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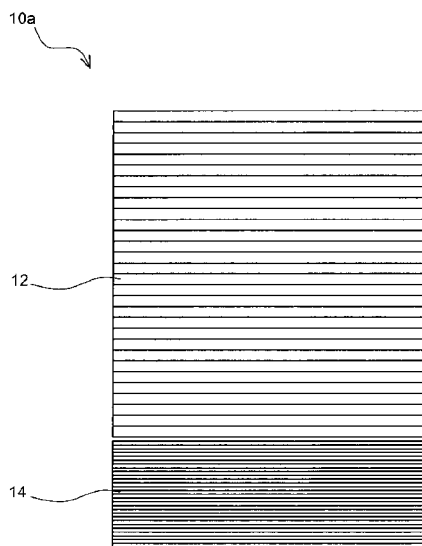


FIG. 1

(57) Abstract: A magnetic fault current limiter core (10a) comprising at least one first magnetic element (12) and at least one second magnetic element (14), the magnetic elements (12,14) being arranged to define a substantially parallel array of magnetic elements (12,14), the or each first magnetic element (12) including a soft magnetic material and the or each second magnetic element (14) including a hard magnetic material, wherein the or each soft magnetic material in a non-saturated state has a higher magnetic permeability than the or each hard magnetic material.

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## A CORE

This invention relates to a magnetic fault current limiter core and its use in a magnetic fault  
5 current limiter.

When operating any electrical apparatus, the electrical current flowing through the apparatus is typically maintained within a predetermined current rating of the electrical apparatus. However, fault or  
10 other abnormal operating conditions in the electrical apparatus may lead to the development of a high fault current exceeding the current rating of the electrical apparatus. For example, during operation of power transmission networks, voltage source converters may be  
15 vulnerable to DC side faults that present a short circuit with low impedance across the DC power transmission lines or cables. Such faults can occur due to damage or breakdown of insulation, movement of conductors or other accidental bridging between  
20 conductors by a foreign object.

The development of high fault current may not only result in damage to the electrical apparatus components, but also result in the electrical apparatus being offline for a period of time. This results in  
25 increased cost of repair and maintenance of damaged electrical apparatus hardware, and inconvenience to end users relying on the working of the electrical apparatus.

The adverse effects may be prevented by  
30 limiting the magnitude of the high fault current using a current limiter.

A known solution for a current limiter is in the form of a magnetic fault current limiter. The magnetic fault current limiter behaves like a variable inductor, which presents low impedance during normal operating conditions and high impedance during fault conditions which results in the development of high fault current in an associated power system. In magnetic fault current limiters that employ permanent magnet material, the magnetic flux passes through the permanent magnet material during normal operating conditions when the associated power system is in a fault-free state, and during fault conditions.

The passing of the magnetic flux through the permanent magnet material results in induced eddy currents and magnetic hysteresis. This not only results in power losses in the current limiter, but also leads to a rise in temperature of the permanent magnet material, which is undesirable because permanent magnet materials may suffer a decrease in performance above a specific temperature.

The size of induced eddy currents can be reduced by sub-dividing a single block of the permanent magnet material into a plurality of thin plates. Each of these plates may be coated with a thin, electrically insulating material and are then joined together via mechanical and/or adhesive means. The relatively smaller cross-section of each plate reduces the circulation of the induced eddy currents and thereby minimises the size of the induced eddy current.

The magnetic flux flowing through the permanent magnet material may be kept relatively low to

reduce hysteresis losses because permanent magnet material experiences a larger degree of magnetic hysteresis as the magnetic flux density increases. This approach however means that the magnetic fault  
5 current limiter will be unsuitable for use above a specific level of electrical current, and thus limits the operating range of the limiter.

The heating effect of hysteresis losses in the permanent magnet material can be reduced by adding  
10 a cooling system to the magnetic fault current limiter. The cooling system however not only forms an additional source of power loss but also decreases device reliability due to the possible breakdown of the cooling system and its various components such as  
15 detection and control equipment, and auxiliary power supplies. The presence of the cooling system also leads to increased hardware costs, size and weight.

Alternatively, the permanent magnet material may be designed to adopt a topology, such as a  
20 large surface area, that encourages natural cooling. The permanent magnet material would however need to occupy a large amount of space so as to be sufficiently cooled during the operation of the magnetic fault current limiter.

25 According to an aspect of the invention, there is provided a magnetic fault current limiter core comprising at least one first magnetic element and at least one second magnetic element, the magnetic elements being arranged to define a substantially  
30 parallel array of magnetic elements, the or each first magnetic element including a soft magnetic material and

the or each second magnetic element including a hard magnetic material, wherein the or each soft magnetic material in a non-saturated state has a higher magnetic permeability than the or each hard magnetic material.

5                   The provision of a substantially parallel array of first and second magnetic elements results in a magnetic fault current limiter core with reduced hysteresis losses because the amount of magnetic flux flowing through the hard magnetic material during  
10 normal operation of the magnetic fault current limiter is minimised.

In use, when a coil is wound around the core to form a magnetic fault current limiter, the substantially parallel arrangement of the first and  
15 second magnetic elements and the higher magnetic permeability of the non-saturated soft magnetic material allow the majority of the magnetic flux to flow preferentially through the soft magnetic material during normal operating conditions of an associated  
20 electrical circuit. This means that a minimal amount of magnetic flux passes through the hard magnetic material during normal operating conditions. This leads to a decrease in hysteresis losses in the core because the soft magnetic material exhibits lower levels of  
25 magnetic hysteresis than the hard magnetic material.

In the event of a fault or other abnormal operating condition resulting in high fault current in the associated electrical circuit, the switch of the flow path of the magnetic flux to the hard magnetic  
30 material leads to high impedance in the coil, which acts to limit the fault current. Although this change

in magnetic flux flow path results in high levels of magnetic hysteresis, the magnetic flux only flows through the hard magnetic material for short periods of time. Consequently the resulting hysteresis losses in  
5 the hard magnetic material are kept at a minimum.

The substantially parallel arrangement of the first and second magnetic elements therefore minimises the amount of magnetic flux flowing through the hard magnetic material during normal operation of  
10 the magnetic fault current limiter and thereby reduces hysteresis losses in the magnetic fault current limiter core.

In addition, the substantially parallel arrangement of the first and second magnetic elements  
15 also means that the control of the flow of magnetic flux through the magnetic fault current limiter is passive in nature and does not require additional control in the form of detection and/or switching equipment. This not only minimises hardware size,  
20 weight and costs, but also increases reliability of the current limiter by removing the risk of breakdown of the associated detection and/or control equipment.

Preferably at least one first magnetic element is separated from at least one neighbouring  
25 second magnetic element by an insulator. The or each insulator may be an air gap or a solid non-conducting material such as an adhesive, varnish, mica or other similar material.

In embodiments of the invention, the  
30 magnetic fault current limiter core may further include a plurality of first magnetic elements and/or a

plurality of second magnetic elements wherein the magnetic elements are arranged to form alternating primary layers of first and second magnetic elements.

In other embodiments, at least one first  
5 magnetic element and/or at least one second magnetic element may include a plurality of secondary layers of magnetic material, each secondary layer being separated from the or each neighbouring secondary layer by an insulator.

10 The provision of primary and/or secondary layers of magnetic elements helps to provide a magnetic fault current limiter core in which the power losses resulting from the creation of eddy currents are reduced. The magnitude of any eddy currents induced in  
15 the magnetic elements when a changing flux flows through the magnetic elements is greatly reduced by the relatively small cross-section of each primary and/or secondary layer of first and/or second magnetic elements, and their electrical isolation one from  
20 another, which together restrict the circulation of the eddy currents.

The magnetic fault current limiter core may include at least one magnetic element having a hollow bore wherein a portion of at least one first magnetic  
25 element is housed within a hollow bore of a second magnetic element having a hollow bore and/or a portion of at least one second magnetic element is housed within a hollow bore of a first magnetic element.

The magnetic fault current limiter core  
30 also may include at least one magnetic element having a hollow and sealed interior, wherein at least one first

magnetic element is housed within a hollow and sealed interior of a second magnetic element and/or at least one second magnetic element is housed within a hollow and sealed interior of a first magnetic element.

5                   In embodiments of the invention each magnetic element may be a rod or bar. In other embodiments, the cross-section of each magnetic element may be circular, oval or polyhedral in shape.

                  The structure of the magnetic fault current  
10 limiter core may vary depending on the requirements of the application associated with the magnetic fault current limiter.

                  Preferably in a fault current limiter core in which at least one first magnetic element is  
15 separated from at least one neighbouring second magnetic element by an air gap, at least one such air gap is filled with electrically insulating material.

                  The use of electrically insulating material in this manner not only provides electrical insulation  
20 between neighbouring magnetic elements, but also provides a supporting structure to hold neighbouring magnetic elements in place.

                  According to a second aspect of the invention, there is provided a magnetic fault current  
25 limiter comprising a magnetic fault current limiter core according to any of the above mentioned embodiments and at least one electrical conductor wound around a portion of the or each core to define a coil.

                  The structure of the current limiter is  
30 straightforward to manufacture and easily adapted to

fit into any apparatus requiring one or more current limiters.

In embodiments of the invention, the or each electrical conductor may be wound around the first  
5 and second magnetic elements.

Winding the or each electrical conductor around both first and second magnetic elements allows the generated magnetic field to have a greater effect on the magnetic elements, and thereby improves the  
10 efficiency of the current limiter in controlling the flow path of the magnetic flux and limiting fault current.

Preferably, in use, the or each electrical conductor carries an alternating current.

15 The or each coil is preferably operably connected in use to one or more electrical circuits. In such embodiments, the or each coil presents an impedance to minimise a fault current created by a fault, in use, in an electrical circuit.

20 The current limiter may be used to minimise fault current in one or more associated electrical circuits during fault conditions or other abnormal operating conditions so as to prevent damage to the or each associated electrical circuit.

25 In other embodiments, the or each coil may be in the form of a solenoid or a toroid so to provide a uniform and controlled magnetic field.

Preferred embodiments of the invention will now be described, by way of non-limiting examples, with  
30 reference to the accompanying drawings in which:

Figure 1 shows a magnetic fault current limiter core according to a first embodiment of the invention; and

Figure 2 shows a magnetic fault current limiter core according to a second embodiment of the invention.

A magnetic fault current limiter core 10a according to a first embodiment of the invention is shown in Figure 1.

The magnetic fault current limiter core 10a comprises a first magnetic element 12 and a second magnetic element 14 arranged to define a substantially parallel array of magnetic elements 12,14.

Each first magnetic element 12 includes a plurality of secondary layers of soft magnetic material. Preferably the soft magnetic material is electrical steel, which has high magnetic permeability and exhibits low hysteresis losses.

Each secondary layer may be coated with a thin, electrically insulating material to provide electrical insulation between neighbouring secondary layers. These coated secondary layers may be joined together mechanically and/or using adhesive to form the first magnetic element 12. It is envisaged that in embodiments of the invention, each secondary layer may be separated from each neighbouring secondary layer by an air gap, and in some instances at least one such air gap may be additionally filled with electrically insulating material.

The provision of secondary layers reduces power losses associated with eddy currents induced in the magnetic fault current limiter core. This is

because the magnitude of any eddy currents induced in the magnetic elements when a changing flux flows through the magnetic fault current limiter core is greatly reduced by the relatively small cross-section  
5 of each secondary layer, which greatly reduces the circulation of the eddy currents.

In addition, the electrical isolation of the secondary layers from one another restricts the circulation of eddy currents.

10 The second magnetic element 14 includes a hard magnetic material and is separated from the first magnetic element 12 by an air gap, which, in other embodiments, may be filled with electrically-insulating material.

15 A magnetic fault current limiter core 10b according to a second embodiment of the invention is shown in Figure 2.

The magnetic fault current limiter core 10b comprises a plurality of first magnetic elements 12 and  
20 a plurality of second magnetic elements 14, these magnetic elements being arranged to form alternating primary layers of first and second magnetic elements 12,14.

Each primary layer may be coated with  
25 electrically insulating material to provide electrical insulation between neighbouring primary layers. As outline above, these coated primary layers may be joined together mechanically and/or using adhesive to form the magnetic fault current limiter core. It is  
30 envisaged that in embodiments of the invention, each primary layer may be separated from each neighbouring

primary layer by an air gap, and in some instances at least one such air gap may be additionally filled with electrically insulating material.

The thickness of each of the second  
5 magnetic elements 14 may be thicker than that of each of the first magnetic elements 12 due to the larger electromagnetic skin depth of hard magnetic materials.

It is envisaged that, in embodiments of the invention, the magnetic fault current limiter core may  
10 comprise any number of first and second magnetic elements 14 and/or at least one of the first and/or second magnetic elements 14 may include a plurality of secondary layers of the respective magnetic material.

In other embodiments, at least one of  
15 either or both of the first and second magnetic elements 12,14 may have a hollow bore so that a portion of at least one first magnetic element 12 is housed within a hollow bore of a second magnetic element 14 having a hollow bore and/or a portion of at least one  
20 second magnetic element 14 is housed within a hollow bore of a first magnetic element 12.

In further embodiments, at least one of either or both of the first and second magnetic elements 12,14 may have a hollow and sealed interior,  
25 wherein at least one first magnetic element 12 is housed within a hollow and sealed interior of a second magnetic element 14 and/or at least one second magnetic element 14 is housed within a hollow and sealed interior of a first magnetic element 12.

Preferably each magnetic element is a rod or bar, and/or the cross-section of each magnetic element is circular, oval or polyhedral in shape.

To form a magnetic fault current limiter, one or more electrical conductors, e.g. electrically conductive wires, may be wound around a portion or the whole of the magnetic fault current limiter core 10a,10b to define one or more coils. Preferably the or each electrically conductive wire is wound around the first and second magnetic elements so as to allow the magnetic hysteresis in the hard magnetic material to have a greater effect on the coil impedance, and thereby improve the efficiency of the current limiter.

The or each coil and the core 10a,10b forms a magnetic fault current limiter which, in use, acts to limit or extinguish fault current in an associated electrical circuit during fault conditions or other abnormal operating conditions.

In use, the or each coil carries an alternating current, which may take the form of a sinusoidal waveform or other types of waveforms. As such, the current limiter may be operably associated with one or more electrical circuits carrying alternating current such as power converters and electric motors.

During operation of the associated electrical circuit, current flows through the associated electrical circuit and through the coil wound around the core 10a,10b. The flow of current through the coil results in the generation of magnetic flux flowing through the core 10a,10b inside the coil,

which leads to magnetization and demagnetization of the magnetic materials of the first and second magnetic elements 12,14 as the alternating current passes through the coil.

5 For the purposes of this specification, positive and negative terms refer to the direction of the magnetizing force and the magnetic flux density.

In order to generate a first magnetic field about the coil, the alternating current flows through  
10 the coil in a forward direction. The increase in magnitude of the alternating current in the forward direction leads to a corresponding increase in magnetizing force in a positive direction, which in turn leads to a development of a positive magnetic flux  
15 density within the magnetic material of the core 10a,10b. The positive magnetic flux density reaches its maximum value at the peak value of the alternating current in the forward direction.

After arriving at its peak value in the  
20 forward direction, the alternating current begins to decrease to zero current, which leads to a corresponding decrease in magnetizing force in the positive direction. At zero current, the magnetizing force has a zero value.

25 The decrease in magnetizing force in the positive direction leads to a decrease in the positive magnetic flux density within the magnetic material. The magnetic material however may retain a positive magnetic flux density at zero alternating current and  
30 magnetizing force. This is because application of a magnetizing force to the magnetic material leads to

magnetization of the magnetic material, which may remain magnetized even after the magnetizing force is completely removed. The retention of magnetism in the magnetic material after removal of the magnetizing  
5 force is known as permanent magnetism.

In order to generate a second magnetic field about the coil, the alternating current flows through the coil in a reverse direction. The increase in magnitude of the alternating current in the reverse  
10 direction leads to a corresponding increase in magnetizing force in the negative direction. The permanent magnetism in the magnetic material however means that the magnetic flux density in the magnetic material will remain positive until the magnetizing  
15 force in the negative direction is sufficiently large to demagnetize the magnetic material.

After the magnetic material is demagnetized, further increases in magnitude of the alternating current in the reverse direction and  
20 thereby the magnetizing force in the negative direction leads to a development of a negative magnetic flux density within the magnetic material. The negative magnetic flux density within the magnetic material reaches its maximum negative value at the peak value of  
25 alternating current in the reverse direction.

During the change of flow of the alternating current from the reverse direction to the forward direction, the magnetic material retains a negative magnetic flux density until the magnetizing  
30 force in the positive direction is sufficiently large to demagnetize the magnetic material. After

demagnetization of the magnetic material, further increases in magnitude of the alternating current in the forward direction, and thereby the magnetizing force in the positive direction, leads to a development  
5 of a positive magnetic flux density within the magnetic material up to its maximum value at the peak value of the alternating current in the forward direction.

The cyclic behaviour mentioned above defines a closed hysteresis loop which describes a  
10 relationship between the magnetizing force and the magnetic flux density. The shape and size of the magnetic hysteresis loop affects the impedance presented by the coil to the associated electrical circuit.

15 The impedance of the coil is a function of coil resistance and reactance.

Additional energy is required to overcome the magnetic hysteresis of the magnetic material. The expenditure of this additional energy contributes to an  
20 increase in coil resistance. Coil resistance therefore increases with the level of magnetic hysteresis in the core.

Coil reactance is a function of coil inductance, which in turn is proportional to the  
25 magnetic material's magnetic permeability. The magnetic permeability is equal to the rate of change of magnetic flux density with magnetizing force, which is dependent on the shape and size of the magnetic hysteresis loop. A wide hysteresis loop leads to steep rate of changes  
30 of magnetic flux density with magnetizing force, and thereby higher values of magnetic permeability, as the

alternating current approaches its peak positive or negative value. Higher values of magnetic permeability lead to increases in coil inductance and thereby coil reactance.

5                   During normal operating conditions, the soft magnetic material of the or each first magnetic element 12 has a higher magnetic permeability than the hard magnetic material of the or each second magnetic element 14 when the soft magnetic material is in a non-  
10 saturated state. This difference in magnetic permeability therefore allows the majority of the magnetic flux to flow preferentially through the soft magnetic material of the or each first magnetic element 12 of the core 10a,10b and thereby minimise the amount  
15 of magnetic flux flowing through the hard magnetic material of the or each second magnetic element 14 of the core.

This leads to a reduction in power losses associated with hysteresis in the core 10a,10b during  
20 normal operation of the associated electrical circuit because soft magnetic materials exhibit lower levels of magnetic hysteresis, and therefore a narrower hysteresis loop, than hard magnetic materials. The low levels of magnetic hysteresis exhibited by the soft  
25 magnetic materials coupled with the relatively low current levels also result in the or each coil presenting low impedance to the associated electrical circuit and thereby having minimal influence on the flow of the alternating current during normal operation  
30 of the associated electrical circuit.

In the event of a fault or other abnormal operating condition resulting in high fault current in the associated electrical circuit, the magnetic flux levels in the core 10a,10b will rise. The magnetic flux will continue to flow preferentially through the or each first magnetic element 12 until the soft magnetic material of the or each first magnetic element 12 reaches saturation. Saturation of the or each soft magnetic material causes the magnetic relative permeability of the respective first magnetic element 12 to drop towards one.

At this stage the hard magnetic material of the or each second magnetic element 14 has a higher magnetic permeability than the saturated soft material of the or each first magnetic element 12. This causes the magnetic flux generated by the current-carrying coil to flow preferentially through the hard magnetic material of the or each second magnetic element 14. This change in medium for magnetic flux flow from the or each saturated first magnetic element 12 to the or each second magnetic element 14 leads to a change in coil impedance which acts to restrict the fault current in the associated electrical current.

This is because the higher levels of magnetic hysteresis in hard magnetic material coupled with the relatively high fault current levels leads to a wider magnetic hysteresis loop area and therefore steeper rates of change of magnetic flux of magnetic flux density with magnetizing force, as the high fault current approaches its positive or negative peak value. This leads to an increase in coil resistance and

reactance as outlined above. As such, the coil presents high impedance to the associated electrical circuit to limit the peak values of the fault current during fault or other abnormal operating conditions.

5                   The provision of hard magnetic material in the core 10a,10b improves the efficiency of the magnetic fault current limiter when it comes to limiting the fault current, because of higher coil impedance resulting from the higher levels of magnetic  
10 hysteresis in hard magnetic material in comparison to soft magnetic materials. Otherwise, in the absence of the hard magnetic material of the or each second magnetic element 14, the provision of soft magnetic material of the or each first magnetic element 12 leads  
15 to a low coil impedance which may be insufficient to limit the fault current.

                  Preferably the high impedance presented to the associated electrical circuit during fault conditions is such that the peak value of the fault  
20 current is kept within the current rating of the associated electrical circuit to protect the various components of the associated electrical circuit.

                  In embodiments of the invention, the current limiter may be designed to limit the magnitude  
25 of the fault current for a short period of time before external circuit breakers are actuated to open the circuit and thereby extinguish the fault current.

                  Since the magnetic flux only flows through the hard magnetic material of the or each second  
30 magnetic element 14 for short periods of time, the

resulting hysteresis losses and temperature rise in the hard magnetic material are kept at a minimum.

As such, the provision of a substantially parallel array of first and second magnetic elements 12,14 results in a magnetic fault current limiter core 10a,10b which, in use, exhibits reduced hysteresis losses and a low temperature rise during operation of the magnetic fault current limiter and therefore can be used in combination with electrical circuits at high levels of electrical current. This therefore leads to a reduction in hardware costs, size and weight since there is no requirement to install a cooling system or utilise a core topology to address the hysteresis losses and temperature rise in the core.

The arrangement also provides a passive way of controlling magnetic flux through the magnetic fault current limiter core 10a,10b. This may eliminate the need for detection and/or switching equipment to provide active control over the flow of magnetic flux through the core 10a,10b. The passive nature of operation of the current limiter means that it may be possible to minimise or eliminate the use of detection and/or control equipment normally employed to monitor and control the current within the associated electrical circuit.

Preferably the hard magnetic material of the or each second magnetic element 14 is selected so that the magnetizing force required to achieve saturation in the hard magnetic material is higher than the magnetizing force arising from the fault current. It may be undesirable for the hard magnetic material of

the or each second magnetic material 14 to reach saturation because it leads to a reduction of its magnetic permeability, which results in low coil impedance and thereby may result in faulty operation of  
5 the current limiter.

**CLAIMS**

1. A magnetic fault current limiter core comprising at least one first magnetic element and at least one second magnetic element, the magnetic elements being arranged to define a substantially parallel array of magnetic elements, the or each first magnetic element including a soft magnetic material and the or each second magnetic element including a hard magnetic material, wherein the or each soft magnetic material in a non-saturated state has a higher magnetic permeability than the or each hard magnetic material.

2. A magnetic fault current limiter core according to Claim 1 wherein at least one first magnetic element is separated from at least one neighbouring second magnetic element by an insulator.

3. A magnetic fault current limiter core according to Claim 1 or Claim 2 further including a plurality of first magnetic elements and/or a plurality of second magnetic elements wherein the magnetic elements are arranged to form alternating primary layers of first and second magnetic elements.

4. A magnetic fault current limiter core according to any preceding claim wherein at least one first magnetic element and/or at least one second magnetic element includes a plurality of secondary layers of magnetic material, each secondary layer being

separated from the or each neighbouring secondary layer by an insulator.

5           5. A magnetic fault current limiter core  
according to any preceding claim including at least one  
magnetic element having a hollow bore wherein a portion  
of at least one first magnetic element is housed within  
a hollow bore of a second magnetic element having a  
hollow bore and/or a portion of at least one second  
10 magnetic element is housed within a hollow bore of a  
first magnetic element.

6. A magnetic fault current limiter core  
according to any preceding claim including at least one  
15 magnetic element having a hollow and sealed interior,  
wherein at least one first magnetic element is housed  
within a hollow and sealed interior of a second  
magnetic element and/or at least one second magnetic  
element is housed within a hollow and sealed interior  
20 of a first magnetic element.

7. A magnetic fault current limiter core  
according to any preceding claim wherein each magnetic  
element is a rod or bar.

25

8. A magnetic fault current limiter core  
according to any preceding claim wherein the cross-  
section of each magnetic element is circular, oval or  
polyhedral in shape.

30

9. A magnetic fault current limiter core according to any preceding claim in which at least one first magnetic element is separated from at least one neighbouring second magnetic element by an air gap, and  
5 wherein at least one such air gap is filled with electrically insulating material.

10.A magnetic fault current limiter comprising one or more magnetic fault current limiter  
10 cores according to any preceding claim and at least one electrical conductor wound around a portion of the or each core to define a coil.

11.A magnetic fault current limiter  
15 according to Claim 10 wherein the or each electrical conductor is wound around the first and second magnetic elements.

12.A magnetic fault current limiter  
20 according to Claim 11 wherein in use, the or each electrical conductor carries an alternating current.

13.A magnetic fault current limiter according to any of Claims 10 to 12 wherein the or each  
25 coil is operably connected in use to one or more electrical circuits.

14.A magnetic fault current limiter according to Claim 13 wherein the or each coil presents  
30 an impedance to minimise a fault current created by a fault, in use, in an electrical circuit.

15.A magnetic fault current limiter according to any of Claims 10 to 14 wherein the or each coil is in the form of a solenoid or a toroid.

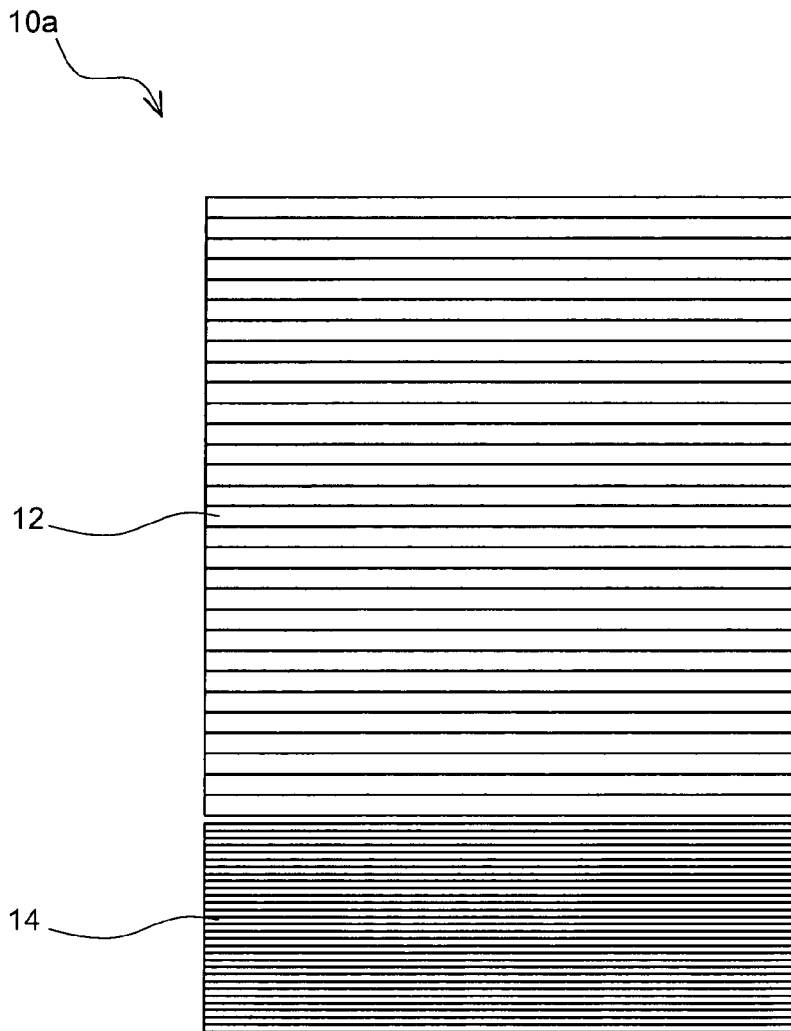


FIG. 1

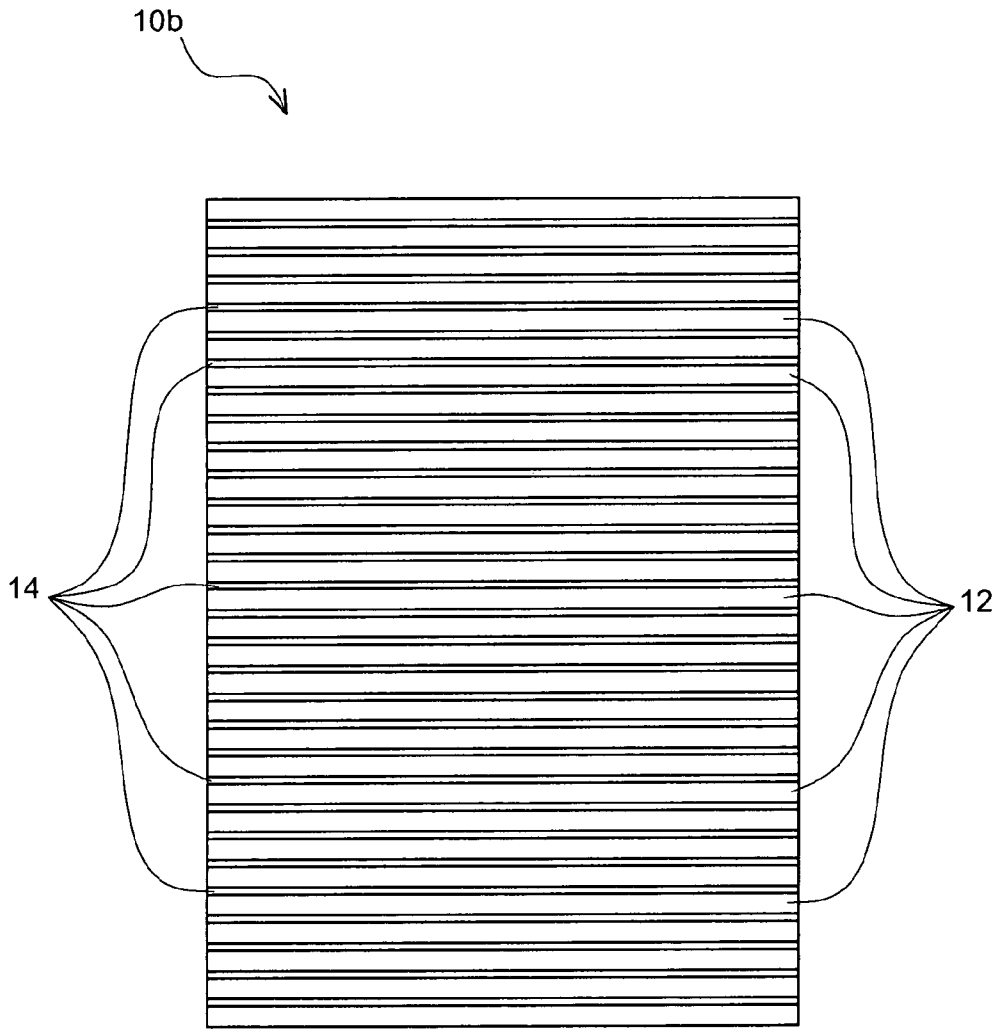


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2010/061258

A. CLASSIFICATION OF SUBJECT MATTER  
INV. H01F3/10 H01F38/02  
ADD.  
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED  
Minimum documentation searched (classification system followed by classification symbols)  
H01F  
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)  
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2003 197436 A (MIYAGI PREFECTURE) 11 July 2003 (2003-07-11) abstract page 5, paragraphs 48,49 page 6, paragraph 64 page 8, paragraph 88 page 9, paragraphs 100,106 page 11, paragraph 126-129 -----	1-4,8-15
X	GB 2 415 833 A (AREVA T & D UK LTD [GB]) 4 January 2006 (2006-01-04) abstract page 1, lines 4-7 page 4, line 24 - page 5, line 6 ----- -/--	1,4,7,8, 10-15

Further documents are listed in the continuation of Box C.

See patent family annex.

\* Special categories of cited documents :

<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p>
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Date of the actual completion of the international search  8 June 2011	Date of mailing of the international search report  05/07/2011
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer  Gols, Jan
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## INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2010/061258

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>RASOLONJANAHARY J-L ET AL: "Design and construction of a magnetic fault current limiter", THE 3RD IET INTERNATIONAL CONFERENCE ON POWER ELECTRONICS, MACHINES AND DRIVES, 2006., March 2006 (2006-03), pages 681-685, XP002640470, [retrieved on 2007-01-01] page 681, paragraph 2 page 683, paragraph 4 - page 684, paragraph 4</p> <p style="text-align: center;">-----</p>	<p>1,2,4, 8-10, 12-15</p>
A	<p>US 2004/134565 A1 (SUN SHOUHENG [US] ET AL) 15 July 2004 (2004-07-15) page 2, paragraph 17 page 5, paragraph 70-72</p> <p style="text-align: center;">-----</p>	<p>5,6</p>

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Information on patent family members

International application No

PCT/EP2010/061258

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