SHUNT REACTOR HAVING IMPROVED INSULATING FLUID CIRCULATING MEANS

Inventor: Robert L. Grubb, New Berlin, Wis.
Assignee: Allis-Chalmers Manufacturing Company, Milwaukee, Wis.
Filed: May 25, 1970
Appl. No.: 40,016

U.S. Cl. 336/57, 336/58, 336/60
Int. Cl. H01F 27/08
Field of Search 336/55, 57, 58, 60, 61

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A shunt reactor immersed in oil within a rectangular casing has cylindrical coils with vertical axes aligned in a common plane and a closed rectangular magnetic shield having laminations in vertical planes surrounding the coils. Annular washers with apertures therethrough and radial spacers on each surface are disposed between the ends of the coils and the magnetic shield and form radial ducts communicating with vertical cooling ducts in the coils. Barrier means form a closed chamber at the bottom of the casing and block flow of oil in paths which bypass the coils and shield and force increased flow of oil into the radial ducts and through the vertical ducts in the coils, and such barrier means include angle collars surrounding the lower end of each coil, baffle members which at one end overlap the angle collars and at the other end project horizontally outward, and flexible elongated steel members affixed to the casing sidewalls which extend inwardly and downwardly of the casing and interfere with and are pushed outwardly by the horizontal baffle member when the reactor is lowered into the casing, thereby forming dams preventing upward movement of oil along the casing sidewalls.

16 Claims, 5 Drawing Figures
SHUNT REACTOR HAVING IMPROVED INSULATING FLUID CIRCULATING MEANS

This invention relates to temperature modifying means for stationary induction apparatus and in particular to insulating fluid circulating means for coreless shunt reactors.

Coreless shunt reactors for reactive compensation may be of the oil-filled type such as disclosed in U.S. Pat. No. 3,443,119 to E. T. Norton wherein the shunt reactor is immersed in an insulating fluid within a casing and the fluid is circulated to dissipate the losses and prevent the temperature rise exceeding the thermal rating of the unit. Coreless inductor shunt reactors utilize magnetic yokes adjacent both axial ends of the reactor coils to straighten the lines of magnetic flux within the coils for the purpose of minimizing eddy current heating caused by cross flux and of increasing the inductance in comparison to an air core reactor of the same coil dimensions. The laminated magnetic yokes adjacent both axial ends of the reactor coils obstruct the flow of cooling liquid in an axial direction through the coils, and U.S. Pat. No. 3,466,582 to William C. Sweeney and Michael W. Waterman discloses a magnetic yoke for a coreless iron reactor having expanded metal spacers at selected positions between the laminations of the magnetic yoke which minimize the amount of iron in the yoke and also provide cooling ducts for the circulation of the liquid insulating coolant through the yoke and through cooling ducts in the coils to aid in dissipating heat generated by dielectric losses in the coil insulation. However, it is often desirable to further decrease the temperature rise of coreless iron shunt reactors, and it is an object of the invention to provide a shunt reactor having improved means for dissipating the losses for the coils and magnetic yoke and for decreasing the copper-over-oil temperature of the reactor.

It is a further object of the invention to provide a shunt reactor having improved means for forcing the insulating fluid through cooling ducts in the reactor coils to dissipate the losses for the reactor coils.

Still another object of the invention is to provide a shunt reactor having improved means for increasing flow of insulating fluid through the coil ducts using barriers for blocking off oil bypass paths around the yoke and coil assembly and for creating a pressure differential between the upper and lower portions of the tank.

A still further object is to provide such a shunt reactor having oil-blocking means which provide efficient sealing off of the bypass paths regardless of substantial variation in dimensions of the casing or of the coil and yoke assembly as a result of manufacturing tolerances and which blocking means does not deteriorate when exposed to hot insulating fluid.

These and other objects and advantages of the invention will be more readily apparent from the following detailed description when considered in conjunction with the accompanying drawing wherein:

FIG. 1 is a plan view of a three phase shunt reactor embodying the invention with the tank cover removed and with parts cut away to better illustrate the internal construction;

FIG. 2 is an elevation view of the shunt reactor of FIG. 1 with the front wall of the tank removed;

FIG. 3 is a transverse sectional view through the shunt reactor of FIGS. 1 and 2;

FIG. 4 is a view taken along line IV–IV of FIG. 1; and

FIG. 5 is an isometric view of a portion of the coil and yoke assembly of the shunt reactor of FIG. 1.

Referring to the drawing, the preferred embodiment of the invention is shown incorporated in a three phase shunt reactor having a three phase coil and yoke assembly 10 immersed in an insulating fluid such as transformer oil 11 within a casing 13 of rectangular cross section. The coil and yoke 10 includes three cylindrical coils A, B, and C, one for each of the phases, disposed with their axes vertical and aligned in a common plane parallel to the longitudinal axis of rectangular tank 12. Each coil A, B, and C preferably is relatively short in the axial direction and has a ratio of coil radius to coil axial length greater than 0.25 to decrease the length of the nonmagnetic fluid path and thus increase the inductance as disclosed in the aforementioned U.S. Pat. No. 3,466,582. Each coil A, B, and C has a non-magnetic core which preferably comprises an axial opening through the coil defined by an insulating support tube 14 with its axis vertical and upon which sheet coil 15 such as aluminum sheet is wound spirally as disclosed in the copending application of Michael W. Waterman, Ser. No. 64,472 filed Aug. 17, 1970, having the same assignee as this invention, with elongated insulating spacers 17 between adjacent conductor turns extending parallel to the coil axis to provide vertical ducts 18 for the circulation of insulating fluid 11 through the coil in a direction parallel to the axis. Alternatively, each coil A, B, and C may be of the drum type or comprise a plurality of axially aligned pancake windings (not shown) surrounding a support tube 14 and having vertical cooling ducts there-through.

A closed magnetic yoke 20 has laminations 21 of magnetic steel in vertical planes parallel to the axis of the three phase coils A, B, and C disposed adjacent both axial ends of all three phase coils A, B, and C to straighten the lines of magnetic flux within the coils and to minimize eddy current heating caused by the radial component of the magnetic flux. The closed magnetic yoke 20 preferably is similar to that disclosed in aforementioned U.S. Pat. No. 3,443,119 and has an elongated horizontal upper yoke portion 22A adjacent the upper end of all three coils A, B, and C and an elongated horizontal lower yoke portion 22L adjacent the lower axial end of the three coils A, B, and C connected by vertical end yoke portions 24 completing a closed, low reluctance magnetic circuit of high permeability in surrounding relation to all three coils A, B, and C. The horizontal yoke portions 22A and 22L may comprise yoke laminations 21Y and the end yoke portions 24 may comprise end laminations 21E, and the ends of the laminations 21Y and 21E may be mitered (not shown) and the miter joints between end and yoke laminations 21Y and 21E may be offset in alternate layers to provide an overlap joint arrangement (not shown) which decreases the reluctance of the iron path and increases the mechanical strength of the yoke 20. Elongated flat fillers, or spacers 26 (see FIG. 1) of expanded metal construction are provided between laminations 21Y in the horizontal yoke portions 22A and also between the end laminations 21E in the end yoke portions 24 to provide ducts for circulation of the insulating fluid 11 through yoke 20, and the number of layers of spacers 26 is varied horizontally in a direction perpendicular to the planes of the laminations so that the magnetic flux density in the iron path external to the coils A, B, and C is approximately uniform along any horizontal cross section through the yoke 20. Preferably the cross sectional area of iron per unit dimension of yoke thickness in a horizontal direction is a maximum near the center of the cross section opposite the axial opening in each coil A, B, and C where the flux density is a maximum and decreases progressively from the center toward the outer edges of the yoke 20 so that the flux density in any horizontal cross section through the yoke 20 is approximately uniform along the entire thickness of the yoke 20.

Structural iron, upper side frame members 28U of box cross section are disposed on opposite sides of upper yoke portion 22U, and transverse I-beam members 29 disposed above upper yoke portion 22U are connected at their ends to the upper side frame members 28U to clamp the yoke laminations 21Y of upper yoke portion 22U. Similarly structural iron, lower side frame members 28L of box cross section are disposed on opposite sides of lower yoke portion 22L, and transverse I-beam feet 32 disposed below lower yoke portion 22L, and resting on the bottom wall 33 of the casing 12 are affixed at their ends to the lower side frame members 28L and clamp the yoke laminations 21Y of the lower yoke portion 22L. Vertical structural iron tie members 35 are welded to the upper side frame members 28U and the lower side frame members 28L adjacent the ends thereof to form a rigid unitary assembly 10 of coils A, B, and C and yoke 20. Vertical tie members 35 are shown as being of box cross section but such members of open channel cross section are equally suitable.
Upper horizontal I-beam bracing members 37U disposed between the end yoke portions 24 and the end walls 38 of casing 12 may be welded to angle support brackets (not shown) affixed to the vertical tie members 35, and similarly lower horizontal I-beam bracing members 37L disposed between the end yoke portions 24 and the casing end walls 38 may be welded to angle support brackets (not shown) affixed to the vertical tie members 35.

A plurality of cooling radiators 40 (see FIG. 3) affixed to a sidewalk 41 of casing 12 communicate with the interior of casing 12 adjacent the upper and lower margins of sidewalk 41, and pump means 42 are provided to circulate the insulating fluid 11 through the cooling radiators 40, the ducts in magnetic yoke 20 formed by spacers 26, and through the vertical ducts 18 in the coils A, B and C.

In accordance with the invention means are provided to force increased flow of oil 11 through vertical cooling ducts 18 in coils A, B and C, and such means may include barriers to form a closed chamber at the bottom of casing 12 which blocks the flow of oil 11 in the upper path which passes the coils A, B and C and yoke 20 which creates a pressure differential between the upper and lower ends of casing 12 to increase the flow of oil through the vertical ducts 18 in coils A, B and C. Such oil blocking barriers are partially formed by insulating angle collars 43 surrounding each cylindrical coil A, B and C a slight distance above the lower end thereof. Further, a plurality of oil-blocking, or baffle plates 44 of suitable insulating material having opposite semicircular cutout portions 45 are disposed in a common horizontal plane with the semicircular portions 45 abutting the outer periphery of each coil and overlapping the horizontal flange 46 on the corresponding angle collar 43.

The oil-blocking plates 44 extend horizontally outward beyond the coils A, B and C and about against elongated flexible steel members 47 affixed to the interior of the casing sidewalks 41 and together therewith form dams which prevent upward flow of oil 11 along the casing sidewalks 41. The flexible steel members 47 may be secured adjacent their upper edge to the interior of the casing sidewalks 41 and bent inwardly and downwardly of the casing 12 so that they interfere with and are pushed outwardly by the oil-blocking plates 44, when the coil and yoke unit 10 is lowered into casing 12, to form the desired dams blocking upward flow of oil 11 along casing sidewalks 41. The angle collars 43 are of sufficiently thin material to be flexible, and the horizontal flange 46 thereof is forced upwardly against the oil-blocking plates 44 by the greater oil pressure at the bottom of the casing 12 to seal between the oil-blocking plates 44 and the angle collars 43.

A horizontally elongated entrance aperture 49 for flow of oil 11 into the vertical ducts 18 in the coils A, B and C is provided in the oil-blocking plate 44 and the corresponding box section lower side frame member 28L, and such oil entrance aperture 49 is in the same horizontal plane as a horizontal lower annular insulating washer 50L having a plurality of apertures 51 (see FIG. 1) therethrough and also having a plurality of radially extending insulating spacer members 53 affixed to both the upper and lower surfaces thereof. An annular washer 50L having radial spacers 53 affixed to both surfaces thereof is disposed between the lower yoke portion 22L and the bottom edge of the coil turns of sheet conductor 15 and defines radial oil flow ducts which communicate with the vertical ducts 18 between adjacent spiral turns of sheet conductor 15.

Similarly an upper annular horizontal washer 50U having a plurality of apertures 51 therethrough and radial insulating spacers 53 affixed to both upper and lower surfaces thereof is disposed at the upper end of each coil A, B and C between the upper edge of the sheet conductor coil turns 15 and the upper yoke portion 22U and defines radial ducts for the oil at the upper end of the coils which communicate with the vertical ducts 18 between adjacent turns of sheet conductor 15.

The oil-blocking plates 44 are secured by suitable fastening means (not shown) to a rectangular framework of horizontal longitudinal wooden members 55 extending longitudinally of casing 12 and wooden members 56 extending transversely of casing 12 between the coils. The wooden members 55 and 56 have rabbed joints at their mating ends, and the transverse members 56 are secured, in turn, by fastening means 58 (see FIG. 1) to metallic vertical tie members 59 which are welded to the box section upper and lower side frames 28U and 28L at positions between the coils.

The lower I-beam braces 37L at each end of the yoke 20 about elongated flexible steel members 61 similar to the flexible members 47 and which are affixed to the inner surface of the end walls 38 of casing 12 to form dams that block upward flow of the oil 11 along the casing end walls 58.

Flat horizontal L-shaped members 63 are positioned at each of the four inside corners of casing 12 in the same horizontal plane as the oil-blocking plates 44 and obstruct upward movement of the oil 11 at the inside corners of casing 12. The L-shaped members 63 may be affixed to said support tubes 14 (see FIG. 4) having one vertical flange secured to the vertical tie members 35, and one leg of each L-shaped member 63 extends as far as the lower I-beam braces 37L along the casing end walls 38 and the other leg of L-shaped member 63 extends as far as the oil-blocking plates 44 along the sidewalks 41 of casing 12 to assure complete blocking of upward movement of the oil in the paths which would bypass the vertical ducts 18 in coils A, B and C.

The support tubes 14 for the coils A, B and C have slots 66 cut at diametrically opposed portions at both the upper and lower end thereof which receive elongated transverse bracing plates 67 at the upper and lower ends of the coils A, B and C. The transverse bracing plates 67 are disposed against the facing horizontal surfaces of the lower side frames 28U and 28L and have vertically extending portions 68 (see FIG. 3) at their ends which overlap the upper and lower side frames 28U and 28L and are secured by suitable fastening means (not shown) to said side frames to prevent movement of the coils A, B and C relative to the yoke 20. Circular members 69 of suitable insulating material are disposed within the support tubes 14 adjacent the upper and lower ends thereof and affixed by suitable fastening means such as insulating transverse bolts (not shown) to the transverse bracing plates 67 to center the coils A, B and C within the window in yoke 20 to hold the coils A, B and C in place during shipping and operation. The circular members 69 distribute the inertia loads over the circumference of the support tubes 14 and prevent concentration of the forces at slots 66. Holes are provided in circular members 69 to allow the support tubes 14 to fill with oil 11.

The oil-blocking plates 44 are secured against movement by the framework of wooden members 55 and 56 that is fastened to the vertical tie members 59, and it will be appreciated that the flexible steel strips 47 on the interior of the tank sidewalks 41 and the flexible insulation angle collars 43 are arranged so that the pressure differential between the upper and lower portions of casing 12 forces the flexible members 47 and 43 against the rigidly held oil-blocking plates 44 to force these sealing surfaces together. Such sealing arrangement is superior to rubber or plastic type gasket seals because it provides an efficient seal over a wide range of differences in dimensions between casing 12 and coil and yoke unit 10 resulting from manufacturing tolerances and also does not deteriorate when exposed to the hot oil 11.

While only a single embodiment of the invention has been illustrated and described, it should be understood that I do not intend to be limited to the single embodiment for many modifications and variations thereof will be obvious to those skilled in the art.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A shunt reactor having increased flow of insulating fluid through cooling ducts in the reactor coil comprising, in combination, a casing, insulating fluid within said casing,
a shunt reactor coil and yoke assembly immersed in said fluid within said casing including a cylindrical coil having a plurality of vertical cooling ducts extending therethrough between coil conductor turns so that said insulating fluid circulating through said cooling ducts is in heat exchange relation with said conductor turns and also having a vertically extending axial window and closed laminated magnetic yoke means enclosing said coil and having upper and lower horizontal laminated magnetic yoke portions having a width approximately equal to the diameter of said coil disposed adjacent to and covering both ends of said coil for straightening the lines of magnetic flux within said coil and said axial window, said magnetic yoke means having no laminations within said axial window,

spacers means forming horizontal radial ducts for said insulating fluid between the axial ends of said coil and said upper and lower horizontal yoke portions, said horizontal radial ducts communicating with said vertical ducts through said coil,

cooling radiator means on a sidewall of said casing communicating with said insulating fluid and the interior of said casing adjacent both the upper and lower ends thereof, pump means for circulating said insulating fluid from the upper portion of said casing downwardly through said cooling radiator means and into said lower portion of said casing,

barrier means for blocking upward flow of said insulating fluid within said casing between said coil and yoke assembly and the sidewalls of said casing, whereby said pump means creates a pressure differential between the upper and lower portions of said casing and increases the upward flow of said insulating fluid through said vertical cooling ducts in said coil.

2. A shunt reactor in accordance with claim 1 wherein said barrier means includes a fluid-blocking member on said coil and yoke assembly extending horizontally therefrom toward a sideway of said coil and an elongated flexible member affixed to a casing sidewall and extending inwardly and downwardly of said casing to a position where it interferes with, and is pushed toward said casing sidewall by, said fluid blocking member when said coil and yoke assembly is lowered into said casing, thereby forming a dam between said fluid-blocking member and said flexible member which prevents upward movement of said insulating fluid along said casing sidewall.

3. A shunt reactor in accordance with claim 2 wherein said barrier means also includes an insulating collar surrounding said coil and having a peripheral flange extending horizontally therefrom and said fluid-blocking member is a horizontal plate having one edge in overlapping relation with said peripheral flange on said said coil and yoke assembly and said edge thereof in overlapping relation to said peripheral horizontal flange conforms to the outer periphery of said coil.

4. A shunt reactor in accordance with claim 3 where said peripheral horizontal flange is flexible and said fluid-blocking plate is rigidly held on said coil and yoke assembly and said edge thereof in overlapping relation to said peripheral horizontal flange conforms to the outer periphery of said coil.

5. A shunt reactor in accordance with claim 1 wherein said means for forming horizontal radial ducts includes horizontal flat annular washers having elongated radial spacers affixed to both surfaces thereof and a plurality of apertures through said washer.

6. A shunt reactor in accordance with claim 2 wherein said casing has vertical side and end walls and said barrier means includes fluid-blocking members affixed to and extending horizontally from the sides and ends of said coil and yoke assembly and elongated flexible members affixed to the interior surface of said casing sidewalls and end walls of extending inwardly and downwardly thereof to a position where they interfere with, and are pushed outwardly by, said fluid-blocking members when said core and yoke assembly is lowered into said casing.

7. A shunt reactor in accordance with claim 2 having means including upper side frame members disposed on opposite sides of said upper yoke portion for clamping said laminations of said upper yoke portion, means including lower side frame members disposed on opposite sides of said lower yoke portion for clamping said laminations of said lower yoke portion, and vertical tie members connecting said upper and lower side frame members.

8. A shunt reactor in accordance with claim 7 wherein said fluid-blocking member is held on said coil and yoke assembly in vertical spaced relation to one of said lower side frame members to define a horizontal aperture for said insulating fluid leading to said vertical ducts and said means for forming horizontal radial ducts at the lower end of said coil includes a horizontal flat annular washer having elongated radial spacers affixed thereto disposed between the lower end of said coil and said lower yoke portion and approximately in the plane of said horizontal aperture.

9. A shunt reactor in accordance with claim 8 wherein said coil is wound from conductive sheet material and said annular washer has a plurality of apertures therethrough and said radial spacers are affixed to both the upper and lower surfaces of said washer.

10. A shunt reactor in accordance with claim 2 wherein said laminated magnetic yoke means have spacers between certain laminations providing vertical cooling ducts for said insulating fluid through said yoke means.

11. A coreless iron shunt reactor having means for increasing flow of insulating fluid through ducts in the reactor coil comprising, in combination, a casing for insulating fluid within the casing, a shunt reactor coil and yoke assembly immersed in said fluid within said casing including a cylindrical coil having a plurality of vertical cooling ducts extending therethrough between coil conductor turns so that said insulating fluid circulating through said cooling ducts is in heat exchange relation with said conductor turns and also having a vertically extending axial window and a closed magnetic yoke having magnetic steel laminations in vertical planes enclosing said coil and having upper and lower horizontal yoke portions approximately as wide as the diameter of said coil disposed above and below the axial ends of said coil respectively connected by end vertical yoke portions, said magnetic yoke having no laminations within said axial window, said coil and yoke assembly also having means including upper horizontal structural iron side frame members disposed on opposite sides of said upper yoke portion for clamping said laminations of said upper yoke portion, means including lower horizontal structural iron side frame members disposed on opposite sides of said lower yoke portion for clamping the laminations of said lower yoke portion, and vertical tie members connecting said upper and lower side frame members,

cooling radiator means on a sidewall of said casing communicating with the interior of said casing adjacent the upper and lower ends thereof, pump means for circulating said insulating fluid from the upper portion of said casing downwardly through said cooling radiator means and into the lower portion of said casing,

spacer means for defining horizontal radial ducts for said insulating fluid between the ends of said cylindrical coil and said upper and lower yoke portions and communicating with said vertical ducts, and

barrier means for blocking upward flow of said insulating fluid between said coil and yoke assembly and the side and end walls of said casing and including oil-blocking members extending horizontally from the sides and ends of said coil and yoke assembly and elongated flexible members affixed to said casing side and end walls and extending inwardly and downwardly of said casing to a posi-
tion where said flexible members interfere with and are bent toward said casing walls by said oil-blocking members when said coil and yoke assembly is lowered into said casing.

12. A shunt reactor in accordance with claim 11 wherein said barrier means includes an angle collar surrounding said cylindrical coil and having a flexible horizontally extending flange and at least one of said oil-blocking members is a horizontal plate having an edge conforming to the outer periphery of said coil and engaging said flexible flange on said angle collar in overlapping relation to form a dam preventing upward movement of said insulating fluid in paths bypassing said coil.

13. A shunt reactor in accordance with claim 12 wherein said oil-blocking plate is spaced above one of said lower side members and forms therewith a horizontally extending aperture for said insulating fluid approximately in the plane of said radial ducts.

14. A shunt reactor in accordance with claim 13 wherein said coil is wound from conductive sheet material and each of said spacer means for forming horizontal ducts includes an annular insulating washer having a plurality of elongated insulating radial spacers affixed to each surface thereof and a plurality of apertures therethrough communicating with said vertical ducts in said coil.

15. A shunt reactor in accordance with claim 14 wherein said magnetic yoke has spacer means between certain of said laminations providing cooling ducts through said magnetic yoke for said insulating fluid.

16. A shunt reactor in accordance with claim 2 wherein said coil and yoke assembly includes a plurality of cylindrical coils with their axes aligned in a vertical plane and each having a plurality of vertical cooling ducts therethrough and a vertically extending axial window and said closed laminated yoke means encloses said plurality of cylindrical coils with said upper and lower horizontal yoke portions covering both axial ends of each of said plurality of cylindrical coils.

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