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(54)

FIRE PROTECTION OF A DRY POWER TRANSFORMER WINDING

(57)

The present disclosure relates to a dry type transformer 1 comprising a low voltage (LV) winding 3 and a high voltage (HV) winding 2. The LV winding and/or the HV winding comprises a cable winding part 2a comprising a winding of a cable 20. The cable comprises an electrical conductor forming a central part of the cable, an electrically insulating layer concentrically positioned outside of the conductor, and a grounded layer of an at least partly conducting material concentrically positioned outside of the insulating layer. The cable winding part comprises an electrically insulating material 6 in solid state moulded around the cable.

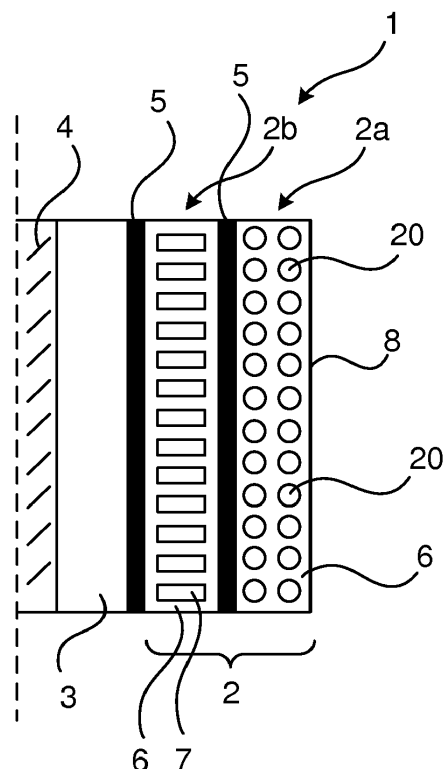


Fig. 1a

Description

TECHNICAL FIELD

[0001] The present disclosure relates to a dry-type high voltage (HV) power transformer.

BACKGROUND

[0002] Dry type small power transformers are often located in the vicinity of customer premises. The materials used in such transformers should hence fulfil minimum fire resistance class, e.g. F1 as per international standards. The traditional dry type transformer windings are casted using epoxy which is moulded around the conductors or the windings, which satisfies the fire class F1.

[0003] A less conventional dry type transformer winding is used in Dryformer™, developed by ABB, which is an oil-free power transformer in which its windings are made of cross-linked polyethylene (XLPE) cables, i.e. XLPE insulated HV cables. Using a cable winding for the HV winding of a dry type transformer may impart improved handling of transient, high frequency events such as lightning strikes, over the traditional casted winding. On the other hand, a cable winding may typically be less compact compared with a traditional casted winding.

[0004] The power rating of a cable winding transformer may thus be lower than for a cast winding transformer to avoid the risk of fire.

SUMMARY

[0005] It has now been realized that the fire resistance of a transformer in which the LV and/or HV, especially HV, winding is in the form of or at least partly consists of a grounded cable winding may be improved by means of embodiments disclosed herein. It has also been realized that a new type of winding for the winding of a dry type transformer, herein called a 'hybrid winding', providing an LV and/or HV winding which is a hybrid of a cast winding and a grounded cable winding, can improve the fire resistance, and thus voltage or power rating, of a transformer over a Dryformer™ type transformer while still obtaining the improved handling of electrical transients e.g. Lightning Impulse (LI) performance. Simulations of a simplified model of the hybrid winding, subject to lightning impulse (LI), show that it is possible to reduce the maximum voltage seen by a traditional cast winding part of a hybrid winding by making use of a grounded cable as a winding conductor, similar to the cable used in the Dryformer™ transformer, in a cable winding part of the hybrid winding.

[0006] The fire resistance of the cable winding (or cable winding part of a hybrid winding) may be further improved by casting or impregnating the cable winding with a fire resistant polymer material, e.g. an epoxy material. However, the amount of fire resistant polymer material is preferably relatively low, especially in comparison with the

amount used in any cast winding part of the hybrid winding, in order to not unduly reduce the heat transfer.

[0007] Additionally, the fire resistance of the cable winding (or cable winding part of any hybrid winding) may be improved by means of a metal foil placed as a barrier outside of the fire resistant polymer material, e.g. outside of the cable winding part of the hybrid winding and/or between the cable winding part and any cast winding part.

[0008] Additionally or alternatively, the fire resistance of the cable winding (or cable winding part of any hybrid winding) may be improved by means of a metal foil as an outer flexible layer of the cable in the cable winding.

[0009] According to an aspect of the present invention, there is provided a dry type transformer comprising a low voltage (LV) winding and a high voltage (HV) winding. The LV winding and/or the HV winding comprises a cable winding part comprising a winding of a cable. The cable comprises an electrical conductor forming a central part of the cable, an electrically insulating layer concentrically positioned outside of the conductor, and a grounded layer of an at least partly conducting material concentrically positioned outside of the insulating layer. The cable winding part comprises an electrically insulating material in solid state moulded around the cable.

[0010] It is to be noted that any feature of any of the aspects may be applied to any other aspect, wherever appropriate. Likewise, any advantage of any of the aspects may apply to any of the other aspects. Other objectives, features and advantages of the enclosed embodiments will be apparent from the following detailed disclosure, from the attached dependent claims as well as from the drawings.

[0011] Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated. The use of "first", "second" etc. for different features/components of the present disclosure are only intended to distinguish the features/components from other similar features/components and not to impart any order or hierarchy to the features/components.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Embodiments will be described, by way of example, with reference to the accompanying drawings, in which:

Fig 1a is a schematic partial longitudinal sectional view of an embodiment of a hybrid dry transformer, in accordance with the present invention.

Fig 1b is a schematic partial longitudinal sectional view of another embodiment of a hybrid dry transformer, in accordance with the present invention.

Fig 2 is a schematic perspective view of an embodiment of a cable for a cable winding of a dry transformer, showing different layers of said cable, in accordance with the present invention.

DETAILED DESCRIPTION

[0013] Embodiments will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments are shown. However, other embodiments in many different forms are possible within the scope of the present disclosure. Rather, the following embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. Like numbers refer to like elements throughout the description.

[0014] High voltage is generally defined as any voltage over 1000 volts, why any cable for voltages above 1 kV may be called high voltage cables. Cables for voltages of less than 33 kV may be called medium voltage cables in which case those for over 50 kV may be called high voltage cables.

[0015] A dry type transformer, as the term is herein used, relates to a transformer which is not insulated by a liquid, cf. oil filled or impregnated transformers, but uses a solid insulation material.

[0016] A cable, as discussed herein, comprises a central elongated conductor e.g. a wire or thread, typically of an electrically conducting metal such as copper or aluminium, surrounded by concentrically (i.e. coaxially) positioned layers such as insulation, semiconducting sheath, metal foil etc. A cable typically has a substantially circular cross section. A cable winding thus contrasts to a traditional cast winding by using a conductor comprised in a cable instead of a conductor which is cast, typically bare/naked (but could have an enamel or oxidized layer on the conductor), in an electrically insulating polymeric material such as epoxy.

[0017] In accordance with the present invention, at least a part of the LV or HV winding of the transformer is a cable winding, e.g. in accordance with Dryformer™ transformer type winding. This implies that a part, e.g. within the range of 10-70%, of the conductor length of the winding of the LV and/or HV winding is done by a cable having a conductor surrounded by an insulating sheath. Alternatively, the whole LV and/or HV winding is in the form of a cable winding, in which case there is no cast winding part.

[0018] In contrast, any cast winding part, which may then (if present) be within the range of 90-30% of the conductor length of the winding of the LV and/or HV winding, is a conventional, non-cable, winding of an electrical conductor cast in an electrically insulating polymer ma-

terial, e.g. an epoxy or thermoplastic material, which has been moulded and solidified (e.g. cured) around the conductor. This conventional LV or HV winding may e.g. be called a foil winding, a disc winding, a foil disc winding, or a strip winding, in which the conductor (in any form) has been formed into a coil and encapsulated in a matrix of the electrically insulating polymer material. Typically, the electrically insulating polymer material (e.g. epoxy) is in direct contact with the material of the conductor (e.g. copper or aluminium), but in some embodiments the conductor of the cast winding may be coated by another insulating, semiconducting or conducting material.

[0019] In the examples herein, the cable winding part is part of the HV winding, which is preferred since the risk of overheating or fire is generally higher for the HV winding, but in some embodiments it may be convenient to, additionally or alternatively, use a cable winding part (or only cable winding) in the LV winding.

[0020] Figures 1a and 1b illustrate two different example embodiments of a dry hybrid transformer 1. The dashed vertical line illustrates a fictive longitudinal central line of the transformer, such that half the transformer is schematically shown in longitudinal section, with turns of the windings of the conductor 7 of the cast HV winding 2b and the cable 20 of the cable HV winding 2a are running in a direction perpendicular to the plane of the section.

[0021] A transformer core 4 and a LV winding 3 are schematically shown. These may be of any conventional, or other, design. An electrically insulating barrier(s) 5 separates the LV winding 3 from the HV winding 2. The conventional cast HV winding part 2b is schematically shown as turns of a conducting strip or discs 7 in a matrix of solid phase electrically insulating material 6, e.g. a cured epoxy or solidified thermoplastic polymer material such as polypropylene (epoxy is preferred since it is more heat and fire resistant), which has been moulded around the HV winding 2b.

[0022] The cable winding part 2a of the HV winding 2 is schematically shown as turns of a cable 20 in a matrix of solid phase electrically insulating material 6, e.g. a cured epoxy or solidified thermoplastic polymer material such as polypropylene (epoxy is preferred since it is more heat and fire resistant), which has been moulded around the cable of the HV winding 2a. In some embodiments the insulating material 6 of the cable winding 2a is the same as insulating material in the cast winding 2b, preferably epoxy, but in other embodiments it is a different insulating material 6 than in the cast winding. The moulded insulating material 6, imparts improved heat and fire resistance to the cable winding 2a. However, in order to not unduly reduce the heat transfer of the cable winding, the thickness of the insulating material 6 is preferably substantially lower in the cable winding 2a, in which there is electrical insulation also in the cable itself which also impairs the heat transfer, than in the cast winding 2b. The minimal thickness of the insulating material 6, as measured from the outer surface of the cable 20 any-

where in the cable winding 2a is preferably not more than a few millimetres, e.g. less than 10 mm or less than 5 mm. The insulating material 6 of the cable winding 2a (and/or of the cast winding 2b) may, in some embodiments, comprise a filler material for improved heat/fire resistance and/or mechanical properties. Such a filler material may be any electrically insulating filler material which improves the heat conduction of the insulating material 6, e.g. any of diamond powder, aluminium nitride (AlN), zinc oxide (ZnO), and boron nitride (BN), e.g. two-dimensional such as hexagonal, or three-dimensional, or other.

[0023] The two embodiments of figures 1a and 1b, respectively, differ in that the transformer 1 of figure 1a exhibits a HV winding 2 in which the cable winding 2a is an outer winding concentrically outside of the cast winding 2b, while the transformer 1 of figure 1b exhibits a HV winding 2 in which the cable winding 2a is an upper winding positioned above and concentrically aligned with the cast winding 2b. Any other configuration of the HV winding 2 is also contemplated, e.g. with the cable winding 2a below the cast winding (e.g. inverse of the embodiment of figure 1b) or with the cable winding concentrically inside of the cast winding (e.g. inverse of the embodiment of figure 1a). In the example of figure 1a, the cable winding is illustrated as having turns in two concentric layers, while in the example of figure 1b, the cable winding 2a is illustrated as having turns in three concentric layers. However, any suitable number of turns in any suitable number of concentric layers in the radial direction or in the vertical direction may be used depending on the requirements for the transformer 1.

[0024] An electrically insulating barrier layer 5 may separate the cable winding 2a from the cast winding 2b.

[0025] Figure 2 illustrates an embodiment of a HV cable 20 which may be used in embodiments of the cable winding 2a of the present invention. In the centre of the cable is a conductor 21, e.g. a thread or wire of twisted threads, of a conducting material, typically a metallic material such as copper or aluminium. The wires are typically coated (natural oxidation or manually) with very thin electrically insulating layer. The conductor may e.g. have a substantially circular cross section of a diameter for instance within the range of from 10 mm to 30 mm, e.g. 20-30 mm. The conductor 21 is surrounded by an insulating concentric layer/sheath 22 of an electrically insulating material, e.g. having XLPE, Tree Retardant XLPE (TR-XLPE), polyurethane, a silicone material and/or Ethylene Propylene Rubber (EPR) as a main constituent. The insulating material is heat and fire resistant, but typically not to the same high degree as the moulded insulating material 6, which is a reason why such an insulating material 6 may preferably be used as well outside of the cable 20. In order to further improve the heat/fire resistance of the insulating layer 22, an additive or filler material with good electrically insulating and thermal properties, e.g. any of silica and/or aluminium tri-hydrate (ATH), may be included in the insulating layer 22. Such an additive

or filler may be relatively expensive, why it may in some embodiments only be mixed into the insulating layer 22 in particularly sensitive parts of the cable 20, e.g. at the beginning and/or the end of the cable winding 2a.

[0026] The cable 20 also comprises a grounded layer/sheath 23, concentrically outside of the insulating layer 22. The grounded layer is at least partly electrically conducting to handle dielectric stress of the cable. The grounded layer may be metallic, but it may be preferred to use a semiconducting polymeric material, e.g. as in the Dryformer™ transformer type cable winding. The grounded layer 23 may be called an insulation shield since it is positioned outside of the insulating layer 22 and protects the same. In some embodiments, a similar or same semiconducting polymeric material may be used for a conductor shield 25 positioned concentrically between the conductor 21 and the insulating layer 22. The grounded layer 23 improves the handling of transient voltages, e.g. in case of a lightning strike, in the transformer 1.

[0027] In some embodiments, especially if the grounded layer 23 is not an electrically conducting metal layer, the cable may comprise a metal layer 24, concentrically positioned outside of the grounded layer 23, which metal layer 24 may be an outer layer of the cable 20, forming an outer surface of said cable, and which metal layer 24 may be in contact with the grounded layer 23 such that both the grounded layer 23 and the metal layer 24 are electrically grounded. The metal layer 24 may be called a metal shield or sheath and may be of any suitable electrically conductive metal, e.g. aluminium or copper, preferably copper. The metal shield is preferably thin enough to be flexible, to allow the cable 20 to be easily wound in the cable winding 2a. The metal layer 24 may thus have a thickness of less than 1 mm, e.g. less than 0.5 mm, 0.1 mm or 0.01 mm.

[0028] Additionally or alternatively to the metal layer 24 of the cable 20, a metal layer 8, which may have the same properties as the metal layer 24 (discussed above, if applicable) may be provided outside of (e.g. in contact with) the insulating material 6 of the cable winding 2a, e.g. forming an outer surface of the cable winding, or inside of (e.g. in contact with) the insulating material 6 of the cable winding 2a i.e. between the wound cable 20 and the insulating material 6 but not part of the cable. The metal layer 8 when outside of the insulating material 6 may e.g. be positioned between the insulating material 6 of the cable winding 6 and the LV winding 3 or the cast HV winding 2b or an outside of the transformer 1. Such an outer metal layer 8 may further improve the heat/fire resistance of the transformer 1.

[0029] The cable 20, including the conductor 21 and its surrounding layers 22-25, may have a substantially circular cross section and/or may have a diameter within the range of 35-50 mm.

[0030] In some embodiments of the present invention, the HV winding 2 further comprises a cast winding part 2b which, in contrast to the cable winding part 2a does not comprise a winding of the cable 20.

[0031] Thus, according to an embodiment of the present invention, there is provided a dry type transformer comprising a low voltage (LV) winding and a high voltage (HV) winding. The HV winding comprises a cast winding part and a cable winding part, wherein the cable winding part, in contrast to the cast winding part, comprises a winding of a cable. The cable comprises an electrical conductor forming a central part of the cable, an electrically insulating layer concentrically positioned outside of the conductor, and a grounded layer of an at least partly conducting material concentrically positioned outside of the insulating layer. The cable winding part comprises an electrically insulating material in solid state moulded around the cable.

[0032] The present disclosure has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the present disclosure, as defined by the appended claims.

Claims

1. A dry type transformer (1) comprising a low voltage, LV, winding (3) and a high voltage, HV, winding (2), wherein the LV winding and/or the HV winding comprises a cable winding part (2a) comprising a winding of a cable (20), said cable comprising:

an electrical conductor (21) forming a central part of the cable;
 an electrically insulating layer (22) concentrically positioned outside of the conductor; and
 a grounded layer (23) of an at least partly conducting material, concentrically positioned outside of the insulating layer;
 wherein the cable winding part (2a) comprises an electrically insulating material (6) in solid state moulded around the cable (20).

2. The transformer of claim 1, wherein the winding (2; 3) which comprises the cable winding part (2a) further comprises a cast winding part (2b) which, in contrast to the cable winding part (2a) does not comprise a winding of the cable (20).
3. The transformer of any preceding claim, wherein the cable (20) further comprises an outer metal layer (24) concentrically positioned outside of the grounded layer (23).
4. The transformer of claim 1 or 2, wherein the cable winding part (2a) further comprises an outer metal layer (8) outside of the wound cable (20) and inside or outside of the electrically insulating layer (6).
5. The transformer of claim 3 or 4, wherein the outer

metal layer (24/8) is of copper or aluminium, preferably copper.

6. The transformer of any claim 3-5, wherein the outer metal layer (24/8) has a thickness of less than 1 mm, e.g. less than 0.5 mm or less than 0.1 mm.
7. The transformer of any preceding claim, wherein the grounded layer (23) is of a semiconducting polymer material.
8. The transformer of any preceding claim, wherein the electrically insulating material (6) comprises an epoxy or polypropylene material, preferably an epoxy material.
9. The transformer of any preceding claim, wherein the electrically insulating material (6) comprises any of diamond powder, aluminium nitride, boron nitride and zinc oxide.
10. The transformer of any preceding claim, wherein the insulating layer (22) comprises cross-linked polyethylene, XLPE, polyurethane and/or a silicone material, preferably XLPE.
11. The transformer of any preceding claim, wherein the insulating layer (22) comprises any of silica and aluminium tri-hydrate, ATH.
12. The transformer of any preceding claim, wherein the winding comprising the cable winding part (2a) is the HV winding (2).

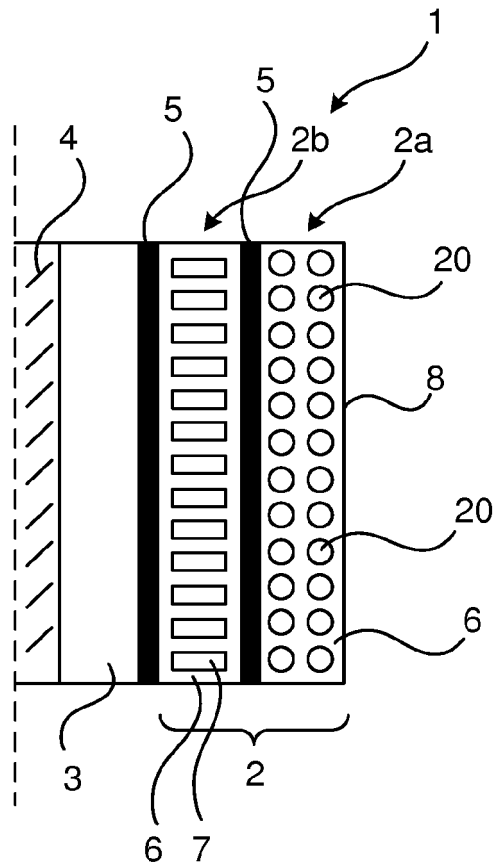


Fig. 1a

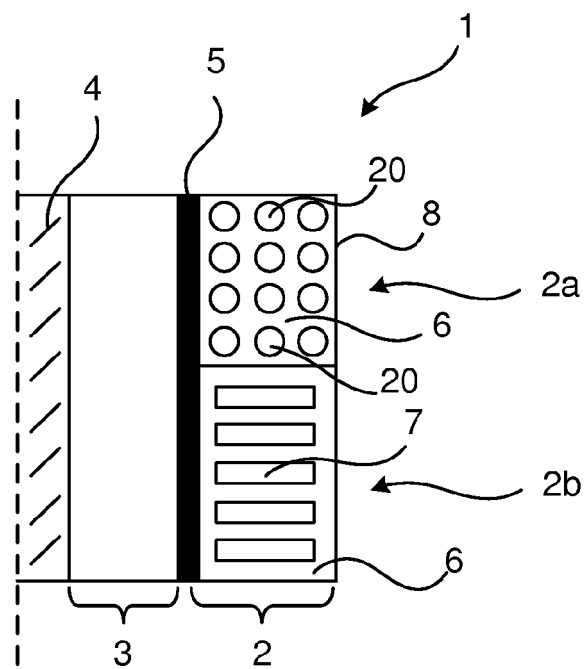


Fig. 1b

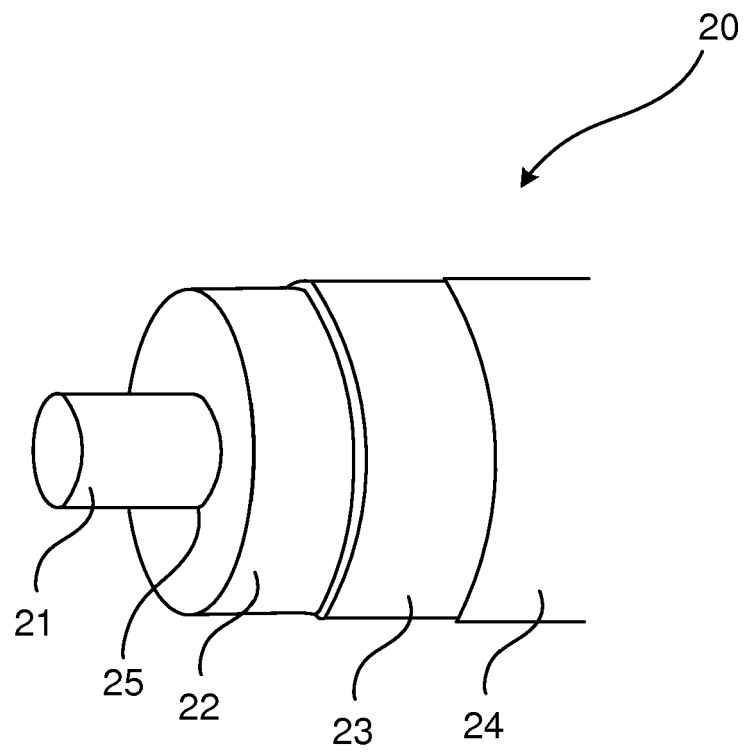


Fig. 2



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 Application Number
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