Fig. 1

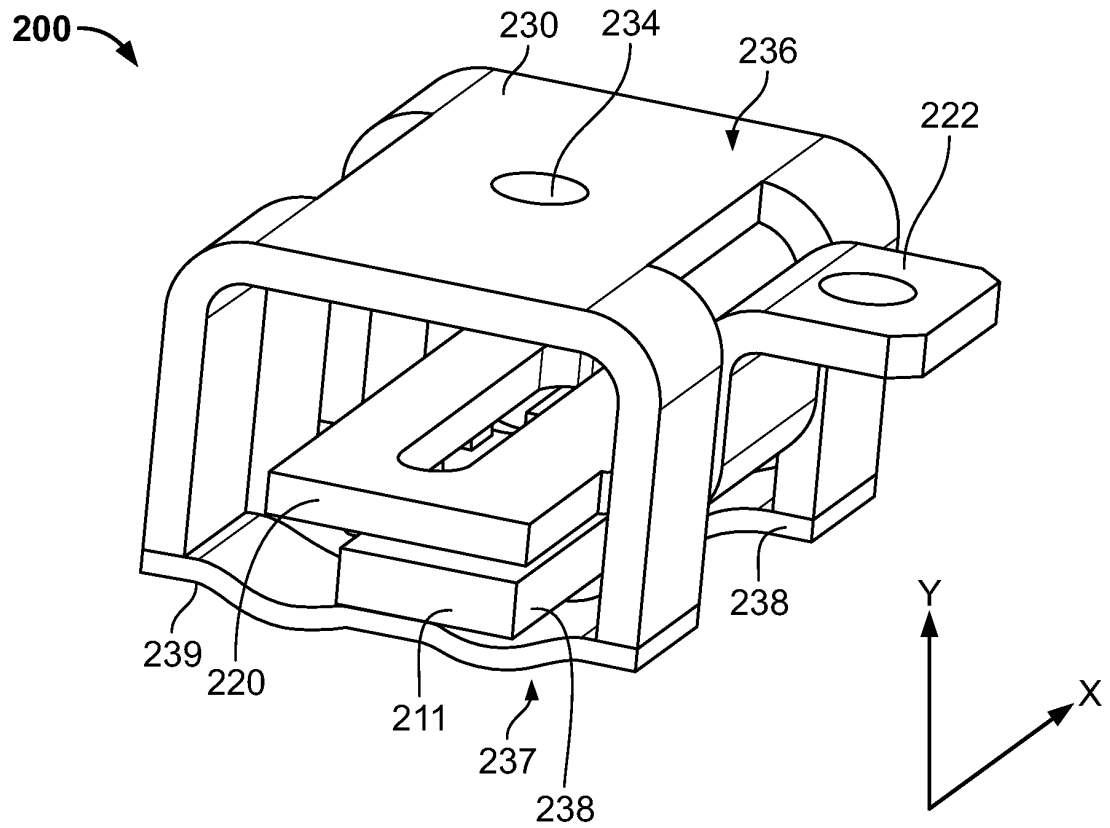


Fig. 2

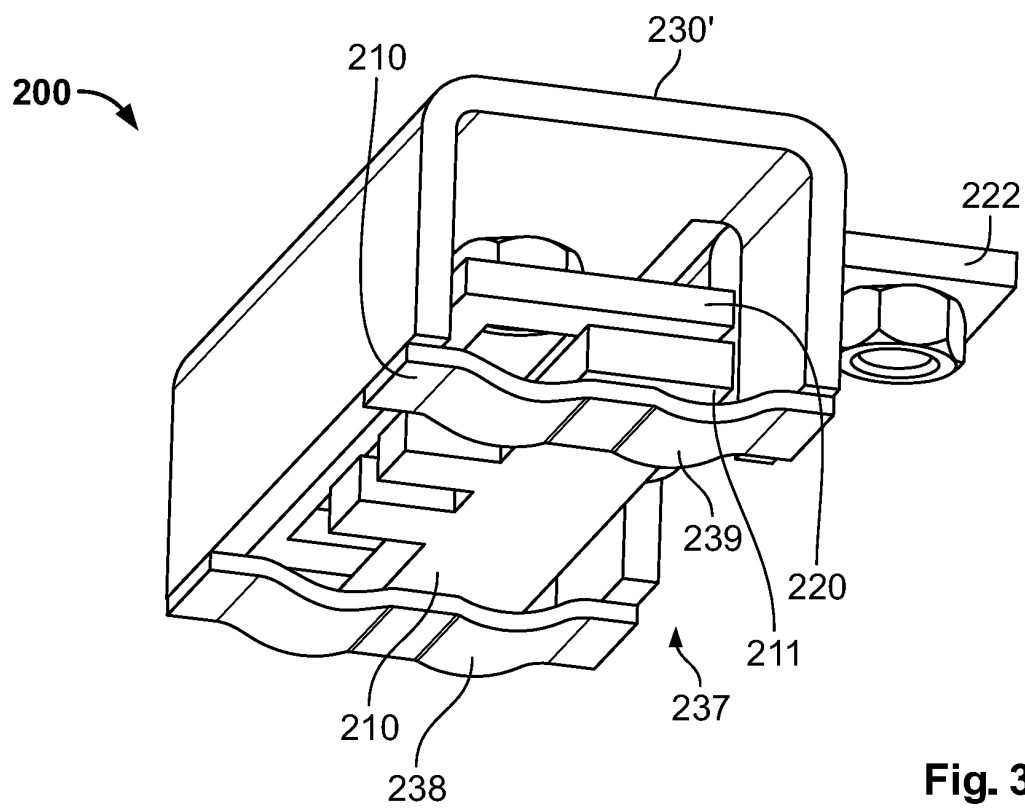


Fig. 3

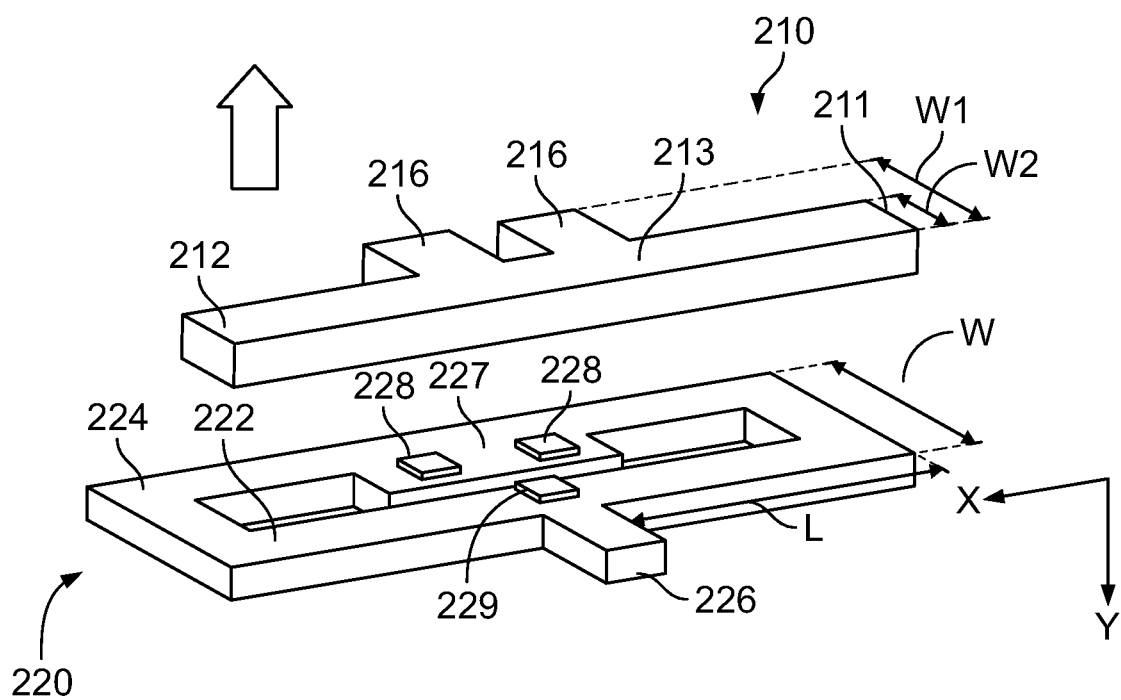


Fig. 4

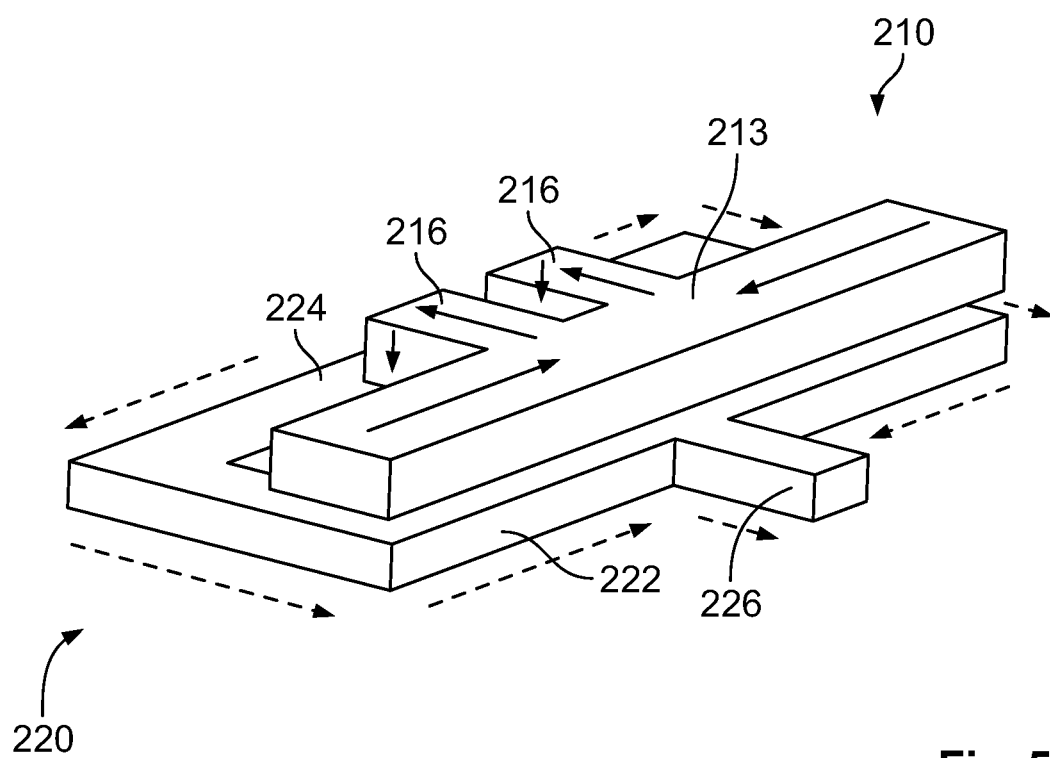


Fig. 5

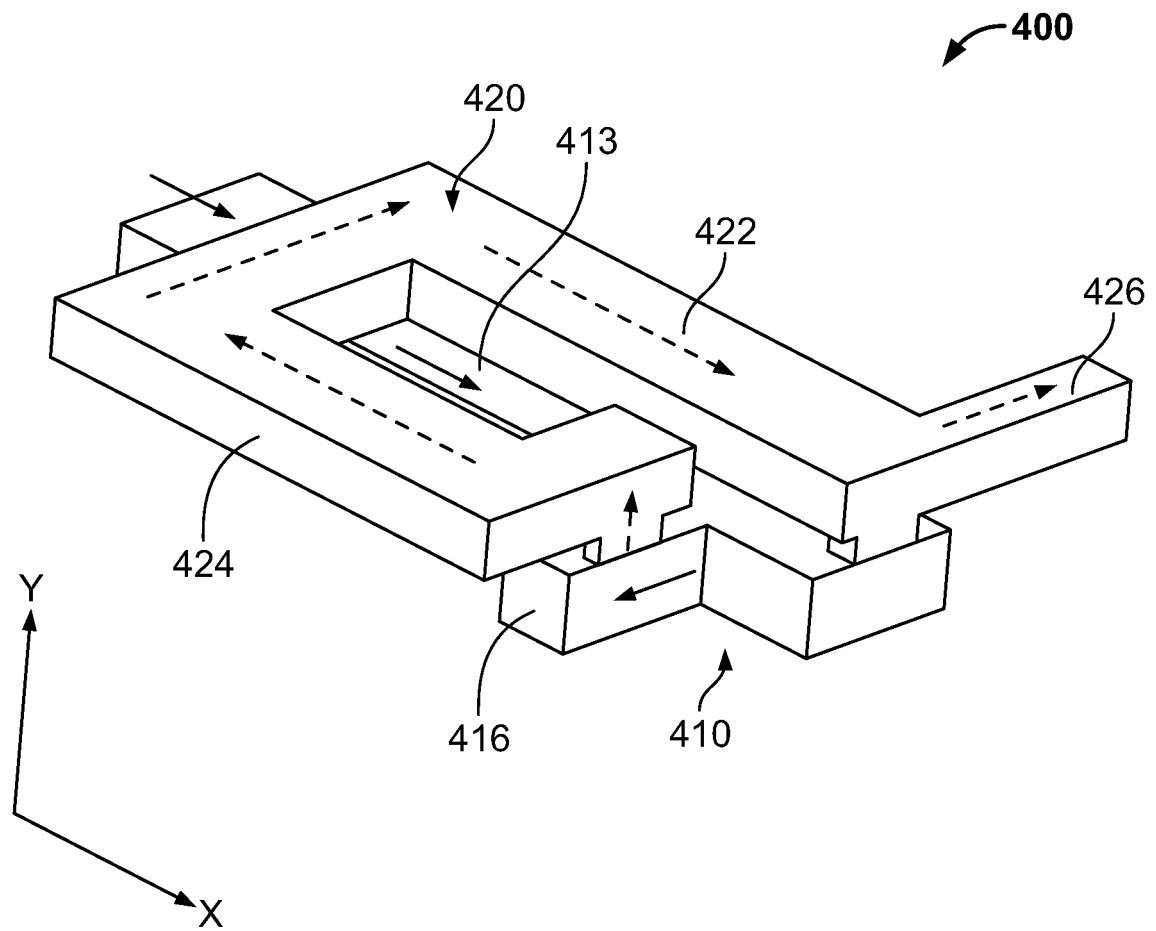


Fig. 6



EUROPEAN SEARCH REPORT

Application Number

EP 21 39 8020

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EPO FORM 1503 03.82 (P04C01)

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X	EP 3 742 464 A1 (ABB SCHWEIZ AG [CH]) 25 November 2020 (2020-11-25)	1-13	INV. H01H1/54
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Y	* column 1, line 11 - line 38 * * column 5, line 50 - column 6, line 16 * * figure 1 *	14, 15	

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The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			H01H
Place of search		Date of completion of the search	Examiner
Munich		20 April 2022	Fribert, Jan
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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20-04-2022

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