Dry-type electrical transformer

Dry-type electrical transformer comprising a magnetic core, an inner winding which is arranged around a portion of the magnetic core and has a first rated voltage, at least one outer winding which is arranged around the inner winding and has a second rated voltage which is different from the first rated voltage, wherein the outer winding is spaced apart from the inner winding so as a desired total air-gap is formed between. A plurality of electrically insulating barriers are positioned between the inner and outer windings and are spaced apart from each other and from the windings so as the total air-gap is divided into a plurality of sub-air-gaps.
Description

[0001] The present invention relates to a dry-type electrical transformer having improved performances and an optimised structure.

[0002] It is widely known in the art the use of dry-type transformer, i.e. electrical induction devices, which exploit the electromagnetic induction for properly transmitting and distributing electricity over power lines.

[0003] In particular, the basic task of an electrical dry-type transformer, common also to various types of power transformers, is to allow exchanging electric energy between two or more electrical systems of usually different voltages.

[0004] Most common dry-type transformers generally comprise a magnetic core composed by one or more legs or limbs connected by yokes which together form one or more core windows; for each phase, around the legs there are arranged a number of windings, i.e. low-voltage windings, high-voltage windings.

[0005] The phase windings are usually realized by winding around the corresponding leg of the core suitable conductors, for example wires, or cables, or strips, so as to achieve the desired number of turns. Cooling of live parts is performed by means of air.

[0006] Due to the intrinsic structural characteristics and functioning of these devices, a very important aspect concerns the distance between the low voltage (LV) and the high voltage (HV) windings of each phase.

[0007] Indeed, on one side such distance should be large enough in order to have enough space for air cooling and what is more important to increase the electric field and so the voltage the windings can support without having any electrical discharge between them so as to properly meet international rules and qualification tests.

[0008] On the other side, instead, the larger is this distance the higher is the overall material cost of the transformer.

[0009] In particular, a larger distance between the LV and HV windings increases the impedance of the transformer and therefore negatively influences the desired electromagnetic performances of the transformers, thus entailing for example an increase of the magnetic core size in order to face such a negative effect.

[0010] At the current state of the art, although the solutions adopted allow achieving appreciable results, there are still some aspects which can be optimised and technically improved, in particular as regard to the construction layout between the phase windings.

[0011] Hence, the aim of the present invention is to provide a dry-type electrical transformer whose constructive structure is optimized with respect to equivalent types of known induction devices, in particular as regard to the distance and constructive layout between the windings of each phase.

[0012] This aim is achieved by a dry-type electrical transformer characterized in that it comprises:

- a magnetic core;
- at least one inner winding which is arranged around a portion of said magnetic core and has a first rated voltage;
- at least one outer winding which is arranged around said at least one inner winding and has a second rated voltage which is different from said first rated voltage, wherein said at least one outer winding is spaced apart from said at least one inner winding so as a desired total air-gap is formed there between;

[0013] The features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawings where:

Figure 1 is a view of an exemplary three-phase dry-type electrical transformer according to the invention with one phase cut in order to better illustrate some details;

Figure 2 is a top plan view schematically showing a first possible embodiment of a phase winding assembly used in a dry-type electrical transformer according to the present invention;

Figure 3 is a top plan view schematically showing a second possible embodiment of a phase winding assembly used in a dry-type electrical transformer according to the present invention;

Figure 4 is a top plan view schematically showing a third possible embodiment of a phase winding assembly used in a dry-type electrical transformer according to the present invention;

Figure 5 is a top plan view schematically showing a fourth possible embodiment of a phase winding assembly used in a dry-type electrical transformer according to the present invention;

Figure 6 schematically shows a lateral cross section of the embodiments of figure 2 or figure 3;

Figure 7 schematically shows a lateral cross section of the embodiments of figure 4 or figure 5.

[0014] For the sake of simplicity, the dry-type electrical transformer according to the present invention will be hereinafter described by making reference to only one electrical phase; clearly, such description and features of the invention are applicable likewise to any phase of a dry-type transformer independently from the number of phases.

[0015] With reference to the above cited figures, the dry-type electrical transformer according to the invention, globally indicated by the reference number 100, comprises a magnetic core 200 which is operatively coupled to a supporting structure.
The exemplary embodiment illustrated, the magnetic core 200 comprises one leg 201 for each phase, namely three, with the legs 201 mutually connected by yokes according to constructive configurations which are well known in the art and therefore will not be described herein in details.

In turn, the supporting structure may for example comprise a couple of clamps 101 which are positioned on the opposite sides of the core and may be connected by one or more vertical connecting elements, for example tie-rods; clearly, also the supporting structure may have different shape or comprise additional or alternative components according to various solutions which are readily available to those skilled in the art.

As better illustrated in figure 2-5, around the magnetic core 200, in particular around each leg 201 there is arranged, for each phase, at least one inner winding 10 which has a first rated voltage, and at least one outer winding 20 which is arranged around the inner winding 10 and has a second rated voltage, preferably higher than said first rated voltage; for example, the rated voltage of the inner winding 10 can be 0.4 kV, while the rated voltage of the outer winding 20 can be 20 kV. Although international standards generally define the field of low-voltage applications as that with voltage levels up to 1kV, and the field of high-voltage application the one with voltage levels above 1 kV, in the technical field of induction devices of the type of the present invention, the outer winding 20 is normally indicated as the high-voltage winding, whilst the inner winding 10 is usually indicated as the low-voltage winding, and these definitions will be used in the following description.

In particular, the inner 10 and outer windings 10, 20 are placed coaxially around the corresponding portion of the magnetic core 200, i.e. the leg 201, and are spaced apart from each so as a desired total air-gap (A), that is a distance measured perpendicularly with respect to a vertical axis 202 of the leg 1. is formed there between.

One or more supporting blocks 103 for the inner winding 10 and outer winding 20 are positioned above and below the windings 10, 20 themselves.

Advantageously, the transformer 100 according to the invention comprises a plurality of electrically insulating barriers 2, 3, 4,...n which are positioned between the LV winding 10 and the HV winding 20 and are spaced apart from each other and from the inner and outer windings 10, 20 so as the total air-gap (A) or distance between such windings 10, 20 is divided into a plurality of sub-air-gaps (A1, A2, A3) as better illustrated in figure 6 and 7.

For example, such barriers 2,3,4,...n are formed by thin sheets or films of electrically insulating materials, such as NOMEX, whose thickness can for instance vary between 0.8 mm and 1.5 mm; further, the barriers have preferably rugged and dark coloured surfaces. In this way, due to the increase in the surface of heat radiation, the cooling of the transformer could be improved. Preferably, each electrically insulating barrier 2, 3, 4,...n has a height (H1), which is higher than the height (H2) of the coaxial LV and HV windings 10, 20 as schematically illustrated in figures 6 and 7; such heights (H1) and (H2) are meant to be measured along the vertical extension of the leg 201, i.e. substantially parallel to its vertical axis 202.

According to a particularly preferred embodiment, the plurality of electrically insulating barriers comprises at least three barriers 2, 3, 4, as illustrated in the embodiment of figures 2-7; clearly, based on the applications, it is possible to increase the numbers of barriers.

Alternatively, it is possible to have only two electrically insulating barriers.

In one possible embodiment illustrated in figures 2-4, the electrically insulating barriers 2, 3, 4, are arranged coaxially to each other and to the LV and HV windings 10, 20, with respect to the respective leg 201, and in particular to its reference vertical axis 202.

Alternatively, as illustrated in the exemplary embodiment of figure 5, the electrically insulating barriers 2, 3, 4, are arranged spirally between the inner and outer windings 10, 20 with respect to the respective leg 201, and in particular to its reference vertical axis 202.

Preferably, when three or more electrically insulating barriers are used, such barriers are positioned relative to each other so as that the sub-air gaps or distance (A1, A2, A3) formed between two adjacent electrically insulating barriers, e.g. barriers 2-3, and barriers 3-4 of the embodiments illustrated, are substantially equal to each other.

More preferably, the electrically insulating barriers (2, 3, 4, n) are positioned relative to each other and between the inner and outer windings 10, 20 so as the total air-gap or distance (A) between the LV winding 10 and the HV winding 20 is divided into a plurality of substantially equal sub-air-gaps (A1, A2, A3). According to a particularly preferred embodiment, each sub air gap is about 10 mm, in any case preferably not greater than 15 mm.

It is to be understood that each air gap is measured taking as reference the centre line of the thickness of each barrier 2, 3, 4; thus for example, in the embodiment of figure 2, the air gap A1 is the distance between the outer surface of the LV winding 10 and the centre line of the inner barrier 2; the air gap A2 is the distance between the respective centre lines of the inner barrier 2 and the adjacent barrier 3; the air gap A3 is the distance between the inner surface of the HV winding 20 and the centre line of the outer barrier 4.

Preferably, between each insulating barrier and the adjacent one there is provided a corresponding set (5, 6,...n) of spacers which are interposed between and connected to the respective faces of the adjacent barriers; for example in the embodiment illustrated in figures 2-7, between the inner barrier 2 and the intermediate barrier 3 there is a first set of spacers 5, and between the intermediate barrier 3 and the outer barrier 4, there is a second set of barriers 6. Preferably, as illustrated in
the adjacent set of spacers, e.g. the spacers of the drawings sheet), the spacers of a set of spacers, for instance the spacers 5, are offset with the spacers of the adjacent set of spacers, e.g. the spacers.

According to one possible embodiment, the electrically insulating barriers 2, 3, 4,...n can be operatively connected to and supported by the blocks 103 supporting the LV and HV windings 10, 20, either by top and bottom blocks, or just by the bottom blocks 103; for example the barriers can be entered into suitable slots of the top and/or bottom blocks 103 or just rest on those placed at the bottom part, or either ways, namely entered into slots of the top blocks 103 and resting on the bottom blocks 103, or any other possible alternative.

In alternative or additionally, some elements, for instance spacers in the form of small blocks (or even clips or rivets) schematically indicated in figure 6 by the reference number 41, at one or both ends of the insulating barriers (2,3,4,...n), where the electric field is small. These spacers 41 connect to each other adjacent barriers 2,3,4,...n.

In this way areas with higher electrical field are not penetrated.

According to one possible embodiment, the electrically insulating barriers 2, 3, 4,...n can be operatively connected to and supported by the blocks 103 supporting the LV and HV windings 10, 20, either by top and bottom blocks, or just by the bottom blocks 103; for example the barriers can be entered into suitable slots of the top and/or bottom blocks 103 or just rest on those placed at the bottom part, or either ways, namely entered into slots of the top blocks 103 and resting on the bottom blocks 103, or any other possible alternative.

In alternative or additionally, some elements, for instance spacers in the form of small blocks may be used and can be operatively connected to the barriers 2,3,4,...n and to the supporting blocks 103; also in this case is possible to use such small blocks only at one edge of the barriers, e.g. the bottom one, or at both edges. These small blocks can be mechanically attached to the support blocks 103, either preferably only to the bottom blocks 103 and/or the top blocks 103, or they can be attached to the top supporting blocks 103 and can rest on the bottom supporting blocks 103.

Furthermore, in addition or in alternative to the above possibilities, it is possible also to use some further fixing elements, such as clips which can be connected to the barriers for example in a plug-in or clip-clap fashion, or even rivets can be used. Also these clips or rivets can just rest on the supporting blocks, e.g. the bottom ones, or can be operatively connected, e.g. mechanically, to the bottom supporting blocks 103 and/or the top supporting blocks 103.

In this way the fixing points of each barrier would be increased thus improving the overall mechanical stability.

As a whole result, the overall cylindrical shape and rigidity is increased and the supporting points are located far away from the areas with higher electric field according to a very simple and cost effective arrangement.

According to these embodiments, set of spacers (5, 6,...n) between adjacent barriers may or may not be used.

According to a different embodiment illustrated in figures 4, 5 and 7, the electrically insulating barriers 2, 3, 4,...n are operatively connected to and supported by the inner winding 10.

In this case, the transformer 100 preferably comprises an additional set of supporting spacers 40 which are interposed between and operatively connected to the inner winding 10 and the inner electrically insulating barrier 2 of the plurality of electrically insulating barriers 2, 3, 4,...n.

Also these spacers 40 have a height, e.g. the same height (H3) of the spacers 5, 6, which is lower than the height (H2) of the coaxial LV and HV windings 10, 20; further such spacers 40 can be preferably positioned offset with the spacers of the adjacent set of spacers, i.e. the spacers 5, with reference to the radial direction 203.

Alternatively, each spacer 40 of the set of supporting spacers may be radially aligned with a corresponding spacer 5 of the adjacent set of spacers 5.

In practice, it has been found that the dry-type electrical transformer according to the invention fully achieves the intended aim giving some significant advantages and improvements with respect to known transformers of the same type. Indeed the use of insulating barriers between the phase windings divides the total air gap into a certain number of smaller sub air gaps; with respect to known transformers, these smaller sub air gaps can withstand higher electric fields compared to known transformers, leading to a significant reduction of the total air gap, and so saving material cost and no-load losses.

In particular, with the proposed invention, the total air gap is reduced to about 65-70% compared to the prior art solutions of the same type and level of rated voltage.

The dry-type electrical transformer thus conceived is susceptible of numerous modifications and variations, all of which are within the scope of the inventive concept as defined in the claims; for example, the features described for only some of the embodiments illustrated can be used in any of the embodiments herein disclosed; the shape and/or material and/or number of the spacers and/or barriers may be changed according to the applications provided they are compatible with the scope of the present invention.

Finally, all the details may furthermore be re-
placed with other technically equivalent elements, and
the materials and dimensions may be any according to
requirements and to the state of the art, provided they
are compatible with the scope of and functioning in the
application.

Claims

1. A dry-type electrical transformer (100) characterized in that it comprises:

- a magnetic core (200);
- at least one inner winding (10) which is arranged around a portion of said magnetic core (1) and has a first rated voltage;
- at least one outer winding (20) which is arranged around said at least one inner winding (10) and has a second rated voltage which is different from said first rated voltage, wherein said at least one outer winding (20) is spaced apart from said at least one inner winding (10) so as a desired total air-gap (A) is formed there between;
- a plurality of electrically insulating barriers (2, 3, 4, n) which are positioned between said inner and outer windings (10, 20) and are spaced apart from each other and from said inner and outer windings (10, 20) so as said total air-gap (A) is divided into a plurality of sub-air-gaps (A1, A2, An).

2. The dry-type electrical transformer according to claim 1 characterized in that said plurality of electrically insulating barriers (2, 3, 4, n) comprises two barriers.

3. The dry-type electrical transformer according to claim 1 characterized in that said plurality of electrically insulating barriers (2, 3, 4, n) comprises at least three barriers.

4. The dry-type electrical transformer according to one or more of the previous claims characterized in that said electrically insulating barriers (2, 3, 4, n) have rugged surfaces.

5. The dry-type electrical transformer according to one or more of the previous claims characterized in that said plurality of electrically insulating barriers (2, 3, 4, n) is positioned between said inner and outer windings (10, 20) so as said total air-gap (A) is divided into a plurality of substantially equal sub-air-gaps (A1, A2, An).

6. The dry-type electrical transformer according to claim 5 characterized in that said substantially equal sub-air-gaps (A1, A2, An) have each a value of about 10 mm.

7. The dry-type electrical transformer according to one or more of the previous claims characterized in that said electrically insulating barriers (2, 3, 4, n) are arranged coaxially to each other and to said inner and outer windings (10, 20) with respect to said portion of the magnetic core (1).

8. The dry-type electrical transformer according to one or more of the previous claims characterized in that said electrically insulating barriers (2, 3, 4, n) are arranged spirally between said inner and outer windings (10, 20).

9. The dry-type electrical transformer according to one or more of the previous claims characterized in that it comprises one or more supporting blocks (103) for said inner winding (10) and/or outer winding (20), and in that said electrically insulating barriers (2, 3, 4, n) are operatively connected to and supported by said supporting blocks (103).

10. The dry-type electrical transformer according to one or more of claims 1-7 characterized in that said electrically insulating barriers (2, 3, 4, n) are operatively connected to and supported by said at least one inner winding (10).

11. The dry-type electrical transformer according to one or more of the previous claims characterized in that between each insulating barrier (2, 3, 4, n) and the adjacent one (2, 3, 4, n) there is provided a corresponding set (5, 6, n) of spacers.

12. The dry-type electrical transformer according to claim 10 characterized in that each spacer (5) of a set of spacers (5) is radially offset with a corresponding spacer (6) of the adjacent set of spacers (6).

13. The dry-type electrical transformer according to claim 10 characterized in that each spacer (5) of a set of spacers (5) is radially aligned with a corresponding spacer (6) of the adjacent set of spacers (6).

14. The dry-type electrical transformer according to claim 9 characterized in that it comprises a plurality of supporting spacers (40) which are interposed between and operatively connected to said inner winding (10) and the inner electrically insulating barrier (2) of said plurality of electrically insulating barriers (2, 3, 4, n).

15. The dry-type electrical transformer according to one or more of the previous claims characterized in that the spacers of each set of spacers (5, 6, n) have a
height which is lower than the height of said inner and outer windings (10, 20).

16. The dry-type electrical transformer according to one or more of the previous claims characterized in that the electrically insulating barriers of said plurality of electrically insulating barriers (2, 3, 4, n) have each a height which is higher than the height of said inner and outer windings (10, 20).

17. The dry-type electrical transformer according to one or more of the previous claims characterized in that it comprises spacers (41) which are positioned between adjacent electrically insulating barriers at one or both ends of the insulating barriers (2, 3, 4, ..., n) themselves.
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