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[54] **INTERLEAVED TRANSFORMER WINDING HAVING THREE PARALLEL CONNECTED CONDUCTORS**

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[51] **Int. Cl.** **H01f 27/28**

[58] **Field of Search** 336/186, 187, 69, 336/70

[56] **References Cited**

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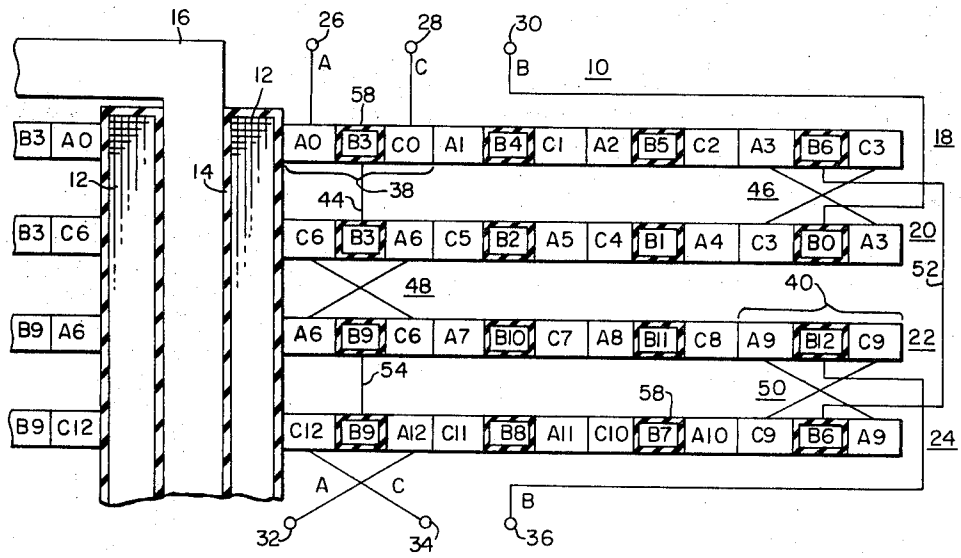
[57] **ABSTRACT**

A disc-type interleaved winding for transformers. Current is conducted through the winding by three conductors connected in parallel and interconnected between the coil discs to provide three different conduction paths. The first and third conduction paths are transposed between adjacent coil discs and progress in radially opposite directions through adjacent coil discs. The second conduction path forms a looping pattern throughout the winding with the conductor forming the second conduction path physically positioned between the other two conductors in each coil disc.

9 Claims, 2 Drawing Figures



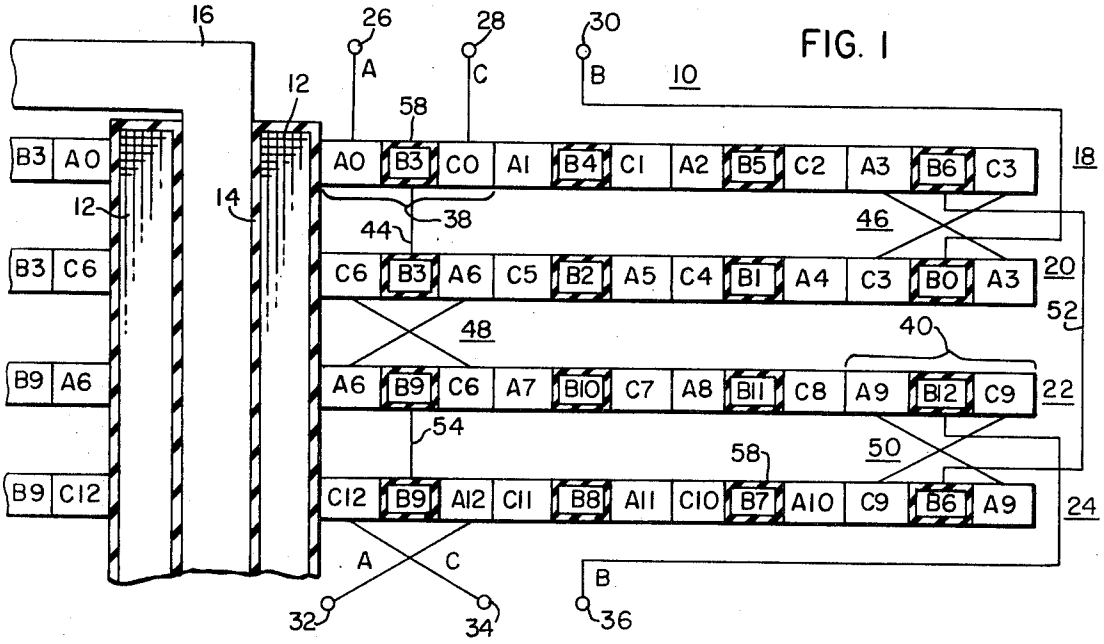

16
26
28
30
A
C
B
10
12
58
B3 A0
12
14
A0 B3 C0 A1 B4 C1 A2 B5 C2 A3 B6 C3
18
44
38
46
B3 C6
C6 B3 A6 C5 B2 A5 C4 B1 A4 C3 B0 A3
20
52
48
40
B9 A6
A6 B9 C6 A7 B10 C7 A8 B11 C8 A9 B12 C9
22
54
58
50
B9 C12
C12 B9 A12 C11 B8 A11 C10 B7 A10 C9 B6 A9
24
A
C
B
32
34
36

FIG. 1

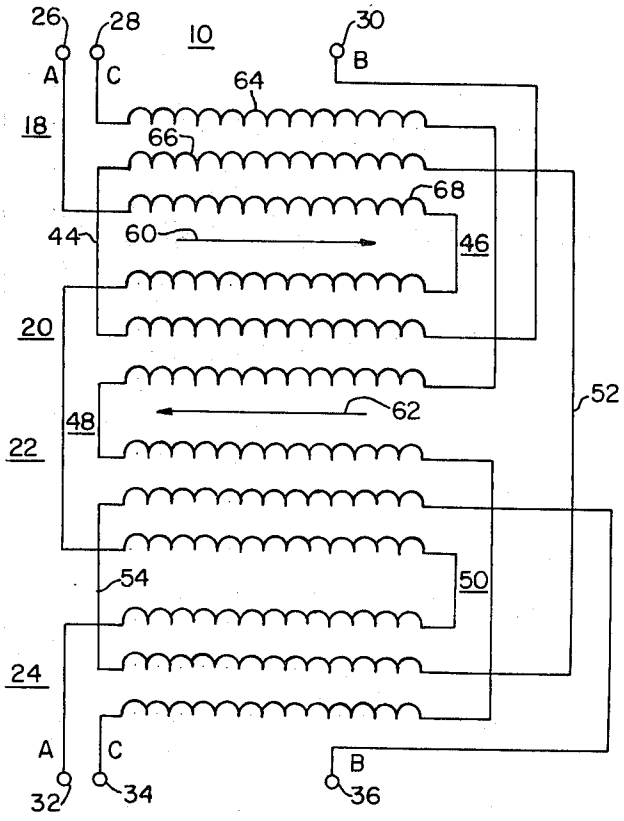

26
28
10
30
A
C
B
64
18
66
68
44
60
46
20
52
48
62
22
54
50
24
A
C
B
32
34
36

FIG. 2

INTERLEAVED TRANSFORMER WINDING HAVING THREE PARALLEL CONNECTED CONDUCTORS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates, in general, to electrical inductive apparatus and, more specifically, to interleaved transformer windings having three conductors.

2. Description of the Prior Art

When a transformer winding is constructed to carry a relatively large amount of current, multiple conductors connected in parallel are frequently used. By using multiple conductors instead of one large conductor, the eddy current losses in the winding are reduced, and connections and transpositions within the winding are less difficult to make due to the better flexibility of the multiple conductor lead.

The use of interleaved windings to increase the series capacitance of a winding structure is well known. Due to the increased series capacitance provided by interleaving, the impulse voltage characteristics of the winding structure are improved. It is also known that the series capacitance of transformer windings is related to the voltage difference between adjacent conductors, with a larger voltage difference providing more energy storage and a higher series capacitance.

Arrangements for interleaving conductors to increase the series capacitance of a transformer winding having three conductors connected in parallel are known by those skilled in the art. Although the prior art arrangements are beneficial electrically, the construction thereof is complicated and costly due to the physical arrangement of the interleaving connections and to the insulation required around the conductors.

It is desirable, and it is an object of this invention, to provide a three-conductor interleaved transformer winding which may be constructed easily and inexpensively.

SUMMARY OF THE INVENTION

There is disclosed herein a new and useful three-conductor interleaved transformer winding. The winding includes at least four coil discs which are axially located at different positions in the winding. The three conductors are wound and interconnected to provide first, second and third conduction paths through the discs of the winding. The first and third conduction paths progress in a first radial direction through one coil disc and then in a second radial direction, which is opposite to the first radial direction, through an adjacent coil disc. The same pattern is repeated in the other discs of the winding. Thus, the first and third conduction paths progress in opposite directions in adjacent coil discs throughout the winding.

The coil discs are arranged into first, second, third and fourth axial positions throughout the winding. The second conduction path forms a looping path throughout the winding. The second conduction path progresses in the second radial direction through the coil disc in the second position, then in the first radial direction through the coil disc in the first position, then in the second radial direction through the coil disc in the fourth position, and then in the first radial direction through the coil disc in the third position. This pattern is repeated throughout every four discs of the winding.

With the arrangement disclosed herein, conductor insulation having a relatively high voltage breakdown strength is only required on one of the three conductors. The interleaving of the conductors provides a winding having a high series capacitance. In addition, the interconnections between coil discs are relatively easy to construct.

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 partial, sectional view of a transformer having a three-conductor interleaved winding; and

FIG. **2** is a schematic diagram of the interleaved winding shown in FIG. **1**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

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

Referring now to the drawings, and FIG. **1** in particular, there is shown a partial, sectional view of a power transformer having an interleaved winding **10.** The winding **10** is illustrated as a high-voltage winding which is positioned around the low-voltage winding **12.** Insulation **14** insulates the low-voltage winding **12** from the magnetic core **16** and from the interleaved high-voltage winding **10.**

The winding **10** includes a plurality of pancake winding sections or coil discs, such as coil discs **18, 20, 22** and **24.** The coil discs **18, 20, 22** and **24** are positioned at different axial positions throughout the winding **10** as is illustrated in FIG. **1.** It is within the contemplation of this invention that more than four coil discs may comprise the winding **10.** The terminals **26, 28** and **30** may be connected together and to associated electrical apparatus, such as a high-voltage bushing. Similarly, the terminals **32, 34** and **36** may be connected together and to a bushing or they may be connected to additional coil discs without being connected together when the winding **10** comprises more than four coil discs.

Each coil disc is wound with three conductors which are denoted as conductors A, B and C. The conductors are spirally wound and are radially disposed on each other throughout the winding **10.** In coil disc **18,** the conductor A at conductor position AO is wound around the low-voltage winding **12,** the conductor B is wound around the conductor A, and the conductor C is wound around the conductor B. Although not completely illustrated, insulation material covers each conductor. Also, each conductor may comprise more than one wire strand.

Although the conductor positions **A0, A1, A2,** etc. designate different physical positions of the electrical conductor A, convenience and commonly accepted practice will be adhered to in this description by referring to such positions as conductors. Each group of three conductors completes a conductor-turn. For example, conductors **A0, B3** and **C0** form the start or first conductor-turn **38** of coil disc **18,** and conductors **A9, B12** and **C9** form the finish or second conductor turn **40** of the coil disc **22.** Any number of conductor-turns may be wound between the first and second conductor-turns; however, only two intermediate conductor-turns

are illustrated in each coil disc of FIG. 1 for clarity. The winding may be constructed in reverse relationship without departing from the spirit of the invention. In reverse relationship, the first conductor-turns, such as the first conductor-turn **38**, would be positioned on the outside of the winding **10** as finsih conductor-turns, such as the second conductor-turn **40**.

The numbers following the conductor designators A, B and C indicate the relative voltage existing on the particular conductor at that location. For example, the voltage existing on conductor A4 in coil disc **20** is two times the voltage existing on conductor A2 in coil disc **18** since the conductor A has progressed two turns in going from conductor A2 to conductor A4. The conductors around which the other conductors in the same conductor-turn are wound, such as conductors A0 and C6, will be referred to as the first conductor in the conductor-turns. The conductors which are wound around the other conductors in the same conductor-turn, such as conductors C0 and A6, will be referred to as the third conductor in the conductor-turns. The conductors which are located between the other two conductors of the same conductor-turn, such as conductors B3 and B9, will be referred to as the second conductor in the conductor-turns. Although referred to as conductors, it is emphasized again that they denote a position in a conductor-turn and may or may not be the same physical conductor at a similar position in another conductor-turn.

As can be seen in FIG. 1, the first conductor-turn **38** of the first coil disc **18** has its first and third conductors, A and C respectively, connected to the terminals **26** and **28**. The terminal **30** is connected to the second conductor B of the second conductor-turn of the second coil disc **20**. Conductors A and C are spirally wound around the low-voltage winding **12** and progress outwardly to the second conductor-turn of the coil disc **18**. Conductor B spirals inwardly to the first conductor-turn of the coil disc **20** and is interconnected to the second conductor B of the first conductor-turn **38** of the first coil disc **18** by the interconnecting lead **44**.

The conduction paths between the terminals **26** and **32** and between the terminals **28** and **34** progress from the first conductor-turn to the second conductor-turn of coil disc **18**, from the second conductor-turn to the first conductor-turn of coil disc **20**, from the first conductor-turn to the second conductor-turn of the coil disc **22**, and from the second conductor-turn to the first conductor-turn of coil disc **24**. The transposed interconnecting leads **46, 48** and **50** connect the appropriate conductors together between adjacent conductor-turns. Transposing the leads **46, 48** and **50** reduces losses caused by circulating currents in the conductors A and C.

The conduction path between the terminals **30** and **36** progresses from the second conductor-turn to the first conductor-turn of the coil disc **20**, from the first conductor-turn to the second conductor-turn of the coil disc **18**, from the second conductor-turn to the first conductor-turn of the coil disc **24**, and from the first conductor-turn to the second conductor-turn of the coil disc **22**. Interconnecting leads **44, 52** and **54** provide the necessary electrical connection between the appropriate conductor-turns.

With the arrangement shown in FIG. 1, the voltage between the conductors A and C is substantially equal to zero in the same conductor-turn. Thus, where the conductors A and C are physically adjacent to each other, such as in the transposed leads **46, 48** and **50**, the insulation material disposed on the conductors A and C need not have a relatively high voltage breakdown strength. Since the voltage between the conductors of radially adjacent conductor-turns is equal to the voltage of one turn, the insulation on these conductors, such as C0 and Al, must only be sufficient to insulate the voltage equal to the voltage induced in one turn of the conductor.

Prior art three-conductor arrangements require a substantial amount of conductor insulation because they have a considerable amount of voltage between each conductor of a conductor-turn. In the present invention, the greatest amount of voltage difference exists between conductor B and the other conductors. Thus, relatively high strength insulation need only be applied to the conductor B. Therefore, a space and material savings may be realized by utilizing the present invention over the prior art. The additional insulation around the conductor B is indicated by the thicker insulation **58** which extends around conductor B. It is within the contemplation of this invention that the insulation **58** need not be thicker if it consists of a material having a higher breakdown strength than the insulation around conductors A and C.

The degree of interleaving of the conductors used in this invention is known as twin interleaving, that is, where the maximum voltage difference between conductors equals the voltage developed in all the turns of one coil disc. One "looping" conductor path is required. The other two conductor paths are continuous throughout the winding **10**. Within the winding **10**, no interconnections are required which connect a first conductor-turn to a second conductor-turn. Thus, relatively long interconnections are not required.

FIG. 2 is an electrical schematic diagram representing the winding **10**. Corresponding to FIG. 1, the direction indicated by the arrow **60** represents the direction going from the inside of the winding **10** to the outside of the winding **10**. Since as previously stated, the winding **10** may be constructed in reverse relationship, the direction indicated by the arrow **60** will be referred to as the first direction to eliminate reference to the physical construction of the winding **10**. Similarly, arrow **62** represents a second direction which is opposite to that of the first direction.

From FIG. 2, it can be seen that a first conduction path begins at terminal **26** and progresses in the first direction through coil disc **18**, in the second direction through coil disc **20**, in the first direction through coil disc **22**, and in the second direction through coil disc **24**. A third conduction path between the terminals **28** and **34** progresses in a similar manner. A second conduction path between the terminals **30** and **36** progresses in the second direction through coil disc **20**, in the first direction through coil disc **18**, in the second direction through coil disc **24**, and in the first direction through coil disc **22**. The vertical position of the conductor coils, such as coils **64, 66** and **68** represents the relative radial position of the conductor in the physical conductor-turn of the coil disc.

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.

We claim as our invention:

1. A winding for electrical inductive apparatus, comprising:

at least, first, second, third and fourth coil discs, said second coil disc being axially positioned between said first and third coil discs, said third coil disc being axially positioned between said second and fourth coil discs;

first, second and third electrical conductors forming first, second and third conduction paths through said coil discs;

said first and third conduction paths progressing in a first direction through said first coil disc, in a second direction through said second coil disc, in the first direction through said third coil disc, and in the second direction through said fourth coil disc, said first and second directions being opposite each other; and

said second conduction path beginning in second coil disc and progressing in the second direction through said second coil disc, in the first direction through said first coil disc, in the second direction through said fourth coil disc, and in the first direction through said third coil disc, respectively.

2. The winding of claim 1, wherein the second conductor is positioned between the first and third conductors throughout each of said coil discs.

3. The winding of claim 1, wherein the first and third conductors are transposed between each coil disc.

4. The winding of claim 1, wherein the second conductor is covered with an insulation structure having a higher voltage breakdown strength than that of insulation covering the first and third conductors.

5. A winding for electrical inductive apparatus, comprising:

at least, first, second, third and fourth coil discs having first and second conductor-turns, said second coil disc being axially positioned between said first and third coil discs, said third coil disc being axially positioned between said second and fourth coil discs;

first, second and third electrical conductors forming first, second and third conduction paths through said coil discs;

said first and third conduction paths beginning at the first conductor-turn of said first coil disc and progressing to the second conductor-turn of said first coil disc, to the second conductor-turn of said second coil disc, to the first conductor-turn of said second coil disc, to the first conductor-turn of said third coil disc, to the second conductor-turn of said third coil disc, to the second conductor-turn of said fourth coil disc, and to the first conductor-turn of said fourth coil disc; and

said second conduction path beginning at the second conductor-turn of said second coil disc and progressing to the first conductor-turn of said second coil disc, to the first conductor-turn of said first coil disc, to the second conductor-turn of said first coil disc, to the second conductor-turn of said fourth coil disc, to the first conductor-turn of said fourth coil disc, to the first conductor-turn of said third coil disc, and to the second conductor-turn of said third coil disc.

6. The winding of claim 5, wherein the second conductor is radially positioned between the first and third conductors in every conductor-turn.

7. The winding of claim 5, wherein the first and third conductors are transposed between each coil disc.

8. The winding of claim 5, wherein the second conductor is covered with an insulation structure having a higher voltage breakdown strength than that of insulation covering the first and third conductors.

9. A winding for electrical inductive apparatus, comprising;

at least, first, second, third and fourth coil discs, said second disc being axially positioned between said first and third coil discs, said third coil disc being axially positioned between said second and fourth coil discs;

first, second and third conductors each comprising at least one electrical strand, said second conductor being radially disposed over said first conductor and said third conductor being radially disposed over said second conductor, said first, second and third conductors being collectively and spirally disposed through each of said coil discs to form at least first and second conductor-turns, the first conductor-turn of each coil disc being located at substantially the same radial position in said winding, said conductors being electrically connected between conductor-turns to provide first, second and third conduction paths;

said first conduction path beginning at the first conductor of the first conductor-turn of said first coil disc and progressing to the first conductor of the second conductor-turn of said first coil disc, to the third conductor of the second conductor-turn of said second coil disc, to the third conductor of the first conductor-turn of said second coil disc, to the first conductor of the first conductor-turn of said third coil disc, to the first conductor of the second conductor-turn of said third coil disc, to the third conductor of the second conductor-turn of said fourth coil disc, and to the third conductor of the first conductor-turn of said fourth coil disc;

said second conduction path beginning at the second conductor of the second conductor-turn of said second coil disc and progressing to the second conductor of the first conductor-turn of said second coil disc, to the second conductor of the first conductor-turn of said first coil disc, to the second conductor of the second conductor-turn of said first coil disc, to the second conductor of the second conductor-turn of said fourth coil disc, to the second conductor of the first conductor-turn of said fourth coil disc, to the second conductor of the first conductor-turn of said third coil disc, and to the second conductor of the second conductor-turn of said third coil disc; and

said third conduction path beginning at the third conductor of the first conductor-turn of said first coil disc and progressing to the third conductor of the second conductor-turn of said first coil disc, to the first conductor of the second conductor-turn of said second coil disc, to the first conductor of the first conductor-turn of said second coil disc, to the third conductor of the first conductor-turn of said third coil disc, to the third conductor of the second conductor-turn of said third coil disc, to the first conductor of the second conductor-turn of said fourth coil disc, and to the first conductor of the first conductor-turn of said fourth coil disc.

* * * * *