

Description

Technical Field

This invention relates to a high voltage isolation transformer.

One of the primary functions of an isolation transformer is to provide sufficient inductive coupling between primary and secondary windings for an efficient transfer of power from alternating currents applied to the primary winding while tolerating the stress of a constant potential difference between the windings when a large voltage is present on one of the windings. Typically, this has been achieved by selective arrangements of air gaps between the primary and secondary windings and by placing layers of electrical insulation and electrostatic shields of various configurations between the windings. These techniques have proven to be inadequate, however, when the constant potential on one of the windings creates electric field stresses on an order of one hundred volts per 0.0254 mm (mils) between the transformer's coils and its core. Field stresses of this magnitude cause arcing across air gaps and corona discharge around the shielding. Moreover, such field stresses cause sparking across air pockets formed between adjacent winding turns, between the windings and insulation, and between the insulation and the core. Continued operation of a transformer at such magnitudes of field stress causes ionization of air within such pockets and a concomitant heating of adjoining transformer surfaces. The heating leads to pitting of the transformer's conductive surfaces and the formation of microcracks in its insulation. Local discontinuities in the insulation caused by the microcracks provide paths of gradually decreasing resistance through the insulation which, over time, enlarge in length and width and ultimately provide a short circuit resulting in catastrophic failure of the transformer.

Attempts to avoid corona discharge and sparking have included the use of flat, ribbon-like conducts wound in concentric turns separated by layers of a resilient insulating material. Although such a technique largely eliminates sparking by avoiding the occurrence of air pockets, it does so at the expense of limiting the number of turns which the windings may have. Other attempts have included placing the entire transformer in a vacuum inside a sealed container. In most instances this has proved to be impractical because the manufacturer of a vacuum tight container capable of accommodating passage of leads is more complicated than the construction of the transformer itself and unreliable because any leak in the vacuum will result in sudden failure of the transformer.

GB-A-863 059 (Philips) describes a high tension transformer according to the first part of Claim 1 with a ferromagnetic core which is embraced by a primary coil. The primary coil is wound on a cylindrical insulating coil former which is provided, on its inner side, with a

slightly conductive graphite layer which is connected to earth.

Statement of Invention

Accordingly, it is one object of the present invention to provide an improved isolation transformer.

It is another object to provide a transformer able to isolate a very high voltage applied to one winding while a constant potential is applied between the windings.

It is still another object to provide an isolation transformer which can be reliably operated at high voltages without degradation due to the occurrence of electric field stress.

It is a further object to provide an isolation transformer which can be reliably operated at voltages on the order of eighty kilovolts.

It is also an object to provide a compact, high voltage isolation transformer.

Briefly, these and other objects are achieved with an isolation transformer having primary and secondary coils wound around separate spool insulators and encased in electrically conductive coatings adhering to the surfaces of the spools. The spools have axial bores lined with electrically conductive coatings adhering to the surfaces of the bores and are mounted upon opposite legs of a magnetic core passing through their axial bores.

Brief Description of Drawings

Figure 1 is a partially cut-away front view of an embodiment of the invention.

Figure 2 is a side view of the embodiment shown in Figure 1.

Figure 3 is an enlarged cut-away sectional view taken along line III-III of Figure 1.

Figure 4 is an enlarged cut-away sectional view taken along line IV-IV of Figure 1.

Figure 5 is a schematic diagram of an embodiment of the invention.

Detailed Description of the Invention

The high voltage isolation transformer 10 according to this invention is shown in Figures 1 and 2 as having primary and secondary solid spools 12, 14, respectively, made of an insulating material exhibiting a high dielectric strength, such as polycarbonate, a thermoplastic polymer. Both spools are mounted on a four-sided ferromagnetic core 16 formed of a pair of low loss segments of a material such as a manganese zinc ceramic ferrite which provides a closed magnetic flux path. Opposite parallel legs 18, 20 of core 16 pass through the axial bores 22, 24 of the primary and secondary spools 12, 14, respectively. Both spools contain a circumferential channel 26, 28 to receive annularly wound primary and secondary coils 30, 32, respectively.

The spools are made in an alternating arrangement of circumferential rings 34 and recesses 36 to provide longer arc paths between the coils and the transformer core. The rings and recesses on each spool are axially spaced to accom-



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tive coatings 50, 60 and return lead 84 of the secondary coil, thereby avoiding the occurrence of sparking between the electrostatic shields and the coils. The lower conductivity of the conducting compound forming the electrically conducting coatings prevents the coatings from acting as short circuit turns across the corresponding coils. Leads 61, 70 and 72 are joined together to assure the absence of any potential difference (or sparking) between the electrostatic shields in the respective axial bores and the transformer core.

When placed in operation, an alternating voltage is applied across leads 82, 90 of the primary coil and by transformer action, an alternating voltage is developed across leads 84 and 92 of the secondary coil for purposes such as maintaining an electrode of an x-ray tube at that voltage. To minimize electric stress across the insulating spools, leads 61, 70 and 72 are coupled to a floating potential voltage equal in amplitude to approximately half, $X/2$, of the potential applied to lead 84, thereby halving the potential difference (and electric field intensity) between the electrostatic shields formed by coatings 48, 50, 60.

The transformer disclosed may be reliably operated at high voltages without degradation due to the occurrence of electric field stresses between its coils and core. One factor which contributes to this reliability is that the effective radii of the primary and secondary coils are determined by the radii of curvature of the electrically conducting coatings 49, 50, 59, 60 (which form an intimate, electrically conductive layer completely encasing the coils) rather than by the much smaller radius of the individual turns of the coils. The proximity between the outer turns of the coils and the electrically conductive coatings and the intimate, adhesive contact between the conductive coatings and the surfaces of the circumferential channels prevents the occurrence of local concentrations in the electric fields across air pockets formed between turns of the coils and between the outer turns and the surfaces of the channels. Consequently, the presence of air pockets between the inner turns of the coils does not result in degradation of the coils because electric fields caused by the several tens of kilo-volts of constant voltage applied to return lead 84 for example, emanate from the electrostatic shield formed by conductive coatings 50, 60 around the secondary coil rather than the individual turns of secondary coil 32. Moreover, as indicated by the spacing of the lines of force, E , shown in Figures 3 and 4, electric fields emanating from the conductive coatings encasing the coils are widely distributed between corresponding pairs of those coatings and the conductive coatings 47, 48 lining the axial bores, thereby avoiding a dense concentration of an electric field across and subsequent degradation of, any part of the coils, spools or air gaps. In one application of an embodiment of the disclosed invention, a constant voltage of minus eight kilovolts was applied to conductive coating 50, 60 and return lead 84 of the secondary coil while a constant voltage of

minus forty kilovolts was applied to the core and conductive coatings 47, 48 in the respective axial bores of both the primary and secondary insulating spools. In that embodiment, the distance between the bottom of the circumferential channels 28, 30 and the surfaces of the axial bores 22, 24 was about 5.08 mm (two hundred mils). The potential gradient, therefore, between conductive coatings 50, 60 around the secondary winding and conductive coating 48 in the axial bore of the secondary insulating spool was approximately two hundred volts per 0.0254 mm (mils). Similarly, the potential gradient between conducting coating 47 in the axial bore of the primary insulating spool and conductive coatings 49, 59 (which were coupled to the return lead of the primary winding) around the primary winding was also approximately two hundred volts per 0.0254 mm (mils). A low, alternating voltage (nine to eighteen volts) was applied across the primary coil. This embodiment performed without sparking or corona, and completely isolated the constant voltage applied to the secondary coil from the primary coil.

The ratio between the number of turns in the primary and secondary coils may be varied, for example, to provide either a step-up or step-down of an alternating voltage applied across the primary coil. Moreover, either the primary or secondary spool may be used to support more than one winding. Also, to minimize the risk of surface arcing when the transformer is incorporated into a very high voltage network, it is desirable to encapsulate the entire high voltage network with a high dielectric potting compound. The present invention is particularly suited for such encapsulation because the presence of the electrically conducting coatings completely surrounding the coils and lining the axial bores avoids the formation of air pockets and, therefore, localized high electrical gradients either between the coils and their spools or between the surfaces of the spools within their axial bores and the transformer core.

Claims

1. An isolation transformer, comprising:
core means (16) for concentrating lines of magnetic flux in a ferromagnetic path including a pair of legs (18, 20);
a pair (12, 14) of electrically insulating elements, one encircling each leg;
coating means (47, 48) having a first electrical conductivity adhering to said insulating elements (12, 14) for separating said insulating elements (12, 14) from said core means (16);
primary (30) and secondary (32) electrical conducting means having a second and greater electrical conductivity wound around respective ones of said insulating elements (12, 14) for generating a magnetic flux in said legs (18, 20); characterised by
other coating means (49, 59, 50, 60) having said first electrical conductivity for encasing said prim-



(12)

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0 130 124

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ary and secondary conducting elements (30, 32) to separate said conducting means (30, 32) from said insulating means (12, 14).

2. The isolation transformer of Claim 1, wherein a first one of said encasing means (49, 59) is electrically coupled to one terminal (82) of said primary conducting element (30) and a second one of said encasing means (50, 60) is electrically coupled to one terminal (84) of said secondary conducting means (32).

3. The isolation transformer of Claim 2 wherein said separating means (47, 48) is electrically coupled to said core means (16).

4. The isolation transformer of Claim 1 wherein said encasing means (49, 59, 50, 60) adhere to respective ones of said primary and secondary conducting elements (30, 32) and adhere to the surfaces of said insulating means (12, 14) adjacent to respective one of said primary and secondary conducting elements (30, 32).

5. The isolation transformer of Claim 1 wherein encasing means (49, 59, 50, 60) completely encase respective ones of said primary and secondary conducting elements (30, 32) and adhere to the surfaces of said insulating elements (12, 14) adjacent to respective ones of said primary and secondary conducting elements (30, 32).

6. The isolation transformer of Claim 5 wherein said separating means (47, 48) comprise discrete layers of said electrically conducting coating adhering to the surfaces of said electrical insulating elements (12, 14) adjacent to said core legs (18, 20).

7. The isolation transformer of Claim 6 wherein said electrically conducting coating comprises a compound of a polymer, a solvent of said polymer, and an electrically conducting material dispersed throughout said polymer.

8. The isolation transformer of Claim 7 wherein said electrically conducting material exhibits a lower conductivity than said electrical conducting means.

9. The isolation transformer of Claim 8 wherein said electrically conducting material comprises carbon black.

Patentansprüche

1. Isoliertransformator mit: Kernmitteln (16) zum Konzentrieren von Magnetflußlinien in einem ferromagnetischen Pfad, der zwei Schenkel (18, 20) aufweist; ein Paar elektrisch isolierender Elemente (12, 14), von denen eines jeweils einen Schenkel umgibt; eine erste elektrische Leitfähigkeit aufweisenden, an den erwähnten Isolier-elementen (12, 14) haftenden Überzugsmitteln (47, 48) zum Trennen der erwähnten Isolierelemente (12, 14) von den erwähnten Kernmitteln (16); und ein primäres (30) und ein sekundäres (32) elektrisch leitendes Mittel mit einer zweiten, größeren elektrischen Leitfähigkeit, die jeweils um eines der erwähnten Isolierelemente (12, 14) herumgewickelt sind, um einen magnetischen Fluß in den erwähnten Schenkeln (18, 20) zu erzeugen, gekennzeichnet durch andere Überzugsmittel (49, 59,

50, 60) mit der erwähnten ersten elektrischen Leitfähigkeit zum Einhüllen des erwähnten primären und sekundären leitenden Elements (30, 32), um die erwähnten leitenden Mittel (30, 32) von den erwähnten Isoliermitteln (12, 14) zu trennen.

2. Isoliertransformator nach Anspruch 1, bei dem ein erstes der erwähnten Einhüllungsmittel (49, 59) elektrisch mit dem einen Anschluß (82) des erwähnten primären leitenden Elements (30) und ein zweites der erwähnten Einhüllungsmittel (50, 60) elektrisch mit dem einen Anschluß (84) des erwähnten sekundären leitenden Mittels (32) verbunden ist.

3. Isoliertransformator nach Anspruch 2, bei dem das erwähnte Trennmittel (47, 48) elektrisch mit den erwähnten Kernmitteln (16) verbunden ist.

4. Isoliertransformator nach Anspruch 1, bei dem die erwähnten Einhüllungsmittel (49, 59, 50, 60) jeweils an einem der erwähnten primären und sekundären leitenden Elemente (30, 32) und an den Oberflächen der erwähnten Isoliermittel (12, 14) in der Nähe von jeweils einem der erwähnten primären und sekundären leitenden Elemente (30, 32) haften.

5. Isoliertransformator nach Anspruch 1, bei dem die Einhüllungsmittel (49, 59, 50, 60) jeweils eines der erwähnten primären und sekundären leitenden Elemente (30, 32) vollständig einhüllen und an den Oberflächen der erwähnten Isolierelemente (12, 14) in der Nähe jeweils einer der erwähnten primären und sekundären leitenden Elemente (30, 32) haften.

6. Isoliertransformator nach Anspruch 5, bei dem die erwähnten Trennmittel (47, 48) diskrete Schichten aus dem erwähnten elektrisch leitenden Überzug aufweisen, der an den Oberflächen der erwähnten elektrisch isolierenden Elemente (12, 14) in der Nähe der erwähnten Kernschenkel (18, 20) haftet.

7. Isoliertransformator nach Anspruch 6, bei dem der erwähnte elektrisch leitende Überzug eine Zusammensetzung aus einem Polymer, einem Lösungsmittel für das erwähnte Polymer und einem elektrisch leitenden Material, das über das gesamte erwähnte Polymer dispergiert ist, aufweist.

8. Isoliertransformator nach Anspruch 7, bei dem das erwähnte elektrisch leitende Material eine niedrigere Leitfähigkeit als die erwähnten elektrisch leitenden Mittel aufweist.

9. Isoliertransformator nach Anspruch 8, bei dem das erwähnte elektrisch leitende Material Kohlen schwarz aufweist.

Revendications

1. Un transformateur d'isolation, comprenant: un circuit magnétique (16) destiné à concentrer des lignes de flux magnétique dans un chemin ferromagnétique, comprenant une paire de branches (18, 20);

une paire (12, 14) d'éléments électriquement isolants, chacun d'eux entourant une branche respective;

des moyens de revêtement (47, 48) ayant une



première conductivité électrique qui adhèrent aux éléments isolants (12, 14) pour séparer les éléments isolants (12, 14) du circuit magnétique (16); des moyens conducteurs électriques primaires (30) et secondaires (32), ayant une seconde conductivité électrique, de valeur supérieure, qui sont enroulés autour d'éléments respectifs parmi les éléments isolants (12, 14), pour produire un flux magnétique dans les branches (18, 20); caractérisé par

d'autres moyens de revêtement (49, 59, 50, 60) ayant la première conductivité électrique, destinés à envelopper les éléments conducteurs primaires et secondaires (30, 32), pour séparer ces moyens conducteurs (30, 32) par rapport aux moyens isolants (12, 14).

2. Le transformateur d'isolation de la revendication 1, dans lequel un premier des moyens d'enveloppement (49, 59) est connecté électriquement à une borne (82) de l'élément conducteur primaire (30), et un second des moyens d'enveloppement (50, 60) est connecté électriquement à une borne (84) des moyens conducteurs secondaires (32).

3. Le transformateur d'isolation de la revendication 2, dans lequel les moyens de séparation (47, 48) sont connectés électriquement au circuit magnétique (16).

4. Le transformateur d'isolation de la revendication 1, dans lequel les moyens d'enveloppement (49, 59, 50, 60) adhèrent à des éléments respectifs parmi les éléments conducteurs primaires et secondaires (30, 32), et ils adhèrent à des surfaces

des moyens isolants (12, 14) adjacentes à un élément respectif parmi les éléments conducteurs primaires et secondaires (30, 32).

5. Le transformateur d'isolation de la revendication 1, dans lequel les moyens d'enveloppement (49, 59, 50, 60) enveloppent complètement des éléments respectifs parmi les éléments conducteurs primaires et secondaires (30, 32), et ils adhèrent aux surfaces des éléments isolants (12, 14) adjacentes à des éléments respectifs parmi les éléments conducteurs primaires et secondaires (30, 32).

6. Le transformateur d'isolation de la revendication 5, dans lequel les moyens de séparation (47, 48) comprennent des couches discrètes du revêtement conducteur de l'électricité qui adhèrent aux surfaces des éléments électriquement isolants (12, 14) adjacentes aux branches de circuit magnétique (18, 20).

7. Le transformateur d'isolation de la revendication 6, dans lequel le revêtement conducteur de l'électricité comprend un composé d'un polymère, d'un solvant de ce polymère et d'une matière conductrice de l'électricité dispersée dans le polymère.

8. Le transformateur d'isolation de la revendication 7, dans lequel la matière conductrice de l'électricité présente une conductivité inférieure à celle des moyens conducteurs de l'électricité.

9. Le transformateur d'isolation de la revendication 8, dans lequel la matière conductrice de l'électricité est du noir de carbone.