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(54) **A bistable magnetic actuator for circuit breakers with electronic drive circuit and method for operating said actuator**

(57) The invention relates to a drive system 20 for a circuit breaker. The drive system comprises an electro-magnetic actuator 10 having a first coil 14, a second coil 15, and an armature 12 arranged to be movable between a first and a second end position by means of the coils 14, 15. In accordance with the invention both coils 14,

15 are energized simultaneously for effectuating the movement of the armature 12 between the two end positions. This is in contrast to the prior art, wherein the coils are energized one at a time; one coil for moving the armature to one of the end positions and the other coil for moving the armature to the opposite end position.

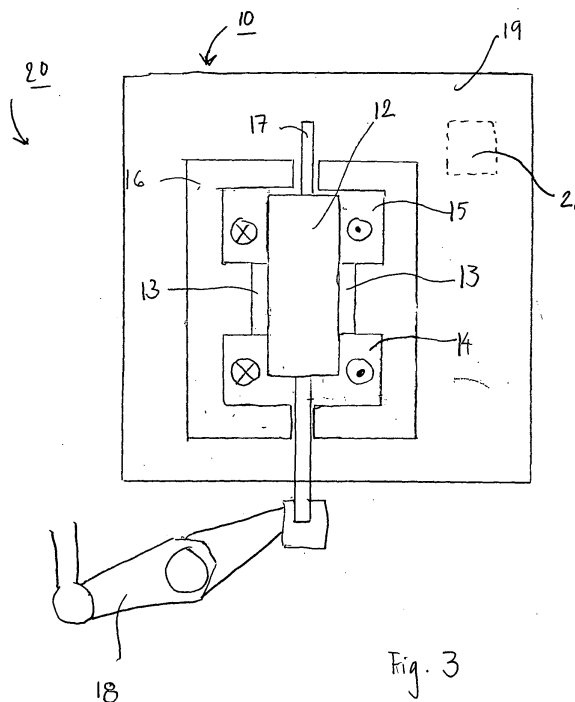


Fig. 3

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Description

Field of the invention

[0001] The invention is related to the field of drive systems for operating circuit breakers. In particular, the invention is related to magnetic actuators used in actuation mechanisms of the circuit breakers.

Background of the invention

[0002] Protective relays are used throughout the electrical power distribution system for providing protection and control. The protective relays detect and isolate faults on transmission and distribution lines by opening and closing circuit breakers. Circuit breakers are thus an important part of power distribution systems and protect the electrical systems from damage caused by overload or short circuit. The circuit breaker is operated by a suitable drive system, which performs the opening and closing of the circuit breaker, and may, for example, be implemented by a magnetic actuator.

[0003] Figure 1 illustrates a state of the art linear magnetic actuator, suitable for operating a circuit breaker. The actuator 1 comprises a central cylindrical moving armature 2, permanent magnets 3, a closing coil 4, an opening coil 5 and a stator 6. The actuator 1 also comprises a shaft 7 extending outside the stator 6 to drive a mechanism for opening and closing circuit breaker contacts.

[0004] In operation, the armature 2 is held at the two ends of its stroke by a magnetic flux produced by the permanent magnets 3; the permanent magnets 3 thus provide a magnetic lock for keeping the armature 2 at one of the end positions. In the figure, the electromagnetic actuator 1 is held in an open position and an air gap 8 is present below the armature 2 adjacent to the closing coil 4. The associated circuit breaker contacts (not illustrated) are thereby held in an open position (tripped). In order to close the circuit breaker, the closing coil 4 has to be energized. The magnetic flux produced by the current flowing through the coil windings of the closing coil 4 is concentrated across the air gap 8 and thereby overcomes the force holding the armature 2 in open position. This causes the armature 2 to be driven over to the closed position. The opening operation is performed in a similar way by energizing the opening coil 5.

[0005] Figures 2A, 2B and 2C illustrate the magnetic fields corresponding to the different positions. In particular, figure 2A illustrates the magnetic fields when the magnetic actuator 1 is in the open position and the closing coil 4 has just been energized; figure 2B illustrates the magnetic field when the magnetic flux produced by the current flowing through the coil windings of the closing coil 4 increases while the force holding the armature 2 in open position is decreased; and figure 2C illustrates the magnetic fields when the armature 2 of the magnetic actuator 1 is driven to the closed position.

[0006] In the prior art solution, the actuator is thus pulled off of the permanent magnet lock. To be able to release the armature 2 from the magnetic lock, the flux generated by the opening coil 5 must be made to exceed the permanent magnet flux. To overcome the permanent magnet flux substantial amounts of energy is required, which adds to the operation costs. Further, high peak currents may occur and this also adds to the costs, since rather expensive high rated components are required.

[0007] In view of the above, it would be desirable to provide an improved means for operating circuit breakers. In particular, the energy storage of the prior art drive systems represents approximately 20 % of their total cost and it would therefore be desirable to provide a more cost-efficient solution.

Summary of the invention

[0008] It is an object of the invention to provide a drive system for circuit breakers providing less energy-consuming circuit breakers and a more energy-efficient operation of them.

[0009] It is another object of the invention to provide a drive system for circuit breakers enabling faster response times of a moving armature of the drive system.

[0010] It is yet another object of the invention to provide a drive system for circuit breakers enabling the use of lower rated components, to thereby lower the cost and size requirements.

[0011] It is still another object of the invention to provide a drive system for circuit breakers having a lower overall size.

[0012] It is yet another object of the invention to provide an improved method for operating circuit breakers, enabling energy savings and faster closing and opening operations of the circuit breakers.

[0013] These objects, among others, are achieved by a drive system, by an electronic drive circuit, and by a method as claimed in the independent claims.

[0014] In accordance with the invention a drive system for a circuit breaker is provided. The drive system comprises an electromagnetic actuator having a first coil, a second coil, and an armature arranged to be movable between a first and a second end position by means of the coils. In accordance with the invention both coils are energized simultaneously for effectuating the movement of the armature between the two end positions. This is in contrast to the prior art, wherein the coils are energized one at a time; one coil for moving the armature to one of the end positions and the other coil for moving the armature to the opposite end position. By means of the inventive drive system considerable energy savings can be obtained, providing cost savings and environmental advantages.

[0015] In a preferred embodiment of the invention, the drive system further comprises permanent magnets for keeping the armature locked at the end positions. The drive system in accordance with the invention releases

the actuator locker provided by the permanent magnets instead of pulling the actuator off of the locker as in the prior art. That is, the permanent magnet locker is neutralized to release the armature of the actuator. By means of this, huge energy savings can be made, approximately up to 60% energy reduction. Up to 80% lower peak currents are obtained, and the rated current for the power switches can be reduced. This in turn provides a less expensive manufacturing, since lower rated components can be used. Lower peak current also entails lower magnetic flux, which in turn enables a reduction of the physical size of the actuator. This also entails a cost saving of up to 50%. Further, the inventive drive system can be utilized in connection with different kinds of actuators. In particular, the inventive drive system enables the use of one common power electronic platform for both the conventional double coil actuator and the new developed single coil actuator.

[0016] In accordance with another embodiment of the invention, the first and second coils are arranged in an anti-series connection. They may thus simultaneously be fed a negative and a positive current, respectively. This is a convenient and easily implemented way of accomplishing the simultaneous feeding thereby enabling the desired energy savings.

[0017] In accordance with still another embodiment of the invention, the coils are arranged so that the magnetic field of one of the coils counteract the magnetic field of the permanent magnets while the magnetic field of the other coil attract the armature, thereby moving the armature to the opposite end position.

[0018] Further embodiments of the invention are defined in the dependent claims.

[0019] In accordance with a further aspect of the invention a method for powering a drive system for a circuit breaker is provided, whereby advantages similar to the above are achieved. In particular, by means of the method, a faster response of the moving armature of the drive system is provided as well as reduced energy consumption of the closing and opening operations of the circuit breakers.

[0020] Further characteristics of the invention and advantages thereof will be evident from the detailed description of embodiments of the present invention given hereinafter and the accompanying figures, which are only given by way of illustration.

Brief description of the drawings

[0021]

Figure 1 illustrates a state of the art magnetic actuator suitable for a medium voltage circuit breaker.

Figures 2A, 2B and 2C illustrate the magnetic fields corresponding to the different positions of the magnetic actuator of figure 1.

Figure 3 illustrates a drive system in accordance with the invention, suitable for a circuit breaker.

Figure 4 illustrates an exemplary powering device for use in the drive system in accordance with the invention.

Figure 5 illustrates the magnetic fields during the initialization of the closing operation.

Figure 6 illustrates the powering device of figure 4 connected to a single coil actuator.

Figure 7 illustrates another exemplary powering device for use in the drive system in accordance with the invention.

Figures 8A-8C illustrate different phases for the closing operation.

Figures 9A-9E illustrate the magnetic fields for different steps of the method in accordance with the invention.

Detailed description of embodiments

[0022] The present invention will now be described with reference first to figure 3. Only parts needed for the understanding of the present invention will be described, but it is realized that other conventionally used parts, such as position sensors, energy storages, vacuum breakers etc., may be included.

[0023] The drive system 20 for a circuit breaker in accordance with the invention comprises an electromagnetic actuator 10, like the prior art actuator described with reference to figure 1. The electromagnetic actuator 10 comprises a central cylindrical moving armature, in the following denoted plunger 12, permanent magnets 13, a closing coil 14, an opening coil 15 and a magnetic yoke 16, preferably made of iron. The electromagnetic actuator 10 is housed within a supporting structure 19. The electromagnetic actuator 10 also comprises a shaft 17 extending outside the supporting structure 19 to drive a mechanism (exemplary mechanism partly shown at reference numeral 18) for opening and closing the circuit breaker contacts (not shown). The circuit breaker may be any suitable one, for example a medium voltage vacuum circuit breaker.

[0024] The magnetic fields of the coils 14, 15 when energized and the magnetic field of the permanent magnets 13 are indicated throughout the figures in a conventional manner.

[0025] In accordance with the invention, the drive system 20 further comprises an electronic drive circuit device, in the following denoted powering device 21 and illustrated schematically in figure 3 by a rectangle in dashed lines. The powering device 21 of the drive system 20 is, inter alia, used for switching the drive system 20

between its opening and closing positions. That is, for instance when a fault is detected and there is a need to trip the circuit breaker, the powering device 21 causes the drive system 20 to switch the circuit breaker to its open position. The circuit breaker may also be reset to assume its normal operation by switching the drive system 20 to its closing position, whereby the circuit breaker is switched to its closed position (i.e. reclosed after having been tripped).

[0026] A first embodiment of the powering device 21 suitable for use in the drive system 20 is illustrated in figure 4. In accordance with the invention, the opening coil 15 and the closing coil 14 are connected in anti-series. The schematic shown in figure 4 is a standard H-bridge driving the opening coil 15 and the closing coil 14 in anti series. For example, during a closing operation, i.e. when the plunger 12 should be moved downwards in figure 3, the opening coil 15 is excited with a negative current. The magnetic flux from the permanent magnets 13 is thereby counter-balanced, or stated differently: the permanent magnets 13 are neutralized. The plunger 12 is thereby released from the magnetic locker that the permanent magnets 13 provide, before start of movement of the plunger 12. The movement of the plunger is then attracted by the other coil, in this case the closing coil 14. In a similar manner, during an opening operation the closing coil 14 is excited with a negative current.

[0027] By counter balancing (neutralizing) the permanent magnet 13 flux, the plunger 12 is released and the required flux generated by the working coil is reduced. The working coil is either the opening coil 15 or the closing coil 14 depending on the desired operation, i.e. the coil that attracts the plunger 12.

[0028] Figure 5 illustrates the magnetic fields during the initialization of the closing operation. The magnetic flux induced by the opening coil 15 is illustrated by the outer field line (arrow I). The magnetic flux from the permanent magnets 13 is illustrated by the inner field line (arrow II), as well as the horizontal field lines. From the figure it is thus clear how the magnetic flux induced by the opening coil 15 counter-balances the magnetic flux from the permanent magnets 13.

[0029] In the above embodiment, the invention has been described and illustrated in connection with a double-coil electromagnetic actuator 10. It is to be noted that the above-described powering device used for powering the actuator 10 may be used for powering a single-coil actuator as well. A circuit diagram illustrating this is shown in figure 6. In a single coil actuator, the current is alternated in order to force the plunger 12 in different directions.

[0030] Further, it is to be noted that separate circuits could be used for controlling the respective coils. For example, a standard H-bridge could be used for controlling the opening coil 15 and another standard H-bridge could be used for controlling the closing coil 14. It is realized that twice the number of components would be required and thus twice the cost. However, in certain ap-

plications this solution could be advantageous, and in view of the lower energy consumption provided by the anti-series connected coils, separate circuits could still be economically justifiable.

[0031] Another embodiment of the powering device 21 suitable for use in the drive system 20 is illustrated in figure 7. Compared to the above-described embodiment, an additional power switch is added, as well as two free wheeling diodes. The added power switch allows overdriving the closing coil 14/opening coil 15 during closing operation/opening operation.

[0032] Figures 8A-8C illustrate different phases for the closing operation. Figure 8A illustrates the start of the closing operation, the two coils 14, 15 being connected in anti-series. The power switches Z1 and Z4 are switched ON and the unbroken line indicate the current paths. As an example, the duration of this phase can be about 20 ms or until the current reaches about 30 A. After this time, the plunger 12 starts to move (downwards in figure 3). The induced voltage in the opening coil 15 is at its maximum.

[0033] Figure 8B illustrates the second phase, when the closing coil is overdriving. At this time, the plunger 12 is released and has started moving. By firing Z5 the whole dc-link voltage is applied across the working coil (i.e. the closing coil 14). The current will increase with significantly higher di/dt, which in turn results in a higher plunger speed, compared with the previous embodiment. The power switches Z1 and Z5 are switched ON and the unbroken line indicate the current paths. Again, in the figure, the dotted line indicates currents when the power switches are off.

[0034] Figure 8C illustrates the final discharging of the closing coil 14. All the power switches are turned off and the dotted lines indicate the currents. The duration of this phase may be approximately 5 to 10 ms.

[0035] The second embodiment of the powering device 21 is primarily suitable for a double-coil electromagnetic actuator. The second embodiment of the powering device 21 may speed up the plunger movement further and the rated currents for the power switches may possibly be reduced.

[0036] The invention is also related to a method for operating an electromagnetic actuator, as described above, in turn suitable for operating a circuit breaker. Figures 9A-9E illustrate the magnetic fields for different steps of the method in accordance with the invention. In particular, the interaction between the magnetic fluxes is illustrated for the first described embodiment of the powering device 21 (the "anti-series connection"). In figure 9A, the electromagnetic actuator 10 is in its open position and the permanent magnets 13 keep the plunger 12 (armature) at this first end position by the permanent magnetic flux. Figure 9B illustrates the case when a negative current energizes the opening coil 15 and a positive current energizes the closing coil 14. The opening coil 15 thereby provides a magnetic field counteracting the magnetic field provided by the permanent magnets 13. The

locker provided by the permanent magnets 13 is thereby neutralized. Figure 9C illustrates how the closing coil 14 starts to attract the plunger 12. Figure 9D illustrates the plunger 12 when it has reached about half way towards the closing position, wherein the closing position is the second end position of the plunger 12.

Figure 9E finally, illustrates the plunger being in the second end position, i.e. the closing position. As shown, the permanent magnets 13 now hold the plunger 12 locked in the closed position.

[0037] In accordance with the method, the opening coil 15 and the closing coil 14 are energized substantially simultaneously in order to move the plunger 12. In particular, the closing coil 14 or the opening coil 15 is fed with a negative current, whereby the permanent magnets 13 are neutralized by the coil being excited with the negative current. At the same time, the other coil is fed with a current so as to move the plunger 12 towards one of its end positions. When the plunger 12 has stopped moving, the permanent magnets 13 again hold it locked at the end position.

[0038] It is to be noted that if a solution comprising separate powering devices for controlling the respective coils is used, then the step of neutralizing the permanent magnets 13 may be initiated before the other coil, i.e. the working coil, is energized in order to attract the plunger. The working coil may be energized after a little while. They are however working in parallel for effectuating the movement of the plunger.

[0039] In summary, the present invention provides an inventive arrangement and way of operating an electromagnetic actuator. In the prior art, only one of the coils of the actuator is used at a time; the closing coil is energized when a closing operation is to be performed and the opening coil is energized when the opening operation is to be performed. In accordance with the invention, both coils are utilized in the opening operation as well as in the closing operation. A substantial energy saving is thereby accomplished, along with improved peak currents and faster response times of the moving armature of the actuator. Further still, the inventive drive system also enables significant cost saving for the actuator since the amount of iron can be reduced with up to 50%.

Claims

1. A drive system (20) for a circuit breaker, the drive system (20) comprising an electromagnetic actuator (10) having a first coil (14), a second coil (15), and an armature (12) arranged to be movable between a first and a second end position by means of said first and second coils (14, 15), **characterised in that** said, first and second coils (14, 15) are arranged so as to be energized substantially simultaneously for accomplishing movements of said armature (12) between said first and second end positions.

2. The drive system (20) as claimed in claim 1, wherein said electromagnetic actuator (10) further comprises permanent magnets (13) arranged to keep said armature (12) locked at said first and second end positions.
3. The drive system (20) as claimed in claim 1 or 2, wherein said first and second coils (14, 15) are arranged in an anti-series connection.
4. The drive system (20) as claimed in any of claims 1-3, wherein said first and second coils (14, 15) are fed a negative and a positive current, respectively.
5. The drive system (20) as claimed in any of claims 2-4, wherein said coils (14, 15) are arranged so that the magnetic field of one of said first and second coils (14, 15) counteract the magnetic field of said permanent magnets (13) while the magnetic field of the other one of said first and second coils (14, 15) attract said armature (12).
6. The drive system (20) as claimed in any of claims 1-5, wherein said second coil (15) is an opening coil arranged to move said armature (12) to an open position, said open position being said first end positions.
7. The drive system (20) as claimed in any of claims 1-6, wherein said first coil (14) is a closing coil arranged to move said armature (12) to a close position, said close position being said second positions.
8. The drive system (20) as claimed in any of claims 1-7, wherein said first and second coil (14, 15) are arranged at a respective end position of said armature (12).
9. The drive system (20) as claimed in any of claims 1-8, further comprising an electronic drive circuit (21).
10. The drive system (20) as claimed in claim 9, wherein said electronic drive circuit (21) is arranged to switch the drive system (20) between its first and second end positions.
11. The drive system (20) as claimed in claim 9 or 10, wherein said electronic drive circuit (21) comprises an H-bridge.
12. The drive system (20) as claimed in any of claims 1-8, further comprising two drive circuits, one circuit for controlling said first coil (14) and one circuit for controlling said second coil (15).
13. An electronic drive circuit (21) for use in a drive system (20) as claimed in any of claims 1-11, **characterised in that** said electronic drive circuit (21) is arranged to switch the drive system (20) between its first and second end positions.

terized by means for connecting said first and second coils (14, 15) in an anti-series connection.

14. A method for operating an electromagnetic actuator (10) for a circuit breaker, the electromagnetic actuator (10) comprising a first coil (14), a second coil (15), an armature (12) movable between a first and a second end positions by means of said first and second coils (14, 15), and permanent magnets (13) keeping said armature (12) locked at said first and second end positions, **characterized by** the step of:

- energizing said first and second coils (14, 15) substantially simultaneously for moving said armature (12).

15. The method as claimed in claim 14, said step of energizing comprising:

- exciting said first coil (14) or said second coil (15) with a negative current, whereby said permanent magnets (13) are neutralized by the coil being excited with the negative current, and
- exciting the other coil of said first and second coils (14, 15) with a current so as to move said armature (12) towards one of said end positions.

16. The method as claimed in claim 15, wherein said steps of exciting said first and second coils (14, 15) are performed essentially simultaneously.

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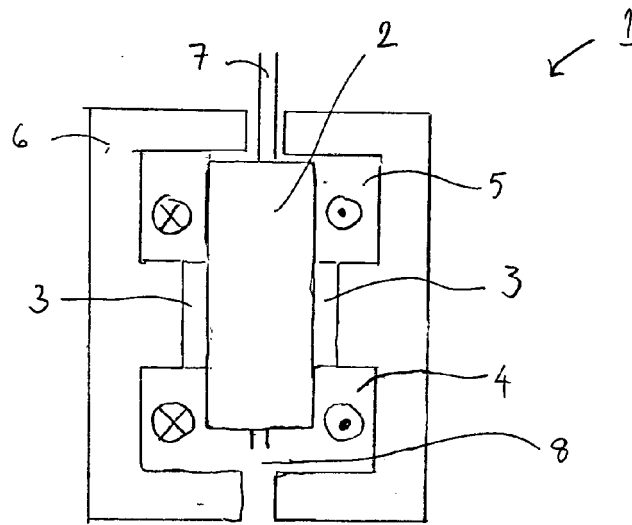
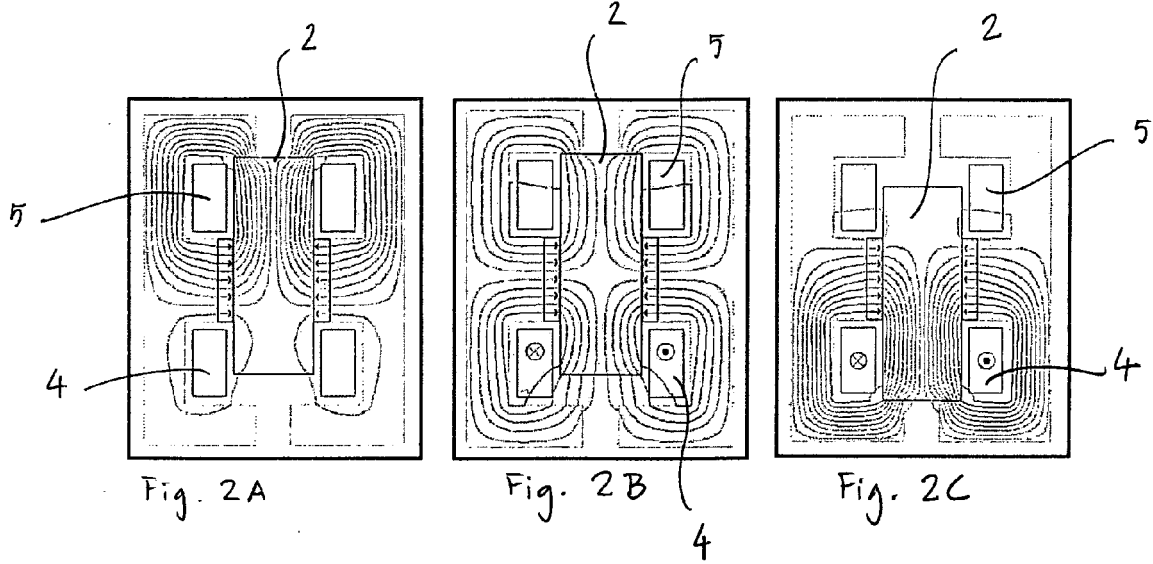
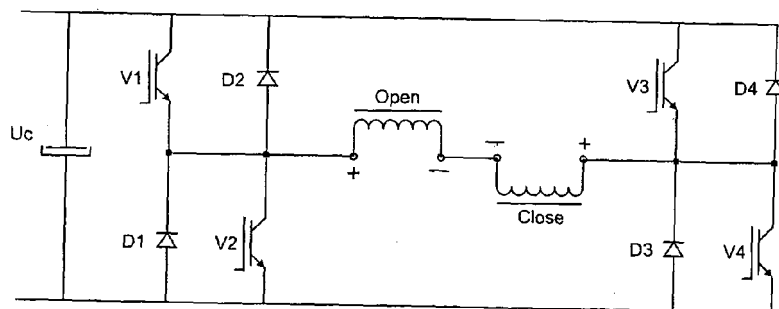
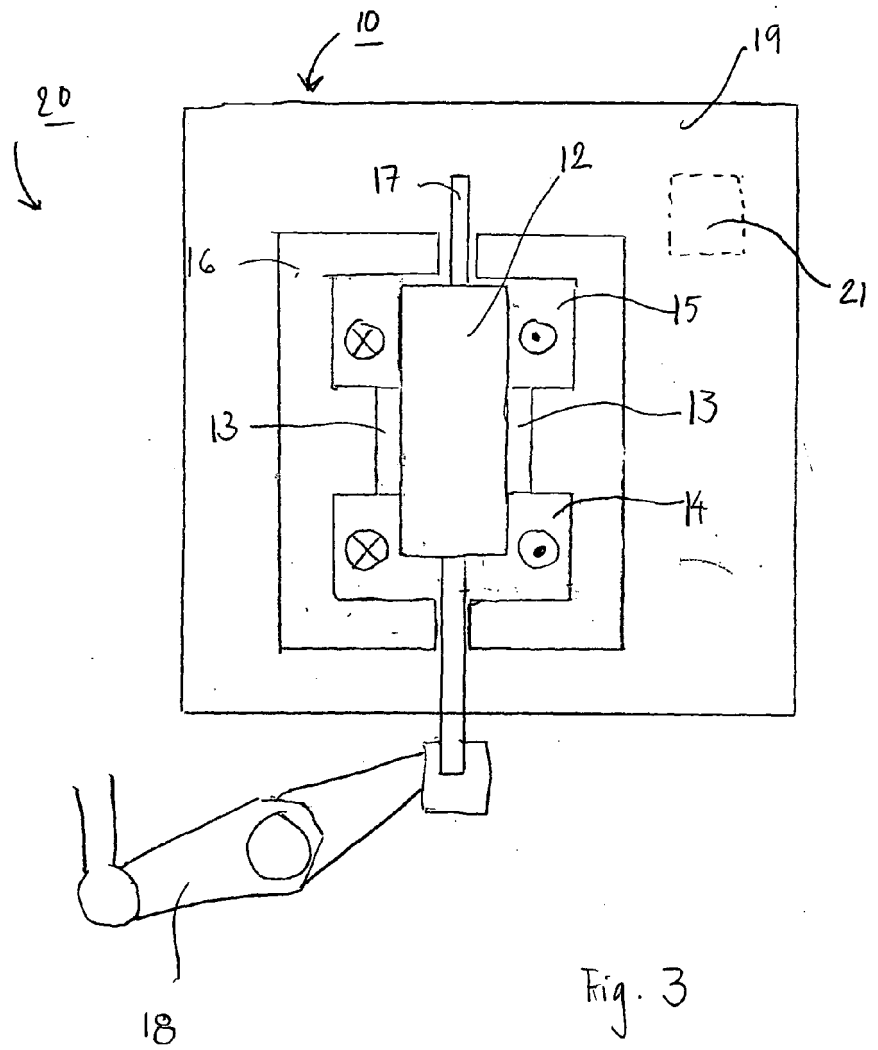


Fig. 1 (Prior Art)





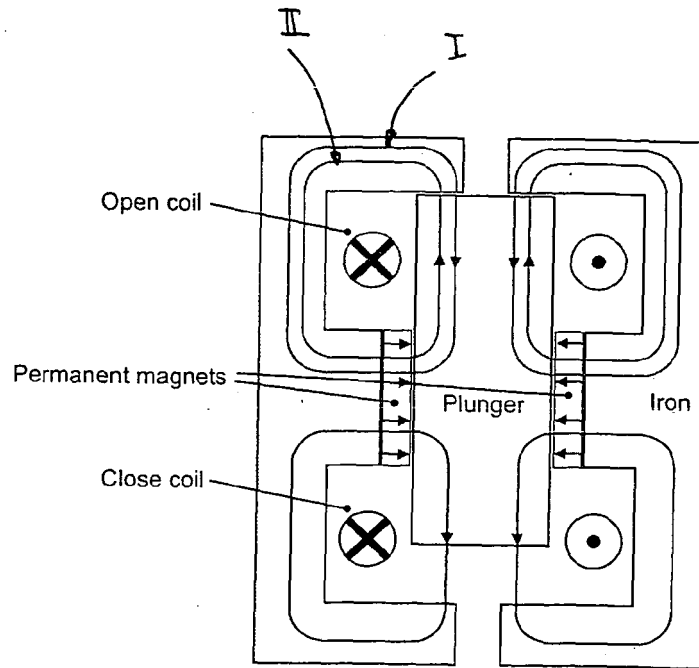


Fig. 5

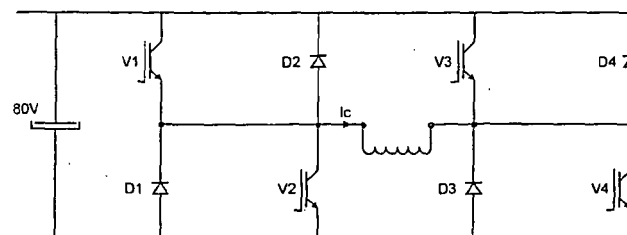


Fig. 6

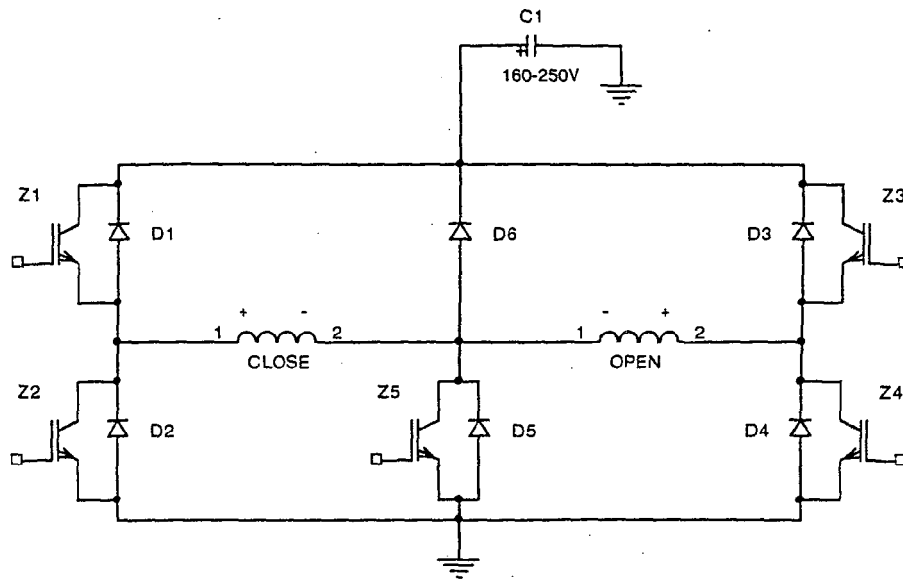


Fig. 7

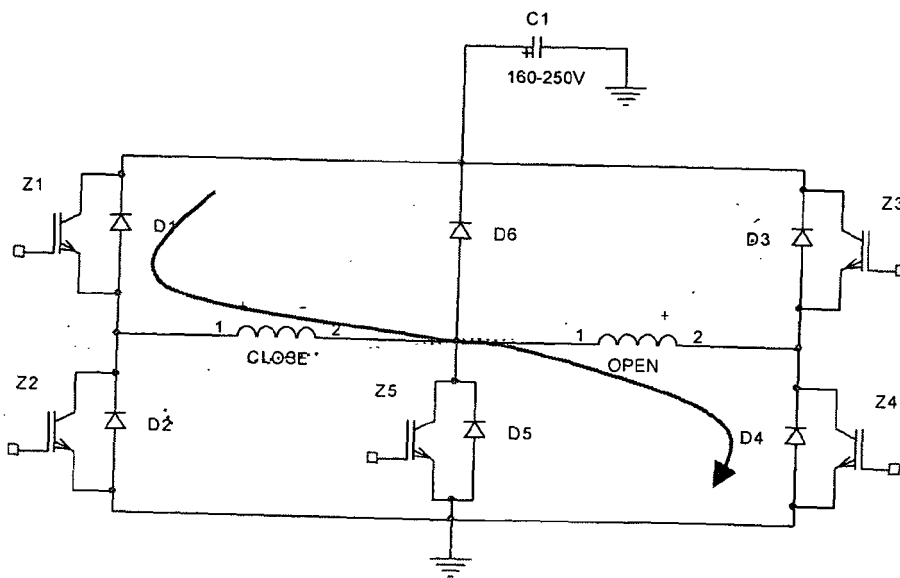


Fig. 8A

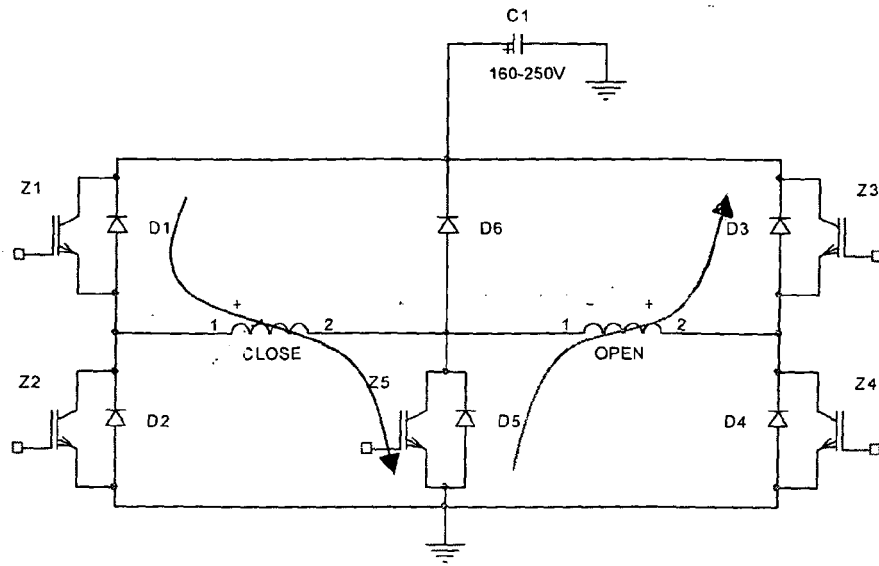


Fig. 8B

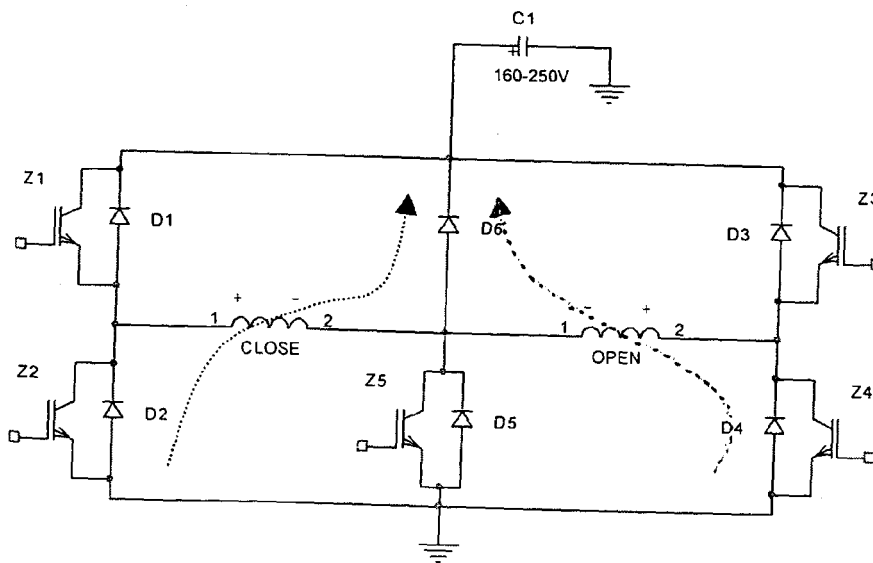
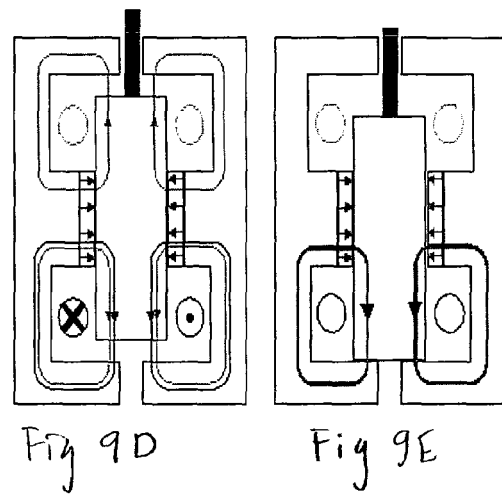
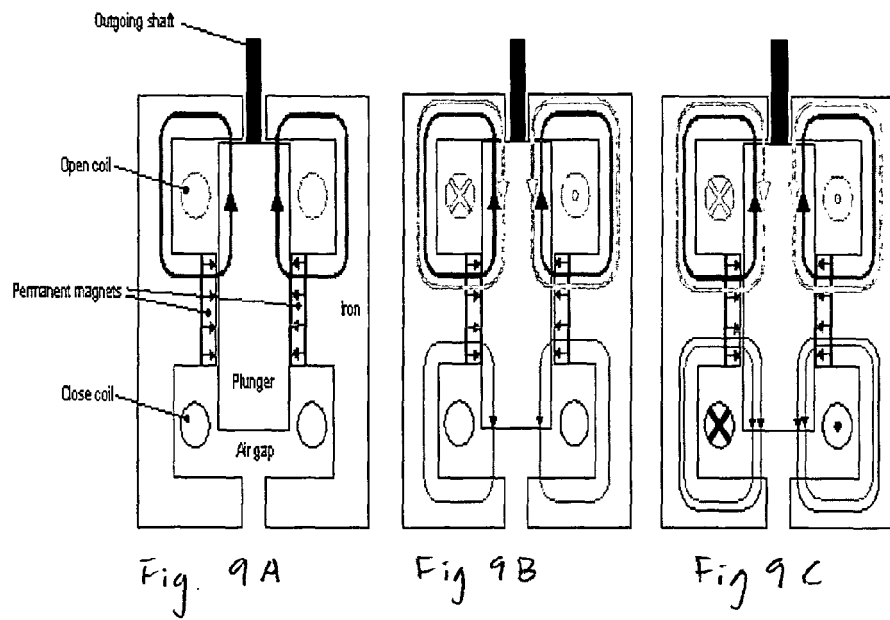


Fig. 8C





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 44 5013

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2004/093718 A1 (TAKEUCHI TOSHIE [JP] ET AL) 20 May 2004 (2004-05-20) * paragraph [0074]; figures 7,10A,18,20 * -----	1-16	INV. H01H33/66
X	EP 0 871 192 A2 (ABB RESEARCH LTD [CH]) 14 October 1998 (1998-10-14) * page 3, lines 29-33 * -----	1-16	
X	DE 199 29 572 A1 (SIEMENS AG [DE]) 4 January 2001 (2001-01-04) * the whole document * -----	1,14	
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
The Hague		20 August 2007	Overdijk, Jaco
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EPO FORM 1503 03.82 (P04C01)

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

EP 07 44 5013

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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20-08-2007

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2004093718 A1		20-05-2004	CN 1501414 A	02-06-2004
			DE 10347452 A1	24-06-2004
			FR 2847380 A1	21-05-2004
			JP 3723174 B2	07-12-2005
			JP 2004165075 A	10-06-2004
			KR 20040042812 A	20-05-2004
			TW 229881 B	21-03-2005

EP 0871192 A2		14-10-1998	CN 1182273 A	20-05-1998
			ES 2241025 T3	16-10-2005
			IT MI962328 A1	11-05-1998
			PT 871192 T	31-08-2005
			US 6084492 A	04-07-2000

DE 19929572 A1		04-01-2001	AU 6148600 A	09-01-2001
			CN 1357166 A	03-07-2002
			WO 0079672 A1	28-12-2000
			EP 1188222 A1	20-03-2002
			US 6888269 B1	03-05-2005
