POWER TRANSFORMER HAVING A SPRING-COMPRESSED WINDING STRUCTURE


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ABSTRACT
Core-form power transformer having a spring loaded winding support structure. The winding is compressed between pressure plates located at the ends of the winding. The compressive force is provided by compressed ring springs which are positioned between structural members of the support structure. The ring springs provide the desired spring constant and damping characteristics for proper winding support during normal and short-circuit conditions.

1 Claim, 4 Drawing Figures
POWER TRANSFORMER HAVING A SPRING-COMPRESSED WINDING STRUCTURE

BACKGROUND OF THE INVENTION

1. Field of the Invention
This invention relates, in general, to electrical inductive apparatus and, specifically, to power transformers having constantly compressed winding structures.

2. Description of the Prior Art
Substantially all large power transformers have a structural supporting system which is designed to restrain the mechanical movement of the winding structures, especially under the vertical or axial forces generated during short-circuit conditions. Under short-circuit conditions, the coils of the windings tend to telescope with respect to each other. Therefore, the ends of the windings must be substantially fixed with respect to each other to prevent destruction of the transformer.

One convenient and useful arrangement for preventing telescoping of the winding coils utilizes pressure plates positioned adjacent to the ends of the winding structure. The pressure plates are firmly held in position by a rigid support structure. The pressure plates are initially forced toward each other during the construction of the transformer to compress the winding structure. This permits the pressure plates to limit the movement of the winding coils immediately upon any tendency to telescope with respect to each other.

The rigid compressing technique used according to the prior art has some disadvantages which may be detrimental to the operation of the transformer. During normal operation and heat cycling of the winding structure, the amount of compressive forces within the winding structure increase and decrease due to the expansion characteristics of the winding structure components and to the limits on the movement thereof. After a sufficient length of time, the cycling enables the winding components to set or acquire a new permanent dimension which is generally smaller than the dimension at the time of original construction. Thus, after the transformer has been in operation for a period of time, the winding structure tends to become "loose" and the ability of the supporting structure to withstand telescoping forces under short-circuit conditions is reduced, since the winding coils acquire a certain amount of inertia before being restrained by the supporting structure.

To keep the winding structure as tight as possible, for as long a period as possible, it is generally preferable to compress the winding structure during the manufacturing of the transformer. However, the limits upon the amount of compression which may be safely used is dependent upon the winding structure components and the strength of the supporting structure. In some cases, the winding insulation may be overstressed mechanically by too much compression and failure thereof may result.

The use of coil springs to provide a resilient force between the pressure plates has not been practical in large core-form power transformers due to the unavailability of suitable coil springs to provide the required amount of force. The size of a normal coil spring which would be required to provide the desired force in a large core-form power transformer would be substantially out of proportion with the other components of the transformer and would not provide a practical solution to providing a resilient force between the pressure plates. In addition, the resonant properties of typical coil springs are detrimental under the influence of the short-circuit forces exerted on the springs by the coils of the transformer winding structure. The resonant frequency of any coil spring which may be used for restraining the pressure plates in a power transformer is generally close to the frequency at which the force from the winding structure is applied to the pressure plates. Thus, without suitable damping mechanisms, an unstable condition may develop with the use of normal coil springs and the structural system may fail violently during short-circuit force conditions.

There have been some attempts to increase the force provided by a coil spring and to dampen the response thereof by effectively providing a dashpot in parallel with the spring. With this type of construction, gradual physical changes due to thermal cycling may compress the spring. When the change in physical dimension is extremely rapid, as it would be under short-circuit stress conditions, the force provided by the spring is effectively increased by the action of the dashpot. Thus, a small amount of telescoping may occur with this type of arrangement. Although this type of arrangement may be feasible for providing the desired spring characteristics to support core-form transformer static plates, the construction arrangement thereof is complicated.

Therefore, it is desirable, and it is an object of this invention, to provide a winding supporting system for power transformers which provides sufficient force to maintain the integrity of the winding structure under short-circuit conditions without excessive force which may damage the insulation structure of the winding system, and which is suitably damped to prevent oscillation of the forcing members due to the frequency of the mechanical stresses produced.

SUMMARY OF THE INVENTION

There is disclosed herein a new and useful arrangement for securing the windings of a power transformer under normal and overloaded conditions. The coils of the windings are positioned between disc-shaped pressure plates which are forced toward each other by a support structure disposed around the magnetic core of the transformer. The support structure includes a lower end frame which is attached to a lock plate which extends into the upper region of the winding structure and through a lock plate guide member. Ring springs are positioned between the guide member and a structural brace which is coupled to the lock plate. The ring springs are initially compressed during construction of the transformer and constantly exert a force on the structural members of the support structure to push the pressure plates together. Any expansion of the winding structure or tendency of the coils in the winding structure to telescope with respect to each other must compress the ring springs further. The large spring constant of the ring springs permits a relatively large force to be applied to the pressure plates and the resistance between adjacent rings of the ring springs provides sufficient damping characteristics to prevent oscillation of the ring springs under short-circuit conditions.

BRIEF DESCRIPTION OF THE DRAWING

Further advantages and uses of this invention will become more apparent when considered in view of the following detailed description and drawing, in which:
FIG. 1 is a sectional view of a core-form power transformer constructed according to a specific embodiment of this invention.

FIG. 2 is a partial top view of a power transformer constructed according to this embodiment;

FIG. 3 is a sectional view of a ring spring used in the embodiment shown in FIGS. 1 and 2; and,

FIG. 4 is a graph representing the load-deflection characteristics of the ring spring illustrated in FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

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

Referring now to the drawing, and to FIG. 1 in particular, there is shown a cross-sectional view of a core-form power transformer constructed according to a specific embodiment of this invention. The section is taken generally along a plane slightly displaced from the center of a leg of the magnetic core of the transformer. The line 1—1 of FIG. 2 indicates the general position of this plane. The transformer core 10 includes a plurality of laminations of a magnetic material. The magnetic core 10 is securely held together by a support structure which also supports the high-voltage coil 12 and the low-voltage coil 14 which form the winding structure 16. Suitable insulating members may be positioned between various components of the transformer, but are not illustrated in FIG. 1 in the interest of clarity.

The winding structure 16 is positioned between the pressure plates 18 and 20 which are constructed of a suitably strong material to uniformly distribute the pressure applied to the winding 16 around the entire periphery of the winding 16. The pressure plate 20 is positioned on the end frame 22 which is attached to the lock plate 24. A similar arrangement is provided on the other side of the magnetic core 10 by the end frame 26 and the lock plate 28. The lock plates 24 and 28 extend upwardly along side the leg of the magnetic core 10 into the region above the upper end of the winding structure 16.

The end frames 30 and 32 are positioned above the pressure plate 18 and are connected to the lock plate guide member 34. The guide member 34 supports the ring springs 36 and 38 which are positioned between the guide member 34 and the structural brace 40.

The ring springs 36 and 38 are initially compressed during the construction of the transformer. Therefore, during the operation of the transformer, the winding structure 16 is subjected to a pressure which tends to move the pressure plates 18 and 20 together. The force providing this pressure is transmitted from the lower ends of the ring springs 36 and 38 through the guide member 34 and the end frames 30 and 32, and from the upper ends of the ring springs 36 and 38 through the structural brace 40, the lock plates 24 and 28, and the end frames 22 and 26. The initial compression of the ring springs 36 and 38 is provided during the construction of the transformer by applying a downward force to the structural brace 40 and inserting suitably sized keys 42 between the structural brace 40 and the stops 44 which are attached to the lock plates 24 and 28.

FIG. 2 is a partial view of the top of a transformer constructed according to this invention. The guide member 34 contains openings 48 and 50 through which the lock plates 28 and 24 extend, respectively. The pressure applied to the pressure plate 18 by the end frames 30 and 32 is transmitted through the pressure plate 18 around the entire periphery of the winding structure positioned below the pressure plate 18. Reinforcing ribs 52 positioned on the various structural members provide the necessary strength to permit sufficient force to be applied to the pressure plate 18.

FIG. 3 is a cross-sectional view of the ring spring 36 shown in FIG. 1 illustrating the shape of the rings contained therein. The ring spring 36 consists essentially of a series of rings having conical surfaces which are assembled as indicated in FIG. 3. The outside rings 60 have a larger diameter than the inside rings 62. Each of the rings is constructed of a suitably tempered material which provides the stress-strain characteristics required. Although the ring spring 36 shown in FIG. 3 has larger diameter rings 60 positioned at each end thereof, it is within the contemplation of this invention that smaller diameter rings 62 may be positioned at each end, or that one end may have a larger diameter ring 60 and the other end may have a smaller diameter ring 62. Although not shown in FIGS. 1 and 3, a suitable guide or sleeve may be disposed either within or around the ring spring 36 to reduce the possibility of buckling of the ring spring.


Referring again to FIG. 3, as the ring spring 36 is compressed, the rings 60 tend to increase in diameter and the material therein is subjected to tensile stresses. The rings 62 tend to decrease in diameter and are subjected to compressive stresses. At the same time, the rings 60 and 62 telescope with respect to each other. The frictional forces between the mating surfaces of the rings 60 and 62 provide the unique characteristics which are used to advantage in the structural supporting system of the transformer as shown in FIG. 1.

FIG. 4 is a load-deflection diagram illustrating the deflection of the springs in relation to the force applied thereto. Curve 64 represents the characteristics of the spring as it is being compressed. Curve 66 represents the characteristics of the spring as it is being recoiled or allowed to return to its uncompressed state, which is indicated by point 68. When the spring is originally compressed, a load L1 is required to deflect the spring a distance D1. As the load is removed from the spring, the deflection remains constant until the load reaches the value L2. As the load decreases below the value L2, the load-deflection characteristics are represented by the curve 66. The hysteresis loop of the load-deflection diagram is provided by the frictional forces between the contacting surfaces of the rings 60 and 62.

The particular load-deflection characteristics represented by the ring spring as shown in FIG. 4 are particularly useful for the application of maintaining the integrity of large transformer winding structures. Due to the frictional forces between the rings of the ring spring, the load required for a specific amount of deflection is relatively high compared with other types of springs. This is advantageous from the standpoint that the physical size of the ring spring which is necessary to provide the desired load capability has a practical size in relation to other transformer components. In addition, under short-circuit conditions when the spring is fur-
ther compressed by the forces occurring during the short-circuit condition, the large effective spring constant decreases the overall deflection of the ring spring and prevents excessive movement of the winding structure. Without excessive compression, the ring spring exhibits characteristics close to normal ring springs in regard to the amount of load produced. Thus, the insulation structure of the winding will not be overstressed by an excessive amount of compression thereon.

The resistance provided by the mating surfaces of the ring springs additionally helps to dampen any oscillations which may be inherent in the ring spring components. This reduces the possibility that the forces tending to compress the spring will drive the spring into oscillation.

Since numerous changes may be made in the above-described apparatus, and since different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all of the matter contained in the foregoing description, or shown in the accompanying drawing, shall be interpreted as illustrative rather than limiting.

I claim as my invention:

1. Electrical inductive apparatus comprising:
   a magnetic core having at least one leg;
   a winding structure having upper and lower ends and being disposed around said leg;
   a first washer-shaped pressure plate which is positioned adjacent to the lower end of the winding structure;
   a first end frame member positioned to push the first pressure plate against the winding structure;
   a lock plate which is rigidly attached to the first end frame member and which extends above the upper end of the winding structure;
   a structural brace coupled to said lock plate;
   a second washer shaped pressure plate which is positioned adjacent to the upper end of the winding structure;
   a second end frame member positioned to push the second pressure plate against the winding structure;
   a lock plate guide member which is attached to the second end frame member for guiding the lock plate; and,
   at least one ring spring disposed in compressed relationship between the structural brace and the lock plate guide member to force the pressure plates together;
   said ring spring including a plurality of rings stacked in axial alignment with each other, with adjacent rings telescoping with respect to each other when the ring spring is compressed.

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