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(54) **Transformer coil with conductive electrical shielding**

(57) The present invention relates to the shielding of coils of transformers, in particular to a coil for a transformer, a transformer with a coil, and a method of manufacturing a coil for a transformer.

A coil (100) for a transformer with a coil body (102) is provided. The coil body (102) comprises a conductor (201). A first insulation material (203) is attached to the conductor (201). A conductive electric shielding device arrangement (200) is provided for reducing the maximum strength of an electric field generated in the coil (100) or for smoothing the field generated by each coil body (102) of a plurality of coil bodies (102).

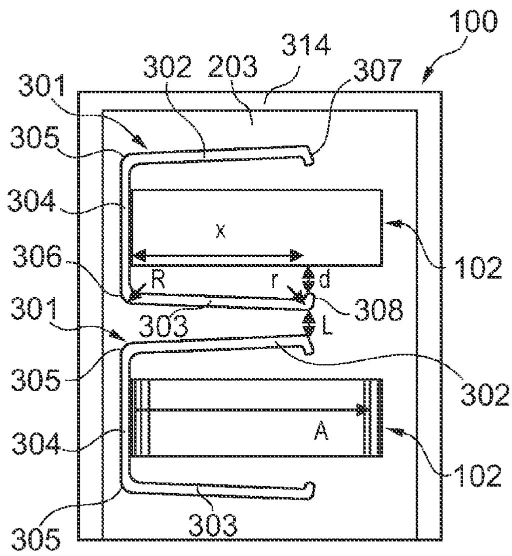

Fig. 1C

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Description

FIELD OF THE INVENTION

[0001] The invention relates to the shielding of coil transformers. In particular, the invention relates to a coil for a transformer, to a transformer with a coil, and to a method of manufacturing a coil for a transformer.

BACKGROUND OF THE INVENTION

[0002] In the field of medium and high voltage applications transformers are widely used.

[0003] Transformers are generally insulated by an insulation material comprising a thermoset such as epoxy and may further comprise glass reinforcement such as a glass filler. Small transformers from 50 VA up to 3 kVA are encapsulated by a thermoplastic.

SUMMARY OF THE INVENTION

[0004] It may be seen as an object of the invention to provide an improved, flexible and efficient electric shielding for a coil of a transformer.

[0005] This object is achieved by a coil for a transformer, by a transformer comprising the coil and by a method of manufacturing a coil for a transformer according to the independent claims. Further embodiments are evident from the dependent claims.

[0006] According to one embodiment a coil for a magnetic component with at least one coil body is provided. The at least one coil body comprises a conductor. The coil further comprises a first insulation material attached to the conductor, and a conductive electric shielding device arrangement for reducing the maximum strength of an electric field generated in the coil. The conductor may be a wound conductor.

[0007] The conductive electric shielding device arrangement may comprise a material selected from the group consisting of a metal, a conducting polymer, and a polymer with conducting surfaces. The conductive electric shielding device arrangement may be made from a metallic sheet manufactured into shape by forging, by wobbling, or by spinning, or may consist of an injection moulded or extruded conducting polymer, or a polymer with conducting surfaces, which may be manufactured by metallization, conductive painting.

[0008] The insulation material may be moulded to the conductor. The conductive electric shielding device arrangement may reduce the maximum field strength of the coil by 50% compared to a coil without a conductive electric shielding device arrangement.

[0009] The first insulation material may be a thermoplastic material instead of a thermosetting material which may make a curing cycle unnecessary when manufacturing the magnetic component, thus decreasing the production time of the magnetic component.

[0010] The at least one coil body may be a high voltage coil body and the arrangement may further comprise a low voltage conductor, wherein the high voltage coil body and/or the low voltage conductor may comprise at least one conductive electric shielding device of the conductive electric shielding device arrangement.

[0011] A conductive electric shielding device of the conductive electric shielding device arrangement may be a self-supporting part or an applied conducting layer.

[0012] According to another embodiment of the invention the magnetic component is a dry-type transformer.

[0013] According to another embodiment of the invention the magnetic component is a reactor. The coil may thus be a reactor coil.

[0014] The reactor may be a cooling reactor with voltage levels up to 36 kV or higher, may have a single or three phases, and may be either air cored, iron cored, or of a shell type.

[0015] According to another embodiment of the invention a conductive electric shielding device of the conductive electric shielding device arrangement is arranged around edges of the conductor.

[0016] The conductive electric shielding device may be applied at the inner edges of the at least one coil body facing another coil body, such as a LV coil or LV conductor, for example, and/or at the outer edges of the coil body. The conductive electric shielding device may comprise rounded edges and may have the same features as the above-mentioned conductive electric shielding device arrangement.

[0017] According to another embodiment of the invention the magnetic component is a transformer.

[0018] According to another embodiment of the invention at least one conductive electric shielding device is electrically connected to a winding of the coil body.

[0019] A conductive electric shielding device of the conductive electric shielding device arrangement may be connected to a given potential such as a winding of the coil body, respectively a winding of a high voltage coil body and a low voltage coil body. The conductive electric shielding device may be electrically connected with a first layer (turn of the coil body winding which may be made from numerous turns of a metallic foil separated by an insulating film. In case of a wire winding the conductive electric shielding device may be electrically connected with one of the inner wire.

[0020] According to another embodiment of the invention the conductive electric shielding device has a C-shaped cross-section with rounded edges. The conductive electric shielding device may be ring-shaped or may have a polygonal form. The cross-section of the conductive electric shielding device may be concave adapted. The conductive electric shielding device may be a foil wound to a disc shaped coil body or to a coil body.

[0021] The C-shaped cross-section of the conductive electric shielding device may comprise a first side, a second side, and a base connecting the first side with a second side. A first rounded edge may connect the first side to the base, a second rounded edge may connect the second side to the base, a third rounded edge may be arranged at the free end of the first side, and a fourth rounded edge may be at the free end of the second side.

[0022] According to another embodiment of the invention the rounded edges of the conductive electric shielding device each have a radius of 1 to 20 mm, in particular 1 to 5 mm.

[0023] Such rounded edges may reduce the electric field enhancement at the edges of the coil body because of the shape, thereby avoiding dangerous field enhancements. For a radius of 2 mm the electric field in the coil body may be reduced at the metal solid/insulation to 75%.

[0024] According to another embodiment of the invention the conductor is in form of a foil and may be wound around the supporting device enabling a faster manufacturing of the coil compared to a manufacturing of the coil wherein the conductor is in form of a wire possibly wound around the supporting device being a further embodiment of the invention.

[0025] According to another embodiment of the invention the coil further comprises a supporting device for supporting the conductor, wherein the supporting device comprises the conductive electric shielding device of the conductive electric shielding device arrangement.

[0026] According to another embodiment of the invention the coil further comprises a second insulation material having a first insulating part arranged at a first inner side of the supporting device, and a second insulating part arranged at a second inner side of the supporting device. The first and second insulating parts are arranged between the supporting device and the conductor.

[0027] The second insulation material may have the same features as the above-mentioned first insulation material. The first insulating part and the second insulating part may be thermoplastic insulations.

[0028] According to another embodiment of the invention the C-shaped cross-section of the conductive electric shielding device further comprises a first side forming a second conductive component, a second side forming a third conductive component, and a base connecting the first side with the second side. The C-shaped cross-section of the conductive electric shielding device further comprises a first rounded edge connecting the first side to the base, a second rounded edge connecting the second side to the base, a third rounded edge at the free end of the first side forming a fourth conductive component and a fourth rounded edge at the free end of the second side forming a fifth conductive component. The base, the first rounded edge, and the second rounded edge form a first conductive component. The cross-section of the conductive electric shielding device may be concave adapted. The conductive electric shielding device may be a foil wound to a disc shaped coil body or to a coil body.

[0029] The first, second, third, fourth, and fifth component may be separate components. The first conductive component, the fourth conductive component and the fifth conductive component may comprise a conducting polymer such as rubber. The second conductive component and the third conductive component may comprise a metallic material such as metallic foil or metallic shield. Such separate components may provide for an easier manufacturing and lower costs compared to manufacturing a second conductive electrical shield device which consists of one component.

[0030] According to another embodiment of the invention the coil further comprises a plurality of coil bodies. Each coil body of the plurality of coil bodies is electrically connected to another coil body of the plurality of coil bodies forming a coil body stack, the stack defining a stack axis, or the coil. A uniform cross-section of each of the plurality of coil bodies may be a non-circular cross-section and the cross-section is in a plane perpendicular to the stack axis.

[0031] To avoid electrical failure of the coil bodies large distances between the coil bodies and between the coil bodies and other metallic parts should be kept, especially when the electric strength of the insulation system is reduced due to the presence of interfaces. The coil with the conductive electric shielding device arrangement may enable to avoid electric failure between coil bodies and between coil bodies and other metallic parts, especially, when the electric strength of the insulation system is reduced due to the presence of interfaces. Cast coils for dry-type transformers may be made of the coil bodies. The insulation material close to the coil edges of the windings may be submitted to increase electrical strength, especially during type testing, and in particular during testing with sharp impulses, when the voltage distribution is non-homogenous.

[0032] The coil with the conductive electric shielding device arrangement may reduce the electric field enhancement at the edges of the coil bodies by providing conductive shielding for each coil body of the plurality of coil bodies. The conductive electric shielding device may be in electrical contact with a first innermost turn of a coil body, carefully choosing the shape of the shields (length and distance to coil body, as the voltage increases from turn to turn). Also the radii of the edges of the shield are designed to avoid dangerous field enhancements. The transformers may have a high voltage, and particularly a voltage of 36 kV and higher.

[0033] Such a coil may provide for considerable cost-savings, especially, for example, for transformers with low ratings. These cost-savings may be provided mainly from faster production cycles compared to a production of a single non-modular coil or in other words one coil body. The coil as described above may provide a high degree of standardization concerning the manufacturing of the coil enabling variable sizing of the coil and thus time and cost savings compared to a manufacturing of a non-modular coil which is generally designed for manufacturing a defined size of a transformer. The coil with the non-circular cross-section may further enable a reduction of the core steel, as the distance between phases of a transformer may be reduced and thereby less core steel may be used, also if the cores are stacked, for example of cut metal sheets. A coil with coil bodies with a uniform non-circular cross-section as described above may enable a faster manufacturing of the core of the transformer. Manufacturing a non-circular core by conventional stacking of cut metal sheets may be more efficient than manufacturing a circular core since all metal sheets may have the same width. Furthermore the transformer with a non-circular cross-section may be built more compact compared to a core with a circular cross-section. The coil may be a modular coil and the transformer may be a dry transformer or a dry distribution transformer. The coil body may be a modular disk or a disk. The disk or modular disk may comprise a supporting device with a thereto wound conductor, wherein an insulation material may be attached to the supporting device and the conductor for insulating the supporting device and the conductor.

[0034] The electrical connecting of the coil bodies to each other may comprise the steps of removing enamel of the connecting means at each coil body of the plurality of coil bodies and crimping the connecting means of each coil body of the plurality of coil bodies to a connecting means of an adjacent coil body of the plurality of coil bodies.

[0035] According to another embodiment of the invention the coil body comprises at least one high voltage (HV) coil body.

[0036] According to another embodiment of the invention the coil body comprises at least one low voltage (LV) coil body.

[0037] The terms high voltage and low voltage may be understood in such a way that high voltage is higher than low voltage according to another embodiment of the invention without limiting high voltage and low voltage to specific voltage levels.

[0038] A coil with coil bodies of a modular type or in other words a coil of a modular type means that HV and/or LV windings may be adapted as disc windings which may be moulded and which may have two connections or terminals such that the disc windings are stackable.

[0039] High voltage and low voltage coils may be combined in one coil body according to another embodiment of the invention.

[0040] Furthermore only high voltage coils may be in one coil body and only low voltage coils may be in one coil body.

[0041] The high voltage coil may be arranged at a secondary possibly low voltage coil comprising a secondary or low voltage coil conductor in insulating material.

[0042] According to another embodiment of the invention the non-circular cross-section of the coil is a cross-section selected from the group consisting of a rectangular, a hexagonal, an oval, and a polygonal cross-section.

[0043] Such a coil with a non-circular cross-section or an oval cross-section may provide for a compact modular arrangement of the cores of the transformer and the transformer itself.

[0044] According to another embodiment of the invention the coil may further comprise a locking means for preventing rotation of adjacent coil bodies of the plurality of coil bodies. By locking means a locking system or locking arrangement is meant that may comprise more than one locking devices.

[0045] According to another embodiment of the invention the locking means comprises a through-hole in each of the plurality of coil bodies and a rod being adapted to pass through the through-hole of each of the plurality of coil bodies.

[0046] The rod may be a threaded rod fitting to threads in the through-holes. Two through-holes may be arranged on opposite sides of the coil bodies and two rods may each pass through one of the two through-holes preventing the coil bodies from rotating among each other.

[0047] According to another embodiment of the invention the locking means comprises a latch arranged at each of the plurality of coil bodies in a recess arranged at each of the plurality of coil bodies such that the latch of the coil bodies of the plurality of coil bodies is adapted to fit to the recess of an adjacent coil body of the plurality of coil bodies.

[0048] Such a latch-recess locking mechanism may prevent the rotation of the coil bodies among each other efficiently, wherein each coil body may be easily stacked to another coil body. There may be more than one recess and more than one latch arranged at each of the coil bodies. Eight latches and eight recesses may be arranged equispaced at each of the coil bodies. The recess and the latch may be part of the coil body and both may have one of a circular, a rectangular, a polygonal, a non-circular, a hexagonal, and a triangular form. Furthermore the latch may be pin-like and the recess may be hole-like.

[0049] According to another embodiment of the invention the locking means comprises a snap-fit connection arranged at adjacent coil bodies of the plurality of coil bodies. The snap-fit connection may comprise a clamp and a matching counterpart being arranged at each of the plurality of coil bodies. There may be a plurality of clamps and counterparts arranged at each of the plurality of coil bodies, for example three clamps and three counterparts per coil body.

[0050] According to another embodiment of the invention the at least one coil body is a high voltage coil body and a first insulation material is attached or moulded to a low voltage conductor. The high voltage coil body is combined with the low voltage coil body surrounding a core of the magnetic component. The insulation material may be moulded to the low voltage conductor.

[0051] According to another embodiment of the invention the coil further comprises a guiding element for the electrical connection, e.g. in form of a clamp connecting or crimp connecting the plurality of coil bodies and for clamp or crimp connecting the coil bodies to a further coil of a transformer. The guiding element may be arranged at each of the conductors of the plurality of coil bodies.

[0052] According to another embodiment of the invention the plurality of coil bodies is a plurality of high voltage coil bodies, forming a high voltage coil body stack, and the first insulation material is attached to the high voltage coil body stack instead of being attached to the conductor of each high voltage coil body of the plurality of high voltage coil bodies separately. A first insulation material is attached to a low voltage conductor. The high voltage coil body stack is combined with the low voltage coil body surrounding a core of the transformer, and the magnetic component, respectively. The first insulation material may be moulded to the high voltage coil body stack. The first insulation material may be moulded to the low voltage conductor. At least one of the at least one conductive electric shielding device of the conductive electric shielding device arrangement is arranged at least one edge of the high voltage conductor, in particular at the inner edges of the high voltage conductor facing the low voltage conductor, and/or at the outer edges of the high voltage conductor not facing the low voltage conductor.

[0053] According to another embodiment of the invention the plurality of coil bodies is a plurality of high voltage coil bodies, and the high voltage coil body stack is combined with a low voltage conductor and may be using centring elements at the front and back ends of the high voltage coil body stack and the low voltage conductor for assuring a constant distance between the high voltage coil body stack and the low voltage conductor. The insulation material is attached to the high voltage coil body stack and the low voltage conductor together instead of being attached to the conductor of each high voltage coil body of the plurality of high voltage coil bodies separately. The high voltage coil body stack and low voltage conductor surround a core of the transformer, and the magnetic component, respectively. The insulation material may be moulded to the high voltage coil body stack and the low voltage conductor. At least one of the at least one conductive electric shielding device of the conductive electric shielding device arrangement is arranged around at least one edge of the high voltage conductor, in particular at the inner edges of the high voltage conductor facing the low voltage conductor, and/or at the outer edges of the high voltage conductor not facing the low voltage conductor.

[0054] According to another embodiment of the invention a transformer with a coil of anyone of the above mentioned embodiments is provided with a core having an outer contour which is adapted to fit to an inner contour of the coil. The core may be an amorphous core.

[0055] The core may be built from thin sheets which are insulated against each other for minimizing the losses from Eddy currents. Concerning the material of the sheets the following steel qualities for the sheets may be used: Standard core steel (usually low C content of less than 0.1% and alloyed with Si of usually less than 3%); grain oriented core steel, wherein the cold rolling of steel orients the magnetic domains which leads to good loss properties in the rolling direction; amorphous core steel. The core of the transformer may be be stacked or wound, wherein the core may be wound around the mandrel in a first step, cut at one position in a second step, spread/ open up for placing the low voltage and high voltage of the transformer in a third step, and the low voltage and high voltage coils may be placed at the core in a fourth step. Four equal wound cores of a transformer may be arranged next to each other being combined by three high voltage and low voltage coils forming the transformer. Two equal wound small cores and one large wound core could be combined by three high voltage and low voltage coils forming a transformer according to a further embodiment.

[0056] According to another embodiment of the invention the transformer further comprises a second coil of anyone of the above-mentioned embodiments and a third coil of anyone of the above-mentioned embodiments, wherein each of the first, second and third coils surrounds the core. The first, second and third coils are arranged in a triangular way next to each other forming a compact transformer.

[0057] Due to the minimal distance of the transformer axes to each other and due to the non-circular cross-sections of the coils in a plane perpendicular to the transformer axes the transformer with triangular arrangement of the coils may provide a greater mechanical stability and a more compact design compared to transformers with coils with a circular cross-section, and also compared to a linear arrangement of the coils. A triangular arrangement of coils with a circular cross-section may provide for a minimized distance of the coil axes to each other and thus a better mechanical stability and space-saving compared to a linear arrangement of coils with a non-circular cross-section.

[0058] According to another embodiment of the invention the transformer further comprises a second coil of anyone of the above-mentioned embodiments and a third coil of anyone of the above-mentioned embodiments, wherein each of the first, second and third coils surrounds the core. The first, second and third coils are arranged in a linear way next to each other forming a compact transformer.

[0059] Such a transformer with a linear arrangement of coils with non-circular cross-sections in a plane perpendicular to the transformer axes or to the core limbs may be built more compact due to a possible more room saving arrangement of the non-circular cross-section coils, for example at edges of the coils, compared to a linear arrangement of coils with circular cross-sections.

[0060] A transformer with a plurality of coils according to anyone of the above mentioned embodiments may be arranged next to each other in the most compact room-saving way depending on the non-circular shape of the cross-section of each of the plurality of coil bodies of the plurality of coils such as a triangular way for a hexagonal, and for an oval-cross section or for a cross-section comprising a combination of a non-circular and a circular cross-section. The plurality of coils may be arranged in line, for example three coils next to each other, forming a transformer, wherein each coil body of the plurality of coil bodies of the plurality of coils of the transformer may have one of a rectangular, hexagonal, oval, non-circular, and polygonal form, or a combination of a circular and a non-circular form. Each core may be surrounded by a low voltage coil which is surrounded by a high voltage coil.

[0061] According to another embodiment of the invention a method of manufacturing a coil for a transformer is provided, with the method elements of winding a conductor of a coil body around the supporting device of the coil body, attaching an insulation material to the conductor and the supporting device, and mounting a conductive electric shielding device arrangement of anyone of the above mentioned embodiments around the coil for reducing the maximum strength of an electric field generated in the coil.

[0062] According to another embodiment of the invention the method further comprises the method elements of stacking each of the conductors and supporting devices forming a coil body to a coil comprising a plurality of coil bodies, and electrically connecting each coil body of the plurality of coil bodies to another coil body of the plurality of coil bodies.

[0063] According to another embodiment of the invention the method further comprises the step of arranging a conductive electric shielding device of the conductive electric shielding device arrangement around edges of the conductor.

[0064] According to another embodiment of the invention the method further comprises the step of moulding the supporting device. The moulding may comprise of an injection moulding of the supporting device by a two component injection moulding process using a first component comprising a conductive electric shielding device of the conductive electric shielding device arrangement and a second component.

[0065] These and other aspects of the present invention will become apparent from and elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0066] The subject-matter of the invention will be explained in more detail in the following text with reference to exemplary embodiments which are illustrated in the attached drawings.

Fig. 1A schematically shows a cross-sectional view of a coil for a transformer according to an embodiment of the invention.

Fig. 1B schematically shows a cross-sectional view of a coil for a transformer according to another embodiment of the invention.

Fig. 1C schematically shows a cross-sectional view of a coil with a conductive electric shielding device according to another embodiment of the invention.

Fig. 1D schematically shows a cross-sectional view of a coil for a transformer with one conductive electric shielding device comprising several parts according to another embodiment of the invention.

Fig. 2 schematically shows a cross-sectional view of a coil for a transformer according to another embodiment of the invention.

Fig. 3 schematically shows a cross-sectional view of a coil body according to another embodiment of the invention.

Fig. 4 schematically shows a cross-sectional view of one phase of a transformer with a coil according to another embodiment of the invention.

Fig. 5 schematically shows a cross-sectional view of one phase of a transformer with a coil according to another embodiment of the invention.

Fig. 6 schematically shows a cross-sectional view of one phase of a transformer with a coil according to another embodiment of the invention.

Fig. 7 schematically shows a flow chart of a method of manufacturing a coil for a transformer according to another embodiment of the invention.

[0067] Reference signs used in the drawings, and their meanings, are listed in summary form as a list of reference signs. In principle, identical parts are provided with the same reference signs in the figures.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0068] Fig. 1A schematically shows a cross-sectional view of a part of one phase of a transformer (instead of the transformer a reactor or generally a magnetic component may be provided according to embodiments of the invention) with a coil 100 and a core 104 of the transformer and a middle axis A separating the core 104 of the transformer. The coil 100 has a coil body 102 which comprises a supporting device 202 for supporting a conductor 201 being wound around the supporting device 202. The supporting device 202 may be omitted according to another embodiment of the invention. A first insulation material 203 is attached or moulded to the wound conductor 201 and the supporting device 202. Fig. 1A depicts a conductive electric shielding device arrangement 200 for reducing the maximum field strength of an electromagnetic field generated in the coil 100. A conductive electric shielding device 301 of the conductive electric shielding device arrangement 200 is arranged around edges 205 of the coil 100 or the coil body 102 or the conductor 205. One conductive electric shielding device 301 may be applied at inner edges 205 facing another coil body or conductor, such as a low voltage coil 403 or low voltage conductor 403 attached or moulded by an insulation material 203 to an attached or moulded low voltage coil 402 or low voltage conductor 402, and an additional conductive electric shielding device 301 may be arranged around outer edges 205 not-facing the adjacent attached or moulded low voltage coil 402 or low voltage conductor 402. The supporting device 202 may comprise at least one of a conductive electric shielding device 204 of the conductive electric shielding device arrangement 200 and. The conductive electric shielding device arrangement 200 may either comprise the conductive electric shielding device 204 or the conductive electric shielding device 301 or both conductive electric shielding device 301, 204 according to exemplary embodiments of the invention.

[0069] Fig. 1B schematically shows a coil 100 with a plurality of coil bodies 102, wherein a conductive electric shielding device 301 is arranged around edges 205 of each wound conductor 201 of each of the plurality of coil bodies 102. First insulation material 203 is attached or moulded to the wound conductors 201, and the coil bodies 102, respectively, forming one single body. As mentioned above, one field conductive electric shielding device 301 may be arranged around inner edges 205 and another conductive electric shielding device 301 may be arranged round outer edges 205 of each coil body 102 or conductor 201 or one conductive electric shielding device 301 may be arranged around the inner and outer edges 205 of each coil body 102 or conductor 201.

[0070] Fig. 1C shows part of a coil 100 with two coil bodies 102 in a first insulation material 203, which could be a resin 203, wherein a conductive electric shielding device 301 of a conductive electric shielding device arrangement is arranged around outer edges 205 of each coil body. The conductive electric shielding device 301 is ring-shaped and has a C-shaped cross-section with rounded edges 305, 306, 307, 308. The conductive electric shielding device 301 comprises a first side 302, a second side 303 and a base 304 connecting the first side 302 with the second side. A first rounded edge 305 is connecting the first side 302 to the base 304, a second rounded edge 306 is connecting the second side 303 to the base 304, a third rounded edge 307 at the free end of the first side 302, and a fourth rounded edge 308 at the free end of the second side 303 are provided. The first and second rounded edges 305, 306 cover outer edges 205 of the coil body 102 reducing the electric field enhancement at the edges 205 of each coil body 102. The conductive electric shielding device 301 may be in contact with the innermost turn of the modular coil 102. As the voltage increases from inner turn to outer turn of windings of the coil body 102 which is indicated by the arrow A, the shape of the conductive electric shielding device 301 should be carefully chosen. The conductive electric shielding device 301 may be electrically connected with a first layer (turn) of the coil body winding which may be made from numerous turns of a metallic foil separated by an insulating film. In case of a wire winding the conductive electric shielding device 301 may be electrically connected with one of the inner wire. The conductive electric shielding device 301 may be connected to a given potential such as a winding of the coil body 102, respectively a winding of a high voltage coil body and a low voltage coil body. The length x of the first and second side 302, 303 may have a length between 1/20 and 2/3 of the length of the core body, preferably 1/10 to 1/2, most preferred 1/10 to 1/3.

[0071] The arrow A depicts the voltage increase within each coil body 102. The distance d of the first and second side 302, 303 to the coil body 102 should be chosen so that the maximum voltage of the turns at the level of the end of the shield is not higher than E*d, where E is the dielectric strength of the material 203. Each conductive electric shielding device 301 should be arranged at least at a distance L from an adjacent conductive electric shielding device 301 of the coil 102, where L>= ΔU/E (ΔU is the maximum voltage difference between two adjacent shields and E is the dielectric strength of material 203).. The first and second rounded edges 305, 306 and the third and fourth rounded edges 307, 308 may each have a radius each of 1-20 mm, and particular of 1-5 mm. A radius of 2 mm may reduce the electric field at the metal/solid insulation to 75%.

[0072] Fig. 1D schematically shows a cross-sectional view of one coil body 102 with a conductive electric shielding device 301 with a C-shaped cross-section. The C-shaped cross-section of the conductive electric shielding device comprises a first conductive component 309 having the base 304, the first rounded edge 305, and the second rounded edge 306 of the conductive electric shielding device 301 of Fig. 3B. A first side 302 forms a second conductive component 310, a second side 303 forms a third conductive component 311, a third rounded edge 307 at the free end of the first side 302 forms a fourth conductive component 312, and a fourth rounded edge 308 at the free end of the second side 303 forms a fifth conductive component. Such a conductive electric shielding device of five separate components 309, 310, 311, 312, 313 may provide for an easier manufacturing and for lower costs compared to a single conductive electric shielding device. The first conductive component 309, the fourth conductive component 312, and the fifth conductive component 313 may comprise the conducting polymer such as rubber. The second conductive component 310 and the third conductive component 311 may comprise the metallic material such as a metallic foil or metallic shield

[0073] Fig. 2 depicts a cross-sectional view of one phase of a transformer with a coil 100. The coil 100 comprises a plurality of coil bodies 102 of a modular type, each of the plurality of coil bodies 102 having a uniform cross-section. Each coil body 102 of the plurality of coil bodies 102 is electrically connected to another coil body 102 of the plurality of coil bodies 102 forming a coil body stack 100, the stack 100 defining a stack axis A, or in other words the coil 100. Electrical connections or guiding elements 103 for clamp connecting the plurality of coil bodies 102 and for clamp connecting the coil body stack 100 to a further core of another transformer are provided and may ensure the electrical connection of the coil bodies 102 to each other. A non-circular part of a core 104 of the transformer is surrounded by the coil 100. The uniform cross section of each of the plurality of coil bodies 102 is a non-circular cross-section and the cross-section is in a plane perpendicular to the stack axis A.

[0074] Fig. 3 shows a non-circular cross-section of a coil body 102 of Fig. 2, the cross-section being in a plane perpendicular to the stack axis A. The coil body 102 comprises a conductor 201 which is supported by supporting device 202, wherein the conductor 201 may be wound around the supporting device 202. A first insulation material 203 is surrounding the conductor 201 and the supporting device 202 and may be used for an electrical insulation of the conductor 201. The supporting device 202 has a U-shape in the form of a ring 205 with sidewalls.

[0075] The supporting device 202 may be moulded by a two compound injection moulding process allowing to have one field grading compound, smoothing the electrical field around the conductor 201 and thereby allowing for a distance between high voltage and low voltage coils to be reduced and a second compound of a material selected form the group consisting of a thermoset and a thermoplast The supporting device 202 may comprise a conductive electric shielding device 204 for reducing the maximum field strength of an electromagnetic field generated in the coil 100. The conductor 201 may form a winding 201 wherein a conductive electric shielding device may be applied directly at edges 205 of the coil body 102. The first insulation material 203 may be impregnated or moulded to the conductor 201 and the supporting device 202 by first over-moulding the conductor 201, then over-moulding the sidewalls of the supporting device 202 in form of a ring 202, and third by over-moulding an inner wall of the ring 202 with the first insulation material 203.

[0076] A second insulation material 206 is provided having a first insulating part 207 arranged at a first inner side of the supporting device 202, and a second insulating part 208 arranged at a second inner side of the supporting device 202. The first and second insulating parts 207, 208 are arranged between the supporting device 202 and the thereto wound conductor 201.

[0077] The following features and embodiments of descriptions may be applicable to all figures, in particular to Fig. 1A, 1B, 1C, 1D, 2, and 3.

[0078] The transformer may be a dry-type transformer and cast coils 201 may be used for the dry-type transformer. The cast coils 201 may be made of a wound foil conductor 201 cast in an insulation media. Mechanical reinforcing structures may be in contact with the disc windings 102 or coil bodies 102. The insulation material 203 close to the edges of the windings 201 may be submitted to increase electrical stress. To avoid electrical failure of the coils 201 large distances between coil bodies 102 and other metallic parts must be kept, especially when the electric strength of the insulation system is reduced due to the presence of interfaces. An electrical field reduction in form of the conductive electric shielding device 301 allows to reduce the dimension of the coils 201 or to increase the voltage rating of a given geometry. The main insulation between primary and secondary coil or high voltage and low voltage coils of the dry-type transformer may be air. The transformers may have high voltage, especially a voltage of 36 kV and higher.

[0079] The transformer may also be a dry-type transformer with no air gap between primary and secondary coils, but solid insulation only.

[0080] Fig. 4 schematically shows a cross-section of one phase of a transformer with a middle axis A (the stack axis according to Fig. 1A and Fig. 2) separating a core 104 of the transformer. The core 104 is symmetrically surrounded by a low voltage coil 403 or low voltage conductor 403 which is attached or moulded by a first insulation material 203 forming a moulded or attached low voltage coil 402 or low voltage conductor 402. The moulded or attached low voltage coil 402 or low voltage conductor 402 is surrounded by two high voltage coil bodies 102. Each high voltage coil body 102 has a supporting device 202 which may comprise a conductive electric shielding device 204 supporting the conductor 201 which may be wound around the supporting device 202. A conductive electric shielding device may be arranged around edges of each coil body or conductor as depicted in Fig. 1B. Each conductor 201 and supporting device 202 is attached or moulded by a first insulation material 203. The high voltage coil bodies 102 form a high voltage coil body stack 401 which is arranged around the moulded or attached low voltage coil 402 or low voltage conductor 402 surrounding the core 104 of the transformer.

[0081] The transformer of Fig. 4 may be manufactured by moulding or attaching the supporting device 202, winding a conductor 201 around the supporting device 202, moulding or attaching the conductor 201 and the supporting device 202 with a first insulation material 203, wherein the supporting device 202 and the conductor 201 are inserted into a mould and over-moulded by the first insulation material 203 forming a high voltage coil body 102. The high voltage coil bodies 102 are stacked to a high voltage coil body stack 401 and the high voltage coil bodies 102 are electrically connected to each other. The first insulation material 203 may comprise a thermoplastic material moulded by injection moulding, or a thermosetting material, processed by vacuum casting or automatic pressure gelation.

[0082] The high voltage coil body stack 401 is then arranged around the moulded or attached low voltage coil 402 or attached low voltage conductor 402 which is applied or wound around the core 104 of the transformer.

[0083] A second insulation material 206 is provided having first insulating part 207 arranged at a first inner side of the supporting device 202, and a second insulating part 208 arranged at a second inner side of the supporting device 202. The first and second insulating parts 207, 208 are arranged between the supporting device 202 and the thereto wound conductor 201. At least one of the at least one conductive electric shielding device may be arranged around at least one edge of the high voltage conductors 201 or the high voltage coil bodies 102 opposite of the low voltage conductor 403 or the low voltage coil 403. The at least one conductive electric shielding device may be arranged around the inner edges of the high voltage conductors 201 facing the low voltage conductor 403, and/or at the outer edges of the high voltage conductors 201 not facing the low voltage conductor 403.

[0084] Fig. 5 schematically shows a cross-section of one phase of a transformer with a middle axis A separating a core 104 of the transformer. An insulation material 203 is moulded or attached to a low voltage conductor 403 or a low voltage coil 403 forming an attached or moulded low voltage conductor 402 or an attached or moulded low voltage coil 402 is arranged or wound around the core 104 according to Fig. 4. A high voltage coil body stack 401 comprising two high voltage coil bodies 102 moulded or attached together by a first insulation material 203 is arranged around the moulded or attached low voltage coil 402 or the moulded or attached low voltage conductor 402. The high voltage coil bodies 102 are not separated, as depicted according to Fig. 4, but form one part being moulded together by the insulation material 203.

[0085] The transformer of Fig. 5 may be manufactured by moulding or attaching the supporting devices 202, mounting the supporting devices 202 to a mandrel with space in between the supporting devices 202, winding a conductor 201 around each supporting device 202 or both supporting devices 202 at once, electrically connecting each conductor 201 of each high voltage coil body 102 to an adjacent conductor 201, e.g. by crimping, and over-moulding or attaching all supporting devices 202 with electrically connected conductors 201 by the first insulation material 203, e.g. by vacuum casting or automatic pressure gelation, thus forming the one body high voltage coil body stack 401. The insulation material 203 may be a low permittivity material. The mandrel is taken out, the low voltage coil body 402 is arranged at the inside of the high voltage coil body stack 401, and the core 104 of the transformer is placed in the low voltage coil body 402. According to an embodiment of the invention a plurality of attached low voltage conductors 402 may be used. At least one of the at least one conductive electric shielding device may be arranged around at least one edge of the high voltage conductors 201 or the high voltage coil bodies 102 opposite of the low voltage conductor 403 or the low voltage coil 403. The at least one conductive electric shielding device may be arranged around the inner edges of the high voltage conductors 201 facing the low voltage conductor 403, and/or at the outer edges of the high voltage conductors 201 not facing the low voltage conductor 403.

[0086] Fig. 6 schematically shows a cross-sectional view of one phase of a transformer with a low voltage coil 403 or conductor 403 and two high voltage coil bodies 102 with conductors being moulded or attached by an insulation material 203 forming a high voltage coil body and low voltage coil unit 601.

[0087] The transformer of Fig. 6 may be manufactured by moulding or attaching all high voltage coil bodies 102 and the low voltage coil 403 or conductor 403 by the insulation material 203 together, wherein the high voltage coil body stack 401 may be inserted into a mould together with a low voltage coil 403 or conductor 403 and over-moulded or attached with low permittivity insulation material 203. To assure a constant distance between low voltage and high voltage coils, the low voltage coil 403 or conductor 403 and the high voltage coil bodies 102 may be fixed into the mould by having centric elements at the front and backend of the high voltage coil body stack 401 and the low voltage coil 403 or conductor 403 positioning them into the mould. The low voltage coil or conductor 403 may be used as a mandrel for the high voltage coil bodies by inserting spacing elements between the outer side of the low voltage winding and the inner surface of the high permittivity supporting devices 202 of the high voltage coil bodies 102, the conductors of the high voltage coil bodies 102 being wound into each supporting device 202 separately or onto a stack of high voltage supporting devices 202. At least one of the at least one conductive electric shielding device may be arranged around at least one edge of the high voltage conductors 201 or the high voltage coil bodies 102 opposite of the low voltage conductor 403 or the low voltage coil 403. The at least one conductive electric shielding device may be arranged around the inner edges of the high voltage conductors 201 facing the low voltage conductor 403, and/or at the outer edges of the high voltage conductors 201 not facing the low voltage conductor 403.

[0088] Fig. 7 schematically shows a flow-chart of a method 2600 of manufacturing a coil for a transformer with the steps of moulding a supporting device 2601, the moulding comprising the steps of injection-moulding the supporting device by a two-component injection moulding process using a first component comprising a conductive electric shielding device and a second component, winding a conductor of a coil body around a supporting device of the coil body 2602, attaching an insulation material to the conductor and the supporting device 2603, mounting a conductive electric shielding device arrangement around the coil for reducing the maximum field strength of an electric field generated in the coil 2604, stacking each of the conductors and supporting devices forming a coil body to a coil body stack or to a coil comprising a plurality of coil bodies 2605, electrically connecting each coil body of a plurality of coil bodies to another coil body of the plurality of coil bodies 2606, and arranging an electric shielding device of the field control layer arrangement around the edges of the conductor 2607. The insulation material may be attached to the conductor and the supporting device.

[0089] The coil comprises a conductive electric shielding device arrangement for reducing the maximum field strength of an electromagnetic field emitted from the coil. The supporting devices may comprise a conductive electric shielding device.

[0090] While the invention has been illustrated and described in detail in the drawings and the foregoing description, such illustration and description are to be considered illustrative or exemplary and not restricted; the invention is not limited to the disclosed embodiments.

[0091] Other variations of the disclosed embodiments may be understood and effected by those skilled in the art and practising the claimed invention, from a study of the drawings, the disclosure, and the appended claims.

[0092] In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single coil or a single transformer may fulfil the function of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures may not be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

LIST OF REFERENCE SYMBOLS

[0093]

100 Coil
102 Coil body(s), high voltage coil body(s)
103 Guiding elements
104 Core
200 Conductive electric shielding device arrangement
201 Conductor
202 Supporting device
203 Insulation material, first insulation material
204 Conductive electric shielding device
205 Edges of conductor(s)
205 Second insulation material
206 First insulating part
207 Second insulating part
301 Conductive electric shielding device
302 First side
303 Second side
304 Base (connecting the first side to the second side)
305 First rounded edge
306 Second rounded edge
307 Third rounded edge
308 Fourth rounded edge
309 First conductive component
310 Second conductive component
311 Third conductive component
312 Fourth conductive component
313 Fifth conductive component
314 air, environment
401 High voltage coil body stack
402 Attached low voltage conductor
403 Low voltage conductor(s)
601 High voltage & low voltage coil(s)
A middle axis

Claims

1. A coil (100) for a magnetic component, the coil (100) comprising at least one coil body (102), the at least one coil body (102) comprising:

   a conductor (201);
   the coil (100) further comprising:

      a first insulation material (203) attached to the conductor (201);
      a conductive electric shielding device arrangement (200) for reducing the maximum strength of an electric field generated in the coil (100).

2. The coil of claim 1,
wherein the magnetic component is a dry-type transformer or a reactor.
coil

3. The coil (100) of anyone of claims 1 to 3,
wherein a conductive electric shielding device (301) of the conductive electric shielding device arrangement (200) is arranged around edges (205) of the conductor (201).

4. The coil (100) of claim 4,
wherein at least one conductive electric shielding device (301) is electrically connected to a winding of the coil body (102).

5. The coil (100) of anyone of claims 1 to 5,
wherein the conductive electric shielding device (301) has a C-shaped cross section with rounded edges (305, 306, 307, 308).

6. The coil (100) of claim 6,
wherein the rounded edges (305, 306; 307, 308) of the conductive electric shielding device (301) each have a radius of 1 to 20 mm, in particular 1 to 5 mm.

7. The coil (100) of anyone of the preceding claims,
wherein the conductor (201) is in form of a foil.

8. The coil (100) of anyone of claims 4 to 8, the coil body (102) further comprising:

a supporting device (202) for supporting the conductor (201);

wherein the supporting device (202) comprises the conductive electric shielding device (204).

9. The coil (100) of claim 9, further comprising:

a second insulation material (206), having:

a first insulating part (207) arranged at a first inner side of the supporting device (202); and
a second insulating part (208) arranged at a second inner side of the supporting device (202);

wherein the first and second insulating parts (207, 208) are arranged between the supporting device (202) and the conductor (201).

10. The coil (100) of claim 6 and anyone of claims 4-5 and 7-10,
wherein the C-shaped cross-section of the conductive electric shielding device (301) comprises:

a first side (302) forming a second conductive component (310);
a second side (303) forming a third conductive component (311);
a base (304) connecting the first side (302) to the second side (303);
a first rounded edge (305) connecting the first side (302) to the base (304);
a second rounded edge (306) connecting the second side (303) to the base (304);
a third rounded edge (307) at the free end of the first side (302) forming a fourth conductive component (312); and
a fourth rounded edge (308) at the free end of the second side (303) forming a fifth conductive component (313);

wherein the base (304), the first rounded edge (305), and the second rounded edge (306) form a first conductive component (309).

11. The coil (100) of anyone of the preceding claims, further comprising:

a plurality of coil bodies (102);

wherein each coil body (102) of the plurality of coil bodies (102) is electrically connected to another coil body (102) of the plurality of coil bodies (102) forming a coil body stack (401).

12. The coil (100) of claim 12,
wherein the plurality of coil bodies (102) is a plurality of high voltage coil bodies (102);
wherein the high voltage coil body stack (401) is combined with a low voltage conductor (403);
wherein the first insulation material (203) is attached to the high voltage coil body stack (401) and the low voltage conductor (403);
wherein the high voltage coil body stack (401) and low voltage conductor (403) surround a core (104) of the transformer.

13. A transformer comprising:

a coil (100) of anyone of claims 1 to 13; and
a core (104) having an outer contour which is adapted to fit to an inner contour of the coil (100).

14. Method (2600) of manufacturing a coil (100) for a transformer, the method (2600) comprising the method elements of:

winding a conductor (201) of a coil body (102) around a supporting device (202) of the coil body (102, 2602);
attaching an insulation material (203) to the conductor (201) and the supporting device (202, 2603);
mounting a conductive electric shielding device arrangement (200) of any of the claims 1-13 around the coil (100) for reducing the maximum strength of an electric field generated in the coil (100, 2604).

15. Method (2600) according claim 14, further comprising the method element of:

stacking each of the conductors (201) and supporting devices (202) forming a coil body (102) to a coil (100) comprising a plurality of coil bodies (102, 2605);
electrically connecting each coil body (102) of the plurality of coil bodies (102) to another coil body (102) of the plurality of coil bodies (102, 2606).

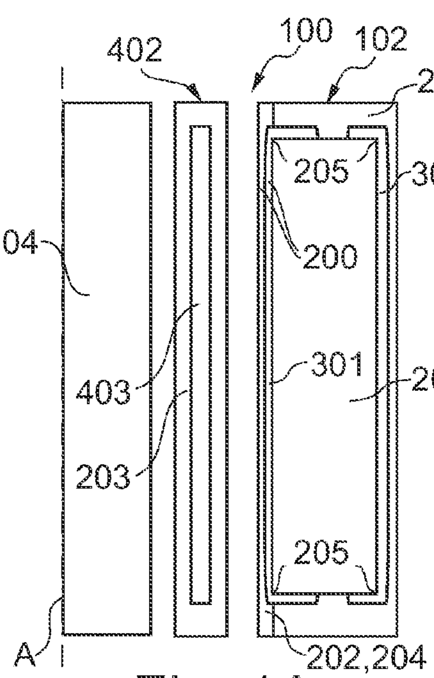

Fig. 1A

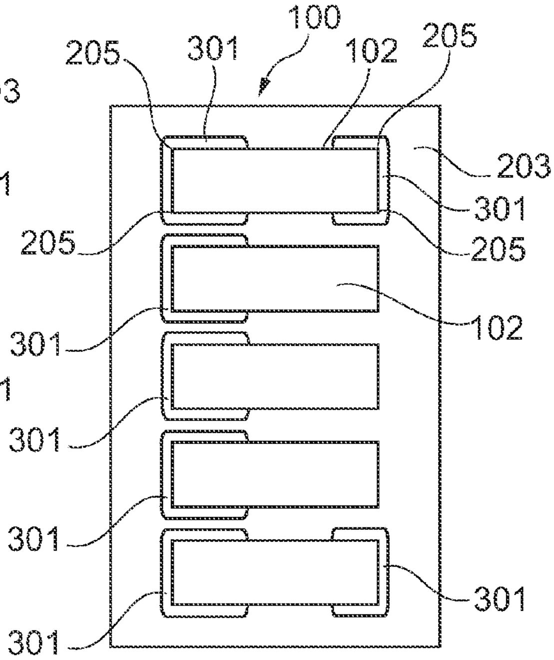

Fig. 1B

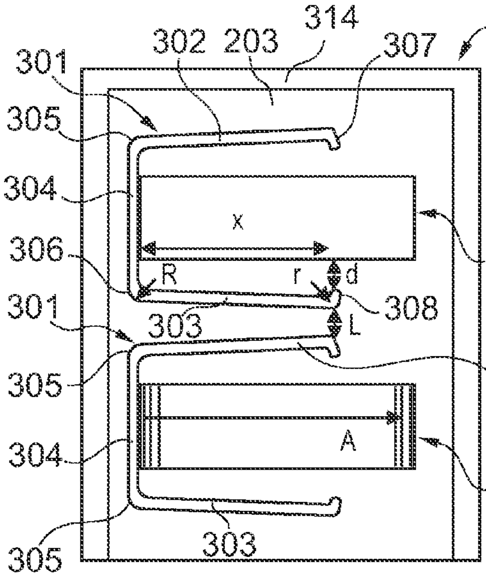

Fig. 1C

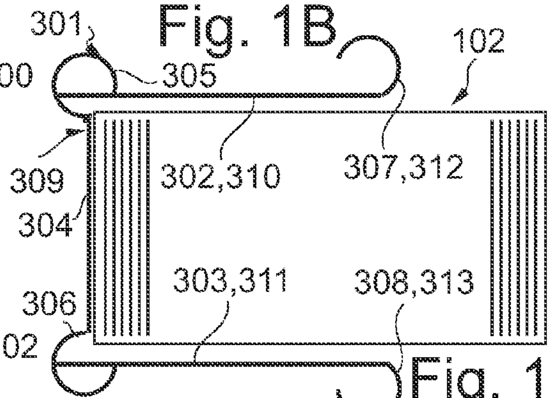

Fig. 1D

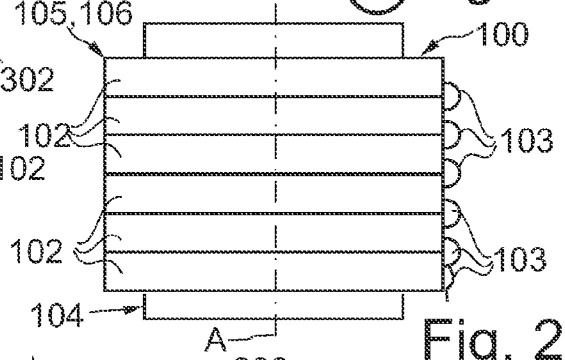

Fig. 2

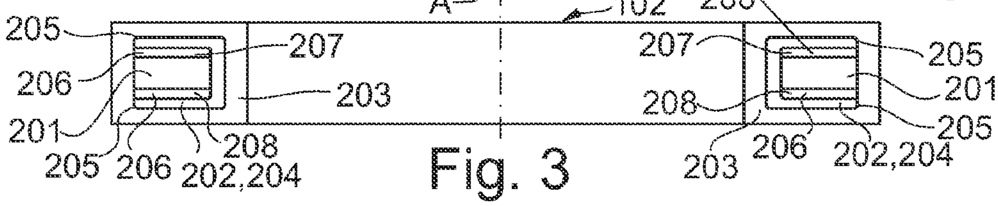

Fig. 3

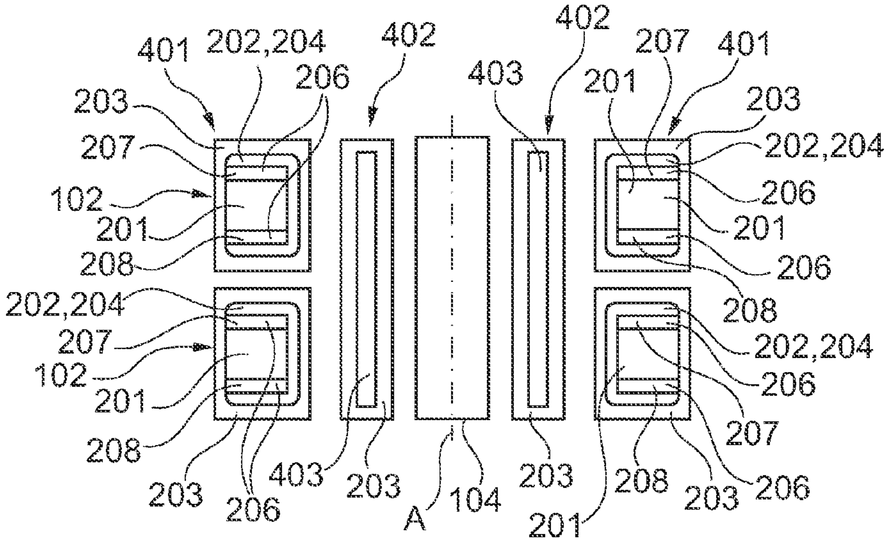

Fig. 4

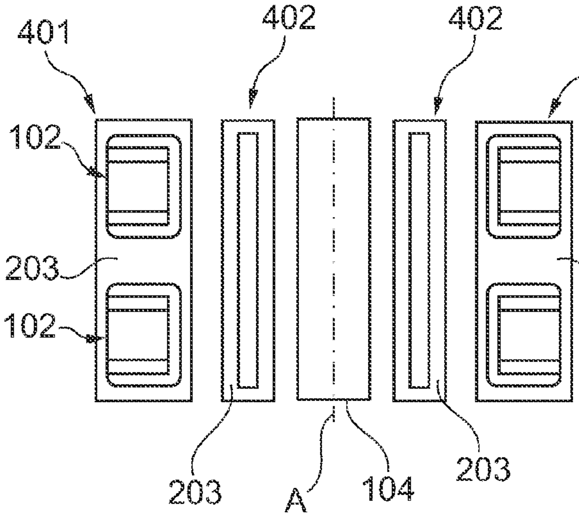

Fig. 5

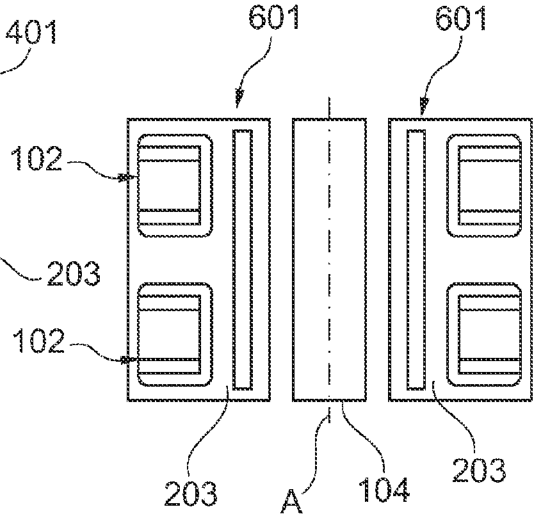

Fig. 6

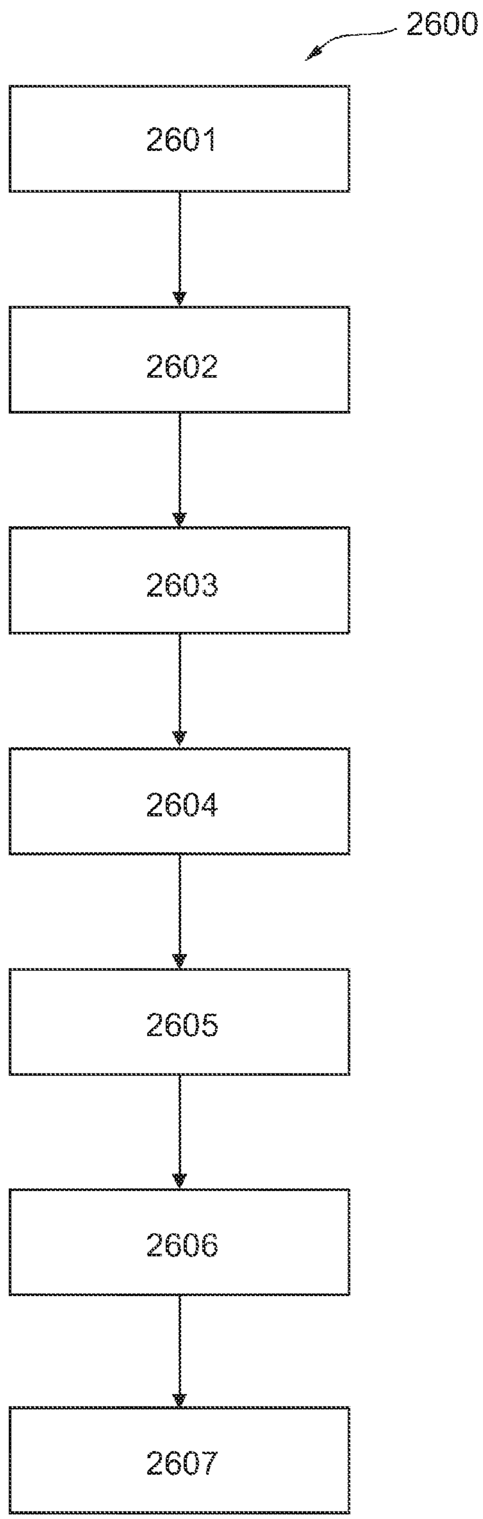

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 10 16 7484

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 4 176 334 A (BURITZ ROBERT S [US] ET AL) 27 November 1979 (1979-11-27) * column 3, lines 3-20 * * column 4, lines 20-24 * * column 5, line 35 - column 6, line 57; figures 1,3 *	1-15	INV. H01F27/28 H01F27/36 H01F27/32
X	DE 42 04 092 A1 (ANT NACHRICHTENTECH [DE]) 19 August 1993 (1993-08-19) * column 1, lines 3-18 * * column 1, line 64 - column 3, line 2; figures 1,2 *	1-15	
X	US 3 708 875 A (MARTINCIC P ET AL) 9 January 1973 (1973-01-09) * column 1, lines 18-22 * * column 4, line 3 - column 6, line 52; figures 1-3,9 *	1-15	
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A	FR 931 580 A (ALSTHOM CGEE) 26 February 1948 (1948-02-26) * page 2, lines 1-32; figure 1 *	1,3,5,9, 10,13	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	2 December 2010	Teske, Ekkehard

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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D : document cited in the application
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 10 16 7484

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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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82