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(54) Condenser type barrier.

(57) Condenser type barrier for field control of the connection of a transformer bushing to the conductor of a transformer winding, preferably in converter transformer. The condenser type barrier (1) is arranged as a condenser body consisting of insulating material with condenser layers (7) of foil type concentrically laid therein. According to the invention the condenser type barrier is arranged as a solid of revolution with an outer circular cylindrical shape, arranged from one end with a first, inwardly-directed straight frustum of a cone (2) with its largest base area at the end of the condenser barrier, and from its other end with a second, inwardly-directed straight frustum of a cone (3) with its largest base area at the other end of the condenser type barrier. The space between the truncated cones in the condenser type barrier is concentrically arranged as an open, inner, straight circular cylinder (4) with a sectional area equal to the smallest bases of the truncated cones.

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CONDERSER TYPE BARRIER FOR FIELD CONTROL IN TRANSFORMER BUSHINGS

The invention relates to a condenser type barrier for field control in transformer bushings according to the precharacterising part of claim 1. The condenser type barrier (in the following referred to as "condenser barrier") is especially designed for transformers which are connected to high voltage converters.

If in a vessel with transformer oil two energized electrodes are positioned at a certain distance from each other, at a certain voltage a flashover will occur between the electrodes. The flashover tendency may be minimized by inserting between the electrodes an insulator body which functions as a barrier.

Transformer bushings may comprise an upper insulator and a lower insulator of electric porcelain. At the joint between these two insulators there is a flange which is connected to the transformer casing. In the centre of the bushing there is a tube on which is wound a condenser body to obtain a favourable electrical field distribution. The current can be conducted through the tube or a flexible conductor passing through the tube.

Power transformers which are used in converter plants entail special problems from the point of view of insulation, which somehow have to be overcome in order to ensure a satisfactory function.

In high voltage direct current (HVDC) plants, there is often used at least one converter per pole and station. Normally, also, several converter bridges are connected in series, with one pole of one bridge normally being connected to ground. The direct voltage potential of each bridge relative to ground is then the higher the more bridges are connected in series between the bridge under contemplation and ground.

Each bridge in the series connection is supplied with an alternating voltage from a separate transformer. With increasing direct voltage potential on the bridges relative to ground, the insulation on bushings and windings on the transformers which are connected to the bridges will also be subjected to an increasingly higher direct voltage potential with a superimposed alternating voltage. The insulation of these must therefore be dimensioned so that they are capable of withstanding the increasingly higher field strengths to which they are then subjected.

The increasing direct voltage potential leads to special problems which do not exist in transformers used for pure alternating voltage transformation.

For converter transformers, the lower insulator and the transition between the conductor of the transformer winding and the bushing present areas of problems from the point of view of insulation technique. This is described, inter alia, in "Power Transmission by Direct Current", by E. Uhlmann, Springer Verlag 1975, pages 327-328.

The electric direct voltage field has a distribution different from that of the alternating voltage field. The distribution of the direct voltage is mainly determined by the resistivity of the various insulating mediums. It is true that transformer oil, cellulose material and electric porcelain are good insulators, but a certain amount of electric current is conducted in these materials. The relation between the resistivity of cellulose material and transformer oil is about 100. This means that the cellulose in series with oil is subjected to a considerably higher field strength than the oil, which in turn, therefore, imposes demands for a sufficient amount of solid insulating material to prevent the field strength from exceeding the dielectric strength of the material. The distribution of the field strength as well as the field strength directions will thus be different from the case with alternating voltage. The current transport also entails a redistribution of charges in the insulating mediums used.

Because of the heavy dependence of the resistivity on moisture content, field strength, temperature, etc., the distribution of direct current is difficult to predict. In addition, the physical nature of the direct voltage, i. e. charge transport, charge, time-dependent behaviour, and so on, gives a picture of the insulation problems arising in connection with HVDC plants, which is very complex and difficult to interpret. In an article entitled "Space Charge and Field Distribution in Transformers under DC-stress" by U. Gäfvert and E. Spicar, CIGRE Int. Conference on Large High Voltage Electric Systems, 1986 Session, 12-04, the complexity of the direct voltage distribution is illustrated. As previously mentioned, problems have arisen at the connection between the transformer bushing and the conductor of the transformer winding. This has led to the lower insulator of electric porcelain having to. be removed in order to manage the stresses at the HVDC terminal at the higher voltage levels.

No simple explanation of the above phenomenon has been presented. However, there are reasons to suspect that the long surfaces which arise in connection with bushings for high voltages in combination with the direction of the field along the long surfaces are of importance in this connection. Admittedly, also the alternating voltage field is directed along the surface of the lower porcelain insulator, but its physical nature is different. One hypothesis is that the distribution of the direct voltage field runs the risk of becoming unstable and uneven along sufficiently long surfaces. Another interesting hypothesis is described in an article entitled "Effect of Duct Configuration on Oil Activity at Liquid/Solid Dielectric Interfaces" by R.E. James, F.E. Trick, R. Willoughby in Journal of Electrostatics, 12, 1982, pages 441-447. In this article it is stated that increased charge transport at surfaces caused by turbulence and access to charge is the reason for low dielectric strength.

As an example of the state of the art there may be mentioned the-condenser body in a muff for direct connection of oil cables to transformers, described, inter alia, in SE-B-214 015 and in ASEA Journal 1963, volume 36, numbers 1-2, page 23. That part of the muff which extends into the transformer is substantially formed as the lower part of a conventional transformer bushing, i. e. with a lower insulator of electric porcelain. The condenser body of the muff is here designed so as to give capacitive voltage control both inwards along the cable end coming from outside and outwards along the porcelain insulator.

The invention aims at providing a condenser type barrier for transformer bushings of the above-mentioned kind, which withstand higher voltages, particularly high direct voltages, than the previously known condenser type barriers.

To achieve this aim the invention suggests a condenser type barrier according to the introductory part of claim 1, which is characterized by the features of the characterizing part of claim 1.

Further developments of the invention are characterized by the features of the additional claims.

The condenser barrier according to the invention is particularly useful for transformers used in HVDC converter plants. The task of the condenser barrier is to overcome the flashovers which have proved to arise at the transition between transformer bushings and the conductor of the transformer. The condenser barrier is designed so as to function as a barrier with both capacitive and resistive control of the electrical field and is dimensioned so that the condenser barrier withstands the voltages and field strengths occurring in this region.

It is assumed that the transformer bushing is provided with a lower insulator which is conically tapering viewed from the flange.

It is further assumed that the conductor coming from the transformer winding and which is to be connected to the electric conductor of the bushing is surrounded by a conducting tube which has an external, wound shield of insulating material. This shield has at its end a conical shape which, in a similar manner as the lower insulator, tapers towards the lower insulator and has largely the same conicity as the lower insulator.

The condenser barrier is built up as a condenser body, i.e. it consists of an insulating material and condenser layers of foil type concentrically laid into the insulating material.

Characteristic of the condenser barrier according to the invention is substantially the geometrical shape of the condenser barrier to make it function as a barrier to both direct voltage and alternating voltage fields.

The condenser barrier is formed as a solid of revolution and has, in its ordinary embodiment, a straight circular cylindrical outer shape. However, it may be formed with a "waist" or a "belly", which influences the distribution of the direct voltage fields.

From one end the condenser barrier is formed as an inwardly directed, first straight frustum of a cone which is largely adapted to surround the lower insulator, i.e. it has its largest base area at the end of the condenser barrier. Since both the condenser barrier and the lower insulator are in an oil-filled space, the gap between the lower insulator and the first straight frustum of a cone will be oil-filled. The conicity of this first cone, however, deviates somewhat from the conicity of the lower insulator. The reason for this somewhat different conicity will be explained below. Concentrically in the condenser barrier, continuing from the smallest base area of the first straight frustum of a cone, the condenser barrier is formed as a cylindrically open space.

From the second end of the condenser barrier, the barrier is also formed as an inwardly directed, second straight frustum of a cone with a smallest base area which faces the concentric, cylindrical first space. This second cone is adapted to surround the shield on the conducting tube around the conductor extending from the transformer. Also with its second straight frustum of a cone, the condenser barrier will surround the shield with a certain oil-filled gap in between. The conicity of this second cone also deviates somewhat from the conicity of the shield.

As mentioned above, the condenser barrier is made from an insulating agent with alternately laid condenser layers to obtain the desired capacitive control of the electric alternating field. The innermost condenser layer, which is concentric with the electric conductor, has an axial length approximately corresponding to the axial length of the inner concentric, cylindrical space. Outside of this there are applied short layers, concentrically arranged in a radial direction and mutually displaced in the axial direction towards the ends of the condenser barrier. These layers are laid so that, concurrently with the increasing radius of the condenser barrier, viewed from the first innermost layer, they are laid in an axial direction so that their outer edges face the straight frustums of cones of the condenser barrier.

As mentioned previously, the direct voltage field is controlled by several factors. Thus, for example, that medium which has the lowest resistivity is field controlling. Between the lower insulator and the surrounding condenser barrier an oil gap is formed, as already mentioned. Since the oil has the lowest resistivity, most of the current is conducted in the oil gap which thus controls the field parallel to the surrounding surfaces. To obtain an even distribution of the field along these surfaces, it is therefore important that the width of the oil gap increases with decreasing radius. Otherwise, the field would be concentrated towards that part where the radius is smallest, i.e. where the axial sectional area is smallest. The conicity of the truncated cones of the condenser barrier is therefore suitably chosen such that the axial sectional area of the oil gap becomes approximately the same along the entire length of the straight frustums of cones.

Another field-controlling part is the radial distribution of the field in the condenser barrier around the innermost layer to which high voltage is applied. Between the oil gap and the mid-portion of the condenser barrier, the layers function as equipotential surfaces in the direct voltage case, which prevents a concentration of the field near the bottom of the lower insulator. It is of importance that the layers of the condenser barrier are directed straight opposite to the layer of the bushing, so that the equipotential surfaces, with the aid of a correctly formed oil gap, are guided over in the desired manner between the bushing and the condenser barrier.

By way of example, the invention will now be described in greater detail, with reference to the accompanying drawing, which shows a section through a lower insulator, a condenser barrier according to the invention, and the conductor of a transformer winding with a surrounding tube with insulation.

The condenser barrier 1 is shown in a section along the longitudinal axis of the barrier. Because of the inwardly-directed straight frustums of cones 2 and 3, the sectional view exhibits a parallel trapezoidal shape. The inner part 4 of the condenser barrier between the straight frustums of cones is cylindrically formed. To give the condenser barrier a certain mechanical stiffness, the inner cylindrical part has been wound onto a cylindrical tube 5. With another insulating material of self-supporting structure, this tube would not be needed. The internal conical shape of the condenser barrier may otherwise be obtained in several different ways, for example by winding, turn by turn, an obliquely cut insulating material with a growing width. The inner con denser layer 6 has approximately the same axial extension as the previously mentioned concentric, cylindrical space. According as the insulting material is wound, there are laid between certain of the turns those condenser layers 7 which are needed to influence the capacitive voltage distribution. These layers have a shorter axial length than the innermost layer and are laid such that their outer edges, concurrently with the wound increasing radius of the condenser barrier, will be facing both of the straight frustoconical surfaces.

To show the invention in its proper context, a lower insulator is also shown at 8. The fastening flange of the bushing is shown at 9. In the example shown in the figure, the condenser barrier with its lower insulator is placed in an oil-filled intermediate flange 10 which is connected to the transformer casing 11. The conductor 12 of the transformer winding is to be connected to the electric conductor of the bushing in a known manner. As mentioned above, the conductor of the transformer winding is surrounded by a tube 13 of conductive material. On this tube are wound several layers of insulating material which forms a shield 14 and which tapers toward the end of the tube in the form of a straight frustum of a cone 15. The tube 13 is electrically connected to both the conductor of the transformer winding and the inner condenser layer. One of the outer condenser layers is grounded.

As mentioned previously, it is important for the direct voltage field distribution that the oil gap 18,19 between the straight frustums of cones of the condenser barrier and the lower insulator 8 and the shield 14, respectively, has largely the same axial cross section along the whole cones. Therefore, the difference in radius is greatest between the smallest bases.

In certain designs, the lower insulator facing the fastening flange is purely cylindrically formed, as shown at 16. In these case it may be suitable for the condenser barrier to terminate in a cylindrical part 17 to cover this part of the lower insulator. A corresponding cylindrical extension may also occur in certain cases over the shield 14.

The axial length/height of the straight frustums of cones of the condenser barrier is adapted to the axial length of the cones of the lower insulator and the shield, respectively, and may therefore be of varying lengths, as is also clear from the figure.

In certain cases, as mentioned above, it may be suitable for the condenser barrier to be formed with a "waist" or a "belly" to obtain special advantages from the point of view of field distribution technique.

The condenser barrier is fixed around the lower insulator and the conductor of the transformer winding with tube and shield in a suitable way (not shown) against the fastening flange of the bushing or against the intermediate flange 10.

Claims

1. Condenser type barrier for field control of the connection of a transformer bushing to the conductor of a transformer winding, preferably in converter transformer, the condenser type barrier (1) being arranged as a condenser body consisting of insulating material with condenser layers (7) of foil type concentrically laid therein, **characterized** in that the condenser type barrier is arranged as a solid of revolution with an outer preferably circular cylindrical shape, that the condenser type barrier is arranged from one end with a first, inwardly-directed straight frustum of a cone (2) with its largest base area at the end of the condenser barrier, that the condenser type barrier is arranged from its other end with a second, inwardly-directed straight frustum of a cone (3) with its largest base area at the other end of the condenser type barrier, and that the space between the truncated cones in the condenser type barrier is concentrically arranged as an open, inner, straight circular cylinder (4) with a sectional area equal to the smallest bases of the truncated cones.

2. Condenser type barrier according to claim 1 where the transformer bushing has a lower insulator (8) with a straight conically tapering shape and where the conductor (12) of the transformer winding is surrounded by a tube (13) with a shield (14) with a straight conically tapering shape, **characterized** in that the conicity of the first, inwardly-directed straight frustum of a cone is adapted such that the sectional area of the gap (18) formed between the lower insulator and the first cone is constant along the whole length of the first cone and that the conicity of the second, inwardly-directed straight frustum of a cone is adapted such that the sectional area of the gap (19) formed between the shield (14) and the second cone is constant along the whole length of the second cone.

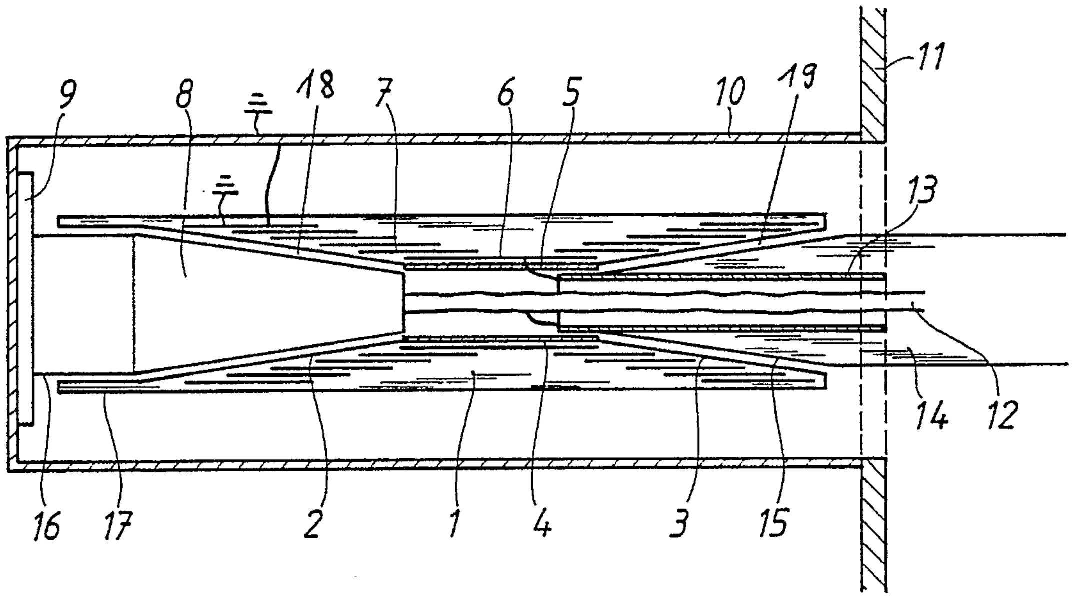
3. Condenser type barrier according to claim 1 or 2, **characterized** in that a first inner condenser layer (6) has an axial length corresponding to the axial length of the open, inner straight circular cylinder, that condenser layers (7) concentrically laid outside of said first condenser layer consist of layers which are short in the axial direction and which are arranged so that, concurrently with an increasing radius of the condenser type barrier viewed from the inner layer, they are laid in an axial direction in such a way that their outer edges will face the straight frustums of cones of the condenser type barrier.

4. Condenser type barrier according to any of the preceding claims, **characterized** in that the first inner condenser layer (6) is electrically connected to the conductor (12) of the transformer winding and that an outer condenser layer is connected to ground potential.

5. Condenser type barrier according to any of the preceding claims, **characterized** in that the condenser barrier, at the first inwardly-directed frustum of a cone (2), is provided with a tubular extension (17).

6. Condenser type barrier according to any of the preceding claims, **characterized** in that the outer shape of the solid of revolution is formed with a waist.

7. Condenser type barrier according to any of claims 1 to 5 **characterized** in that the outer shape of the solid of revolution is formed with a belly.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EUROPEAN SEARCH REPORT

Application number
EP 90111272.2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int Cl 5)
A	CH-A-506 165 (HITACHI, LTD) -----	1	H 01 F 27/04 H 01 B 17/28
			TECHNICAL FIELDS SEARCHED (Int Cl 5)
			H 01 F H 01 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
STOCKHOLM	27-09-1990	WESTÖÖ M.

CATEGORY OF CITED DOCUMENTS

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