INTERWINING SHIELD FOR POWER TRANSFORMERS

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ABSTRACT
An electrostatic shield for placement between the high and low voltage windings of a power transformer. The shield is constructed from interleaved layers of insulating and conducting strips which are assembled onto an insulating member and placed around the low voltage winding of the power transformer. The shield may be connected to ground potential by means of a header lead which is connected to each conducting strip. The unique construction of the shield provides adequate isolation between the windings without excessive heat development in the conducting strips.

6 Claims, 8 Drawing Figures
INTERWINDING SHIELD FOR POWER TRANSFORMERS

BACKGROUND OF THE INVENTION

1. Field of the Invention
   This invention relates, in general, to electrical inductive apparatus and, more specifically, to electrostatic shields for power transformers.

2. Description of the Prior Art
   Special applications of power transformers require that the electrostatic coupling between the high and low voltage windings be kept to a minimum. One of the most efficient ways to achieve this characteristic is to place a grounded conducting shield between the two windings. Such a shield intercepts the electric field and effectively decouples the windings.

   Various arrangements have been used for providing an interwinding shield. One of the most common arrangements uses a conducting foil layer wound around the low voltage winding. Insulation is placed near the end of the foil where it overlaps. This eliminates the shorted turn which would result if the foil ends touched. Although providing an effective interwinding shield, this arrangement has detrimental effects when used in high power transformers having relatively large leakage flux components. Eddy-currents developed in the foil by the leakage flux produce excessive heating of the shield. Therefore, it is desirable to provide an effective interwinding shield which will not produce excessive heating when used in high power transformers. Additionally, the interwinding shield should be capable of being easily constructed from economical materials.

SUMMARY OF THE INVENTION

The interwinding shield of this invention is constructed from an interleaved arrangement of insulating and conducting strips. The strips are assembled onto an insulating member which is then placed around the low voltage winding. A lead is soldered to each conducting strip and may be attached to a point at ground potential.

   By effectively dividing the interwinding shield into a combination of smaller shields, the total heat produced in the shield due to leakage flux is substantially reduced. As a general rule, the loss per square inch of shield is proportional to the square of the width of the shield. Thus, a shield comprising 50 2-inch conducting strips would have one twenty-five-hundredth the loss per square inch of an equivalent shield (neglecting strip overlap) comprising a foil wrap having a width of 100 inches. The interwinding shield of this invention performs satisfactorily over the entire frequency range of the voltages which establish the electrostatic fields.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages and uses of this invention will become more apparent when considered in view of the following detailed description and drawings, in which:

FIG. 1 is an elevational view of a transformer phase winding assembly with parts broken away and shown in phantom for clarity;

FIG. 2 is a cross-sectional view taken along the line II—II of FIG. 1;

FIG. 3 is a partial sectional view illustrating in detail the interwinding shield shown in FIG. 2;

FIG. 4 is a plain view illustrating the relative positions of the insulating and conducting strips of the interwinding shield;

FIG. 5 is a view illustrating one method of constructing the interwinding shield;

FIG. 6 is a view illustrating another method of constructing the interwinding shield;

FIG. 7 is a schematic diagram illustrating an arrangement for electrically interconnecting the conducting strips; and

FIG. 8 is a schematic diagram illustrating another arrangement for electrically interconnecting the conducting strips of the interwinding shield.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Throughout the following description, similar reference characters refer to similar members in all figures of the drawing.

Referring now to the drawings, and FIG. 1 in particular, there is shown a phase winding assembly 12 of a power transformer. The laminated magnetic core 10 is constructed from a plurality of metallic laminations arranged in a cruciform pattern. A low voltage winding 14 is disposed concentrically around the magnetic core 10. An insulating material 16 surrounds the low voltage winding 14 and may comprise, as illustrated, pressboard spacers, winding cylinders and other insulating materials. An insulating material 18, which is disposed around the low voltage winding 14, provides a base onto which the interwinding shield 20 is constructed. An insulating material 22 covers the interwinding shield 20 and defines a cylindrical surface around which the winding tube 24 and the high voltage winding 26 are disposed. The high voltage winding 26 comprises a plurality of interconnected coils 28 to which the leads 30 and 32 are attached.

The interwinding shield 20 is formed by an interleaved arrangement of the conducting strips 34 and the insulating strips 36. The interwinding shield 20 provides a cylindrical conducting surface between the high and low voltage windings 26 and 14 respectively. When grounded, the interwinding shield 20 provides an efficient electrostatic shield between the high and low voltage windings.

The relationship between the windings is illustrated in FIG. 2, which is a sectional view taken along the line II—II of FIG. 1. The high voltage winding 26 is wound around the winding tube 24. The interwinding shield 20 is disposed between the insulating materials 18 and 22. The conducting strips 34 overlap each other throughout the winding cross section to provide adequate shielding between the high and low voltage windings. The insulating spacers 42 are positioned between the interwinding shield 20 and the low voltage winding 14. The purpose of the spacers 42 is to provide channels for convection of the cooling media and to add mechanical support to the winding assembly 12. Insulating spacers 40 separate the low voltage winding 14 and the insulating material 38, Circular and semicircular insulating spacers, 35 and 37 respectively, tightly secure the winding assembly 12 around the magnetic core 10.

Although the interwinding shield 20 is illustrated at a position between the insulating spacers 42 and the high voltage winding 26, it may be positioned between the insulating spacers 42 and the low voltage winding 14. It may also be advantageous to place insulating spacers adjacent both sides of the interwinding shield 20. Although the interwinding shield 20 must be placed between the high and low voltage windings, 26 and 14 respectively, the physical distance between the interwinding shield 20 and the windings, and the location of the cooling channels, are dependent upon the type and rating of the transformer.

The interwinding shield 20 effectively isolates the high and low voltage windings, 26 and 14 respectively, from each other with respect to capacitive coupling. The sum of the eddy-currents which are developed in the conducting strips 34 due to the magnetic flux is substantially lower than would be realized if a solid shield were used.

FIG. 3 illustrates the construction details of the interwinding shield 20. The insulating material 18 provides a cylindrical base onto which the conducting strips 34 and the insulating strips 36 are disposed. The insulating material 22 covers the strips and holds them in place during the manufacturing process. The insulating strips 36 prevent the conducting strips 34 from touching adjacent conducting strips. With this arrangement, each conducting strip 34 functions as an independent shielding member. Since an electric field in the radial direction intersects at least one conducting strip, and since no open spaces exist around the interwinding shield 20, the over-
lapping arrangement of the conducting strips 34 provides adequate shielding characteristics. FIG. 4 illustrates the relative position of the insulating and conducting strips, 36 and 34 respectively. The conducting strips 34 overlap a sufficient distance a, such as three-sixteenths inch, to prevent the electric field from passing between two adjacent conducting strips. The insulating strip 36 is positioned a distance b, such as nine-sixteenths inch, over the conducting strips and extend a distance c, such as nine-sixteenths inch, beyond the edge of the conducting strips. The insulating strips 36 extend beyond the edge of an upper conducting strip a distance d, such as three-eighths inch, to prevent creepage and corona between adjacent conducting strips. The insulating strips extend below the conducting strips a distance f, such as one-eighth inch, for similar reasons. To eliminate the possibility of high stress concentrations at the corners of the conducting strips 34, the corners thereof are diagonally cut to reduce their sharpness. The diagonals may be cut at a 45° angle at a distance e, such as one-fourth inch, from the conducting strip edge.

The conducting strips 34 may be constructed of a suitable electrical conducting material, such as copper, aluminum, or German silver, having a suitable thickness, such as 0.0015 inch. The insulating strips 36 may be constructed of a suitable electrical insulating material, such as pressboard, having a suitable thickness, such as 0.010 inch. FIG. 5 illustrates a method of constructing the interwinding shield 20. The insulating member 18 is a hollow cylindrical tube made from an insulating material, such as micarta or pressboard. The insulating member 18 is positioned on its end and the insulating and conducting strips, 36 and 34 respectively, are bent over the top end 19 of the insulating member 18. The strips hanging from the top end 19 may be secured to each other and to the insulating member 18 by a suitable adhesive or resin. FIG. 5 shows only part of the strips comprising the interwinding shield 20. A completed interwinding shield 20 would comprise strips disposed around the entire circumference of the insulating member 18. The strips are wrapped with a suitable insulating material 22, such as crepe paper. The interwinding shield 20 may also be wrapped with a semicurled resin impregnated tape and cured in an oven.

A header lead 44, made from an electrical conducting material, is connected to each of the conducting strips 34 at the positions 46. Soldering, brazing, welding or another suitable process may be used for making the connection. The header lead must be broken at least once around the interwinding shield 20 to prevent formation of a shorted turn in the winding assembly 12.

The completed interwinding shield 20 is slipped over the low voltage winding 14 and secured by suitable means, such as spacers and pressure plates. A ground lead may be connected to the header lead 44 to complete the path to ground. However, this invention is applicable to interwinding shields which are not connected to ground potential.

The interwinding shield 20 may be constructed by the application of the strips onto a flat insulating surface which can be wrapped around the low voltage winding 14. FIG. 6 illustrates the details of this method of construction. The insulating member 18 is made of a suitable insulating material, such as pressboard, which has a sufficient thickness, such as 0.056 inch, to provide adequate mechanical support for the interwinding shield 20. Insulating and conducting strips, 36 and 34 respectively, similar to those used in the cylindrical construction method, are applied to the flat insulating member 18. A suitable adhesive or cement is used to attach the insulating strips 36 to the conducting strips 34 at the junction 50. A suitable adhesive is used to attach the insulating strips 36 to the insulating member 18 at the junction 48. Adhesive or cement is not applied to the junction 52 which is between the conducting strips 34 and the insulating member 18 so that the assembly can be easily wrapped around the low voltage winding 14.

The insulating member 22 is applied over the interwinding shield 20 with an adhesive applied between the insulating member 22 and various points of the insulating member 18. The insulating member 22 is made of suitable material such as kraft or crepe paper. When crepe paper is used, the crepe lines should be parallel to the strip edges to facilitate bending of the interwinding shield 20. The insulating member 22 extends beyond the strips and may be folded around the top and bottom of the insulating member 18 and cemented to the backside of the insulating member 18. The header lead 44 is soldered to the conducting strips 34 and looped up a sufficient distance, such as one-eighth inch, to allow bending of the interwinding shield 20. The interwinding shield, along with its insulating members and leads, is wrapped around the low voltage winding 14 to isolate it from the high voltage winding 26.

An arrangement for attaching a lead to the interwinding shield 20 is illustrated schematically in FIG. 7. Physically, the interwinding shield 20 is cylindrically shaped, thus the "ends" 54 and 56 of the header lead 44 are electrically connected. The lead gap 58 prevents the header lead 44 from forming a shorted turn in the winding assembly. A stress shield or plate 60 may be located at the top of the interwinding shield 20 and connected to the lead 62 to reduce stress concentrations on the top of the interwinding shield 20. The lead 62 may be connected to a member having the desired potential characteristics.

The conducting strips 34 may, in high power applications, develop excessive stresses adjacent to their lower ends. An arrangement is illustrated schematically in FIG. 8 which reduces stress concentrations at the lower end. The points 54 and 56 are physically and electrically connected together. The gap 58 prevents a shorted turn, the stress plate 60 reduces stress concentrations, and the lead 62 is connected to the desired potential. The subheader leads 64 are soldered to the conducting strips 34 and connected to the stress plates 66. The number of conducting strips 34 which are attached to a single sub-header lead 64 is not critical, however, too many strips may cause excessive strip-to-strip circulating currents. Consequently, the number of separate sub-header leads 64 and stress plates 66 is dependent upon the type and rating of the apparatus.

In summary, there has been described an efficient shielding means, and methods of constructing same, which may be placed between the windings of a power transformer. We claim as our invention:

1. An electrostatic shield for power transformers comprising a plurality of substantially rectangular insulating and conducting strips, said strips being alternately interleaved around a winding of said power transformer to define a cylindrical shield having first and second ends, said strips having their longest edge parallel to the axis of said winding with the edges of said conducting strips overlapping each other and being separated by said insulating strips.

2. The electrostatic shield of claim 1 including a header lead which is electrically connected to each conducting strip near the first end of said cylindrical shield.

3. The electrostatic shield of claim 1 wherein the shield is physically positioned between the windings of the power transformer.

4. The electrostatic shield of claim 2 including a plurality of sub-header leads, each of said sub-header leads being electrically connected to a plurality of conducting strips near the second end of the cylindrical shield.

5. A power transformer comprising a laminated magnetic core, first and second windings concentrically disposed in inductive relationship with said laminated magnetic core, a cylindrical shield having first and second ends, said cylindrical shield being positioned between said first and second windings with the axis of said cylindrical shield coincident with the axis of said first and second windings, said cylindrical shield comprising a plurality of substantially rectangular, alternately interleaved, insulating and conducting strips, said strips having their longest edge parallel to the axis of said windings with the
edges of said conducting strips overlapping each other and being separated by said insulating strips, a header lead which is electrically connected to each conducting strip near the first end of said cylindrical shield and being connected to ground potential.

6. The power transformer of claim 5 including a plurality of sub-header leads, each of said sub-header leads being electrically connected to a plurality of conducting strips near the second end of the cylindrical shield.

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