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## (54) Electric coil device for electro-technical and power electronics applications

(57) The present invention relates to a coil device (1), particularly for use in traction applications for providing an inductivity, comprising:
- a coil (2) for providing inductivity;
- a magnetic shell (3), particularly made of soft-magnetic material, to guide a magnetic field around the coil (2); and
- an inner volume (5) inside the magnetic shell (3) which is filled with an insulating liquid, so that the coil (2) is at least partly immersed in the insulating liquid.

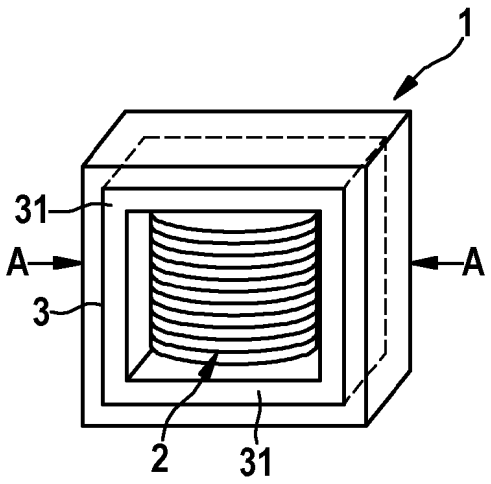


Fig. 1a

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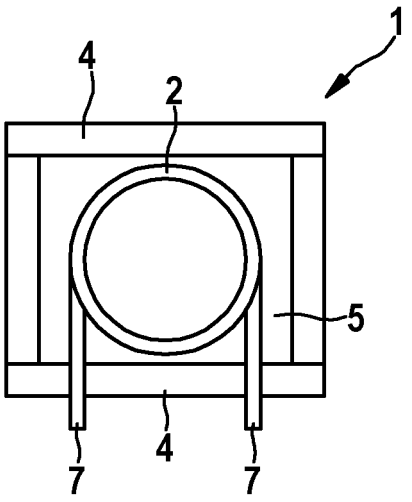


Fig. 1b

## Description

### Technical field

**[0001]** The present invention relates to electric devices, in particular to housings for such electric devices.

### Related art

**[0002]** In many electro-technical and power electronics applications, converters are used to convert AC or DC electrical power from a power source, such as an electric power grid, to AC or DC voltage and/or current which is needed for the load or the device to be operated.

**[0003]** Conventionally, huge transformer units having magnetically coupled primary and secondary coils are applied between the grid and the load to provide AC/AC power transformation. In such applications, an inductivity-type choke is often applied between the load and the secondary side of the transformer and can be used as part of an LC filter in a motor converter.

**[0004]** Recently, especially for traction applications in trains or the like, the bulky line frequency transformer units on grid side in combination with a rectifier are replaced by power electronic traction transformers (PETT) which provide a conversion capability with strongly reduced weight and size. The power electronic traction transformer in such an AC-traction application comprises a power electronic circuit with at least one multilevel converter connected to the grid and uses medium frequency transformer (MFT) for isolation purposes. Such circuitry of a PETT is shown in Figure 4. The use of the power electronic traction transformer requires the use of an input choke on grid side used to limit a short circuit current, to control the power flow and to smooth the AC input current. There is an important focus on weight and size of the input choke which may substantially affects the overall weight and size of the system.

**[0005]** In traction applications, the bulky conventional transformers are housed in an oil container filled with oil to provide electrical insulation and uniform heat dissipation away from the windings of the transformer. Cooling of potential auxiliary choke(s) required by the customer can easily be managed by placing the choke(s) in the oil container together with the transformer without the need to substantially increase the size of the oil container.

**[0006]** A conventional input choke has a coil with a number of windings and an air core. Owing to the air core, the inductivity can be kept unaffected by the current it carries, thus efficiently limiting a short circuit current, if necessary. The coil is surrounded by a magnetic shell to guide the magnetic flux produced by the coil around the windings, thereby preventing an induction of Foucault currents into the walls of the oil container and enabling compliance with EMC rules.

**[0007]** The benefits coming along with the use of power electronic traction transformers with respect to weight and size are contradicted by the bulky input choke which additionally requires its core to be immersed in oil for cooling and insulation purposes. In particular, replacing the bulky conventional transformer with a power electronic traction transformer would still require the oil container to accommodate the input choke.

**[0008]** It is therefore an object of the present invention to provide an oil-immersed coil device, such as an input choke, with substantially reduced weight and size.

**[0009]** Furthermore, it is an object of the present invention to avoid the need for a full oil container for accommodating the coil device.

### Summary of the invention

**[0010]** The above objects have been achieved by the electric coil device for use with applications according to claim 1 and the system according to the further independent claim.

**[0011]** Preferred embodiments of the present invention are indicated in the dependent subclaims.

**[0012]** According to a first aspect, a coil device for use with high-voltage/high-power applications for providing inductivity is provided, comprising:

- a coil for providing inductivity;
- a soft-magnetic magnetic shell to guide a magnetic field around the coil; and
- an inner volume inside the magnetic shell which is filled with an insulating liquid, particularly oil.

**[0013]** Particularly, the coil may be immersed in the insulating liquid oil.

**[0014]** One idea of the coil device is to use the magnetic shell, which at least partly surrounds the coil for guiding a magnetic field produced by the coil when operated between the axial ends of the coil, as walls or as housing for the oil container of a conventional shell-type coil device. In this way, the coil device has a coil with a number of windings which is provided within a magnetic shell. The magnetic shell magnetically couples one end of the coil with the opposite end thereof. The magnetic shell substantially encompasses the coil and can be of a cylindrical shape, so that the magnetic shell can form a container for keeping the oil or an oil container can be enclosed by the magnetic shell.

**[0015]** As a first effect, it can be achieved that the coil is kept in an oil volume without the need of an additional oil container in which the coil device, including the magnetic shell, is immersed. Thereby, a substantial weight reduction is achieved firstly by omitting the additional oil container and secondly by reducing the amount of oil since the volume of the casing built in/by the interior of the magnetic shell to keep the oil is much smaller than the volume of an oil container surrounding the magnetic shell of the electric coil device.

**[0016]** Furthermore, the inner volume may be formed by the magnetic shell.

**[0017]** It may be provided that the magnetic shell has

end faces which are covered with end covers to tightly enclose the inner volume. The open axial ends of the coil device are thus substantially covered with portions of the magnetic shell, wherein the axial ends of the magnetic shell are tightly closed, so that the inner volume of the magnetic shell can hold the oil contained in it.

**[0018]** According to an embodiment, a terminal for electrically connecting the coil may pass through at least one of the end covers.

**[0019]** Furthermore, the end covers may be made of metal, insulating material or metal coated with an insulating material.

**[0020]** According to a further embodiment, the inner volume may be formed by an enclosure fully enclosed by the magnetic shell and accommodating the coil, wherein the enclosure is made of a non-magnetic material.

**[0021]** The enclosure may be further formed by a lateral wall and portions of the magnetic shell covering end faces of the coil.

**[0022]** Moreover, the magnetic shell may be formed by first portions covering the end faces of the coil and at least one second portion connecting the first portions on at least one side of the coil.

**[0023]** It may be provided that the magnetic shell has a cylindrical body having an axis which is perpendicular to the coil axis.

**[0024]** According to a further aspect a system is provided, comprising:

- a high-voltage/high-power device, particularly a power electronic transformer, and
- the above coil device electrically connected to the high-voltage/high-power device.

Brief description of the drawings

**[0025]** Preferred embodiments of the present invention are described in more detail in the following description in conjunction with the accompanying drawings, in which:

Figure 1a shows a perspective view onto a coil device with an open face side;

Figure 1 b shows a cross-sectional view across the axial direction of the coil along line A-A;

Figure 2 shows a perspective view onto a coil device according to another embodiment; and

Figure 3 shows a perspective view of the coil device, wherein the open ends of the magnetic shell are closed with metal covers.

Figure 4 shows a schematic of circuitry of a power electronic traction transformers (PETT) connected via a coil device to the grid

Description of embodiments

**[0026]** Figures 1 a and 1 b show a perspective view of a coil device 1 without an end cover and a cross-sectional view of the coil device 1, respectively. The coil device 1 is made for providing a constant inductivity and can be used as an input choke for e.g. high-voltage/high-power applications, such as in combination with a power electronic traction transformer, a conventional transformer or any other power electrical arrangement. Other applications may use the coil device 1 as a current-limiting reactor, a smoothing reactor, a harmonic filter reactor, a damping reactor, a power flow control reactor or the like. Furthermore, the coil device 1 can be a stand-alone device or can be a functional part of a conventional transformer arrangement or of any other electrical device, including one or more coils 2.

**[0027]** The coil device 1 comprises a coil 2 having single-layer windings, e. g. forming a cylindrical body with an annular cross section. In other embodiments, the coil 2 can have multi-layer windings and can be cylindrical with differently shaped cross-sections such as square or rectangular cross-sections.

**[0028]** The coil 2 is housed and mounted in a magnetic shell 3 having soft magnetic properties and being configured to encompass the coil 2 in a plane parallel to an axis of the cylindrical body of the coil2. Hence, the magnetic shell 3 provides first portions 31 covering the end faces of the cylindrical body of the coil 2 and second portions 32 extending parallel to the axis of the coil 2 on at least two lateral surfaces. Preferably, the magnetic shell 3 forms a rectangular box with its first and second portions 31, 32 and with two open end faces. In other embodiments, the magnetic shell 3 can be formed as a cylinder having a non-rectangular cross section or a circular cross section. Basically, the axis of the cylindrical magnetic shell 3 is perpendicular to the axis of the cylindrical body of the coil 2.

**[0029]** Substantially the length of the magnetic shell 3 between the end faces may be larger than the diameter or dimension of the coil 2 housed therein in the same direction, so that the coil 2 is fully enclosed in the magnetic shell 3.

**[0030]** The open end faces of the magnetic shell 3 are closed with end covers 4, such as to tightly keep oil within an inner volume 5 formed by the magnetic shell 3 and the end covers 4. The inner volume 5 is filled with oil.

**[0031]** The coil 2 is mounted within the magnetic shell 3 such that the outer surface of the windings is spaced from the inner surfaces of the walls of the magnetic shell 3, thereby providing electrical insulation. Furthermore, the coil 2 is filled with oil to reduce insulation distances and cool the windings. As there is no magnetic material which passes through the axis of the coil the inductivity is kept unaffected by the current it carries.

**[0032]** The coil 2 has electrical terminals 7 which pass through one of the end covers 4.

**[0033]** Figure 2 shows a tight enclosure 6 surrounding

the cylindrical body of the coil 2, wherein the oil is kept only within the volume of the tight enclosure 6, so that the magnetic shell 3 does not come into contact with the oil. The tight enclosure 6 encompasses the cylindrical body of the coil 2 on a lateral surface thereof, using the inner walls of the first portions 31 of the magnetic shell 3 at the end faces of the coil 2 to provide the tight oil-filled volume or it can provide a closed container fully housing the coil 2 which is contained within the magnetic shell 3. The material of the enclosure 6 is preferably a non-magnetic material and either made of insulating material or insulated, such as by a coating, with respect to the windings of the coil 2.

**[0034]** Figure 3 shows a perspective view onto the closed coil device 1, where the end faces of the magnetic shell 3 are closed with metal covers, such as plates made of aluminum, which can be soldered or attached with other suitable attachment means onto the end faces of the magnetic shell 3. Another attachment means is, e. g., riveting with the provision of a gasket.

**[0035]** Furthermore, the end covers 4 can also be fully made of insulating material or the surface of a metal cover can be coated with an insulating material, e. g. with epoxy.

**[0036]** The tightness of the magnetic shell 3 can be achieved through various processes. For instance, the magnetic shell 3 with its closed end faces can be dipped into a liquid coating, such as epoxy or polyester, which helps to reinforce the tightness of the casing or the liquid coating can be poured into low-thickness hollows previously created on each of the faces of the magnetic shell 3, followed by curing of the coating.

**[0037]** The assembly of the coil device 1 provides a high weight reduction, in particular because the required amount of oil is substantially reduced. Furthermore, also the size of the system as shown in figure 4 in which the coil device 1 is implemented, in particular is connected between the grid and the power electronic traction transformer, can be essentially reduced as a separate oil container is no longer needed for the coil device 1.

**Reference list**

| | |
|---|---|
| 1 | coil device |
| 2 | coil |
| 3 | magnetic shell |
| 31 | first portion of the magnetic shell |
| 32 | second portion of the magnetic shell |
| 4 | end cover |
| 5 | inner volume |
| 6 | enclosure |
| 7 | terminal |

## Claims

**1.** Coil device (1), particularly for use in traction applications for providing an inductivity, comprising:

- a coil (2) for providing inductivity;
- a magnetic shell (3), particularly made of soft-magnetic material, to guide a magnetic field around the coil (2); and
- an inner volume (5) inside the magnetic shell (3) which is filled with an insulating liquid, in particular in oil, so that the coil (2) is at least partly immersed in the insulating liquid.

**2.** Coil device (1) according to claim 1, wherein the coil (2) is at least partly immersed in the insulating liquid.

**3.** Coil device (1) according to claim 1 or 2, wherein the inner volume (5) is formed by the magnetic shell (3).

**4.** Coil device (1) according to claim 3, wherein the magnetic shell (3) has end faces which are covered with end covers (4) to tightly enclose the inner volume (5).

**5.** Coil device (1) according to claim 4, wherein a terminal (7) for electrically connecting the coil (2) passes through at least one of the end covers (4).

**6.** Coil device (1) according to claim 4 or 5, wherein the end covers (4) are made of metal, non magnetic material, insulating material or metal coated with an insulating material.

**7.** Coil device (1) according to claim 1 or 2, wherein the inner volume (5) is formed by an enclosure (6) fully or partially enclosed by the magnetic shell (3) and accommodating the coil (2).

**8.** Coil device (1) according to claim 7 wherein the enclosure (6) comprises a non-magnetic and not electrically conductive material.

**9.** Coil device (1) according to claim 7, wherein the enclosure (6) is formed by a lateral wall portion of the magnetic shell (3) covering end faces of the coil (2).

**10.** Coil device (1) according to any one of claims 1 to 8, wherein the magnetic shell (3) is formed by first portions (31) covering the end faces of the coil (2) and at least one second portion (32) connecting the first portions (31) on at least one side of the coil (2).

**11.** Coil device (1) according to claim 9, wherein the magnetic shell (3) has a cylindrical body having an axis which is perpendicular to the coil axis.

**12.** System comprising:

- a device, particularly a traction transformer device or a power electronic transformer; and
- a Coil device (1), particularly for use in trac-

tion applications for providing an inductivity, the coil device (1) comprising:

- a coil (2) for providing inductivity;
- a magnetic shell (3), particularly made of soft-magnetic material, to guide a magnetic field around the coil (2); and
- an inner volume (5) inside the magnetic shell (3) which is filled with an insulating liquid, in particular in oil, so that the coil (2) is at least partly immersed in the insulating liquid, and wherein
- the coil device (1) is electrically connected to the device.

**13.** System according to claim 12 wherein a coil device (1) according to any one of claims 2 to 11 is provided.

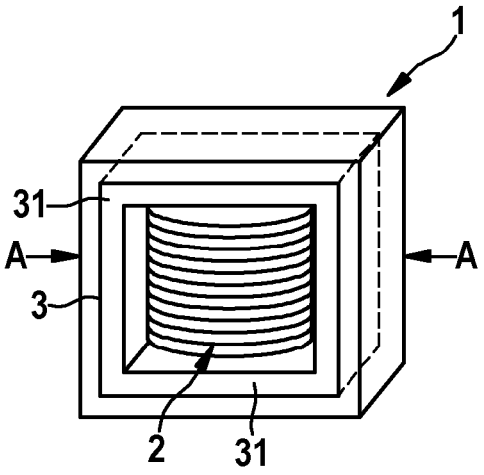


Fig. 1a

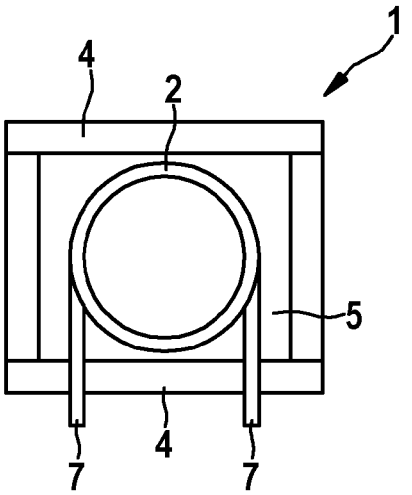


Fig. 1b

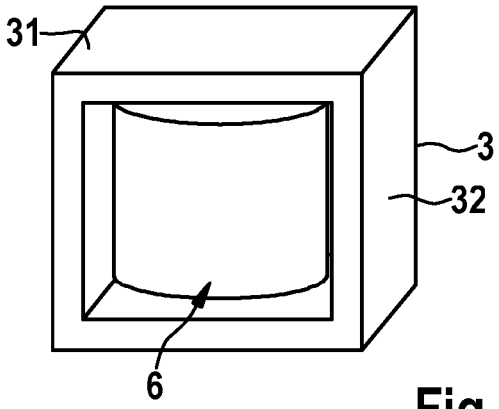


Fig. 2

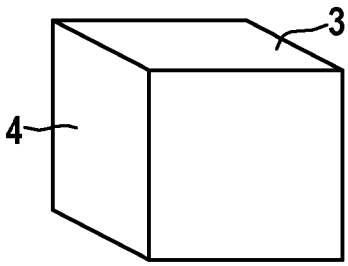


Fig. 3

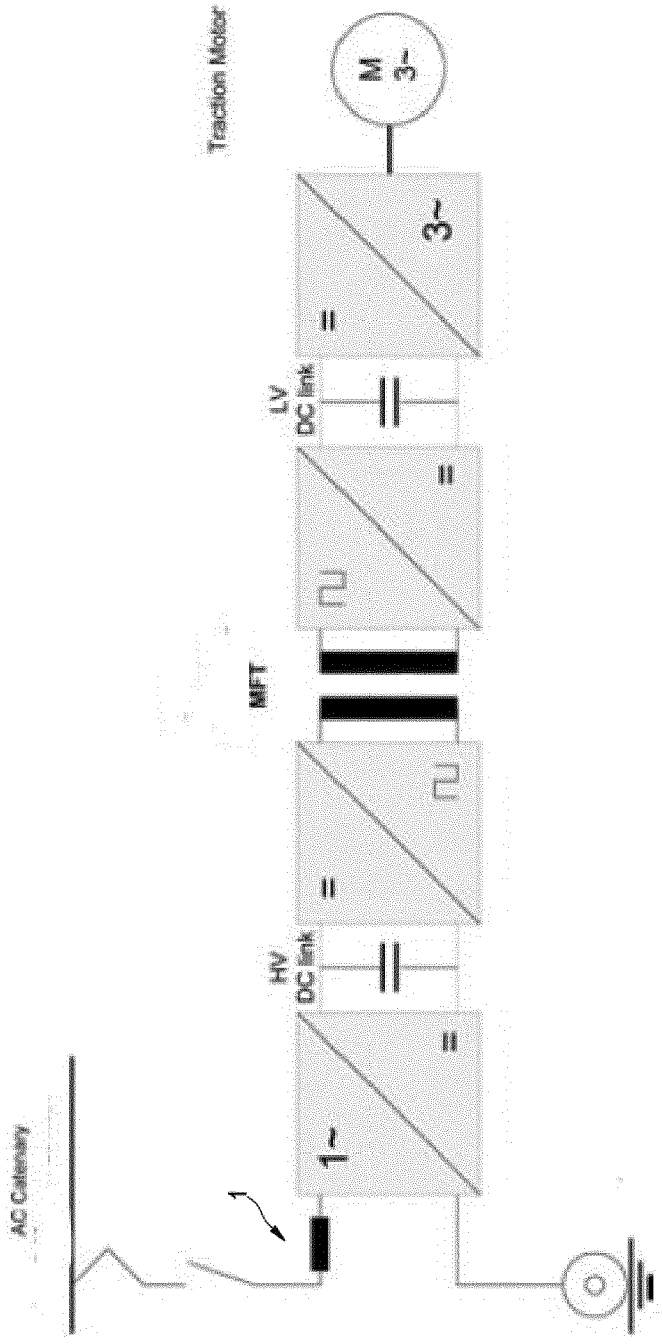


Fig. 4

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# EUROPEAN SEARCH REPORT

Application Number
EP 13 17 3505

## 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 | EP 0 618 596 A1 (SMIT TRANSFORMATOREN BV [NL]) 5 October 1994 (1994-10-05)<br>* abstract *<br>* column 1, line 1 - column 4, line 1 *<br>* figures 1,2 * | 1-6,10, 12,13 | INV.<br>H01F27/36<br>H01F37/00<br>H01F27/12 |
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| X | US 3 362 001 A (WISHMAN AUGUST F ET AL)<br>2 January 1968 (1968-01-02)<br>* column 3, lines 27-66 *<br>* figures 1,2,3 * | 1-6,10 | |
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| TECHNICAL FIELDS SEARCHED (IPC) |
|---|
| H01F |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 21 November 2013 | Kardinal, Ingrid |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 13 17 3505

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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