United States Patent [19]

Van Nice

[11] **3,899,764**

[45] **Aug. 12, 1975**

[54] **FOUR-STRAND INTERLEAVED-TURN TRANSFORMER WINDING**

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[73] Assignee: **Westinghouse Electric Corporation,** Pittsburgh, Pa.

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[52] **U.S. Cl.** **336/70;** 336/187

[51] **Int. Cl.** **H01f 15/14**

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

[56] **References Cited**

FOREIGN PATENTS OR APPLICATIONS

1,147,282 11/1957 France 336/70

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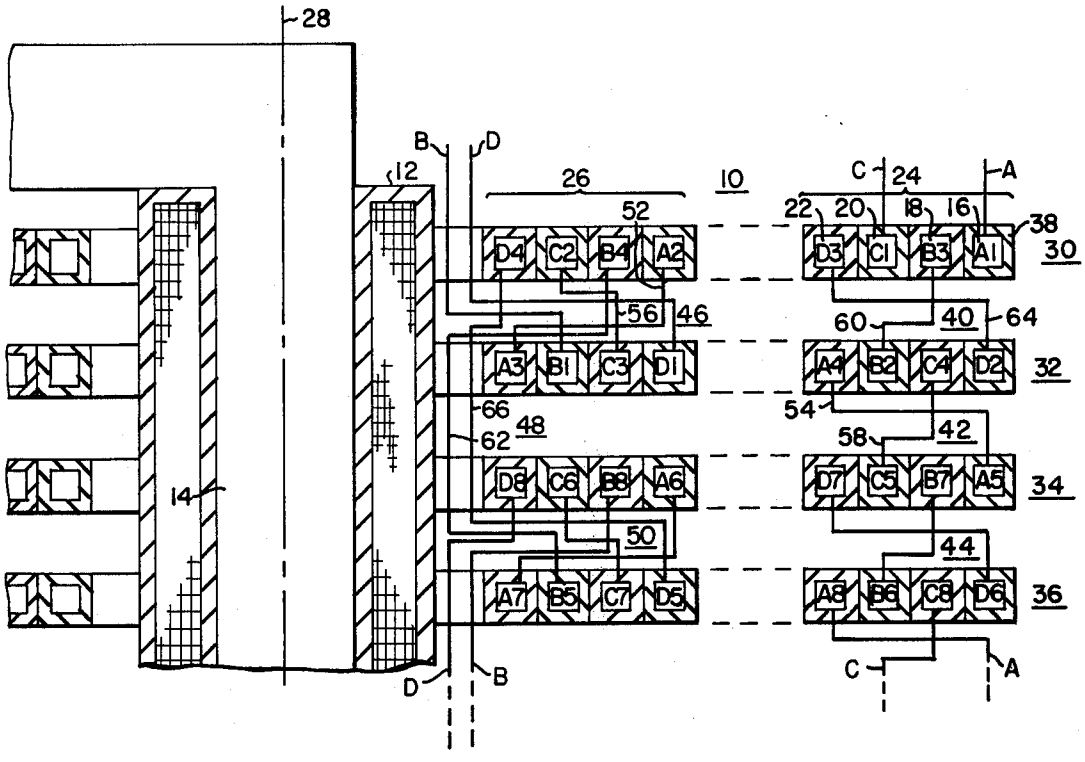
Attorney, Agent, or Firm—J. R. Hanway

[57] **ABSTRACT**

An interleaved-turn winding for electrical inductive apparatus. Four conduction paths through the windings are provided by interconnections between the coil disks of the winding. Two of the conduction paths begin at an upper coil disk and spiral inwardly toward the center of the winding. These paths are directed to the adjacent and lower coil disk by interconnecting leads and then progress outwardly through the adjacent coil disk. The other two conduction paths begin at the adjacent coil disk and spiral outwardly therethrough and then inwardly through the upper coil disk. High series capacitance is obtained by positioning a conduction path from one pair of conduction paths between the conduction paths of the other pair.

3 Claims, 2 Drawing Figures



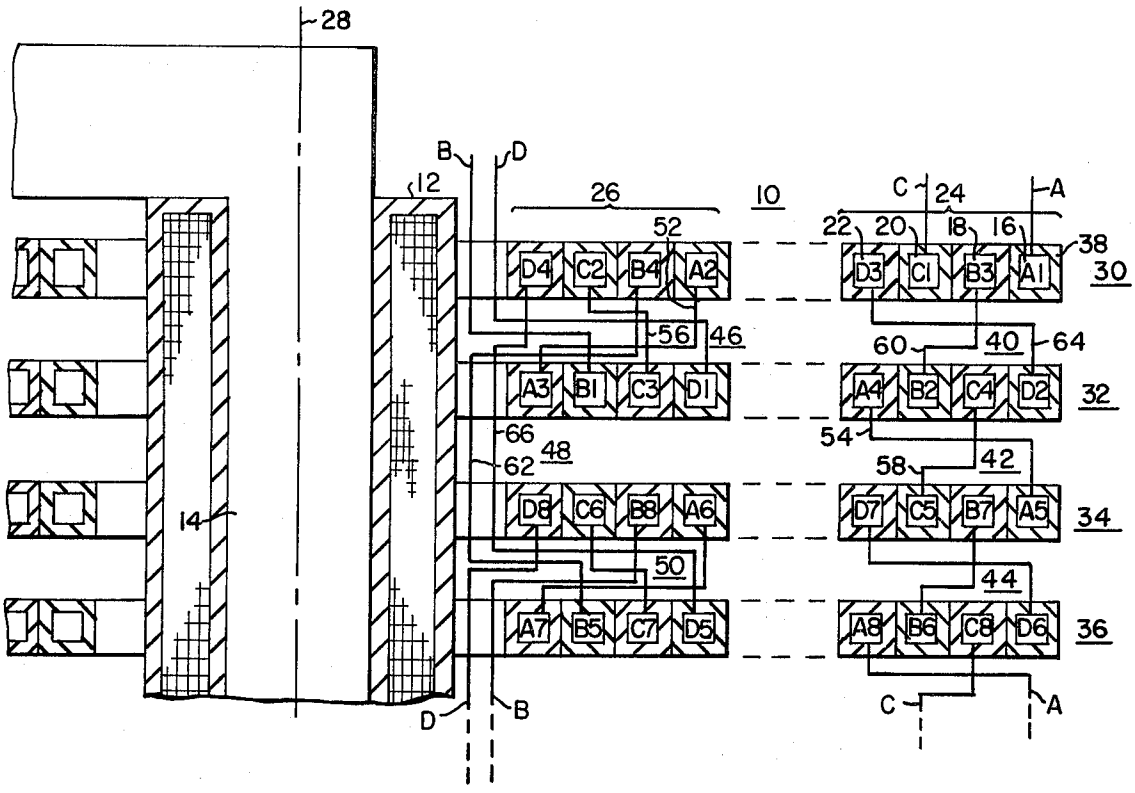

28
B
D
12
26
10
C
24
A
52
22
20
18
16
38
30
D4 C2 B4 A2
D3 C1 B3 A1
56
46
60
40
64
A3 B1 C3 D1
A4 B2 C4 D2
32
66
62
48
54
58
42
14
D8 C6 B8 A6
D7 C5 B7 A5
34
50
44
A7 B5 C7 D5
A8 B6 C8 D6
36
D
B
C
A

FIG. 1

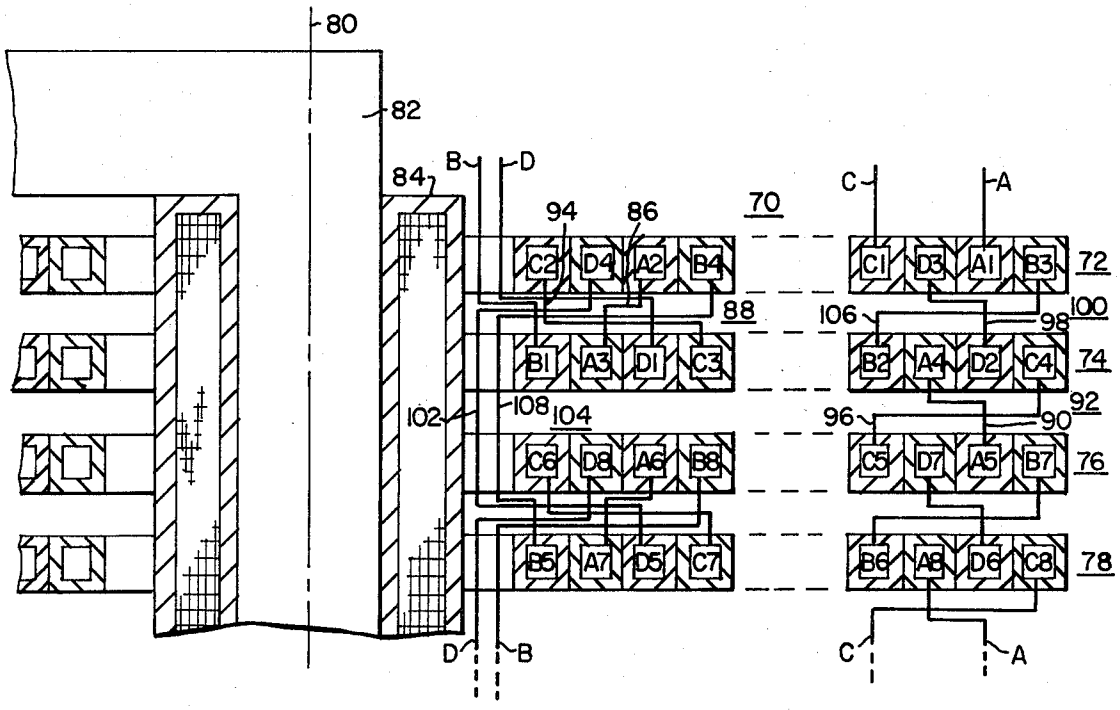

80
82
84
B
D
94
86
70
C
A
C2 D4 A2 B4
C1 D3 A1 B3
72
88
106
100
98
B1 A3 D1 C3
B2 A4 D2 C4
74
102
108
104
96
92
90
C6 D8 A6 B8
C5 D7 A5 B7
76
B5 A7 D5 C7
B6 A8 D6 C8
78
D
B
C
A

FIG. 2

FOUR-STRAND INTERLEAVED-TURN TRANSFORMER WINDING

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates, in general, to electrical inductive apparatus and, more specifically, to interleaved windings for power transformers.

2. Description of the Prior Art

When the current capacity of a transformer winding is relatively large, it is desirable to use several conductor strands instead of one large conductor. Multiple-strand conductors offer easier handling and lower eddy current losses than large single conductors. As a result thereof, most high-current transformer windings are constructed of multiple-strand conductors.

The use of interleaved winding arrangements to improve the surge or impulse strength of a winding is well known to those skilled in the winding art. However, in general, the winding development and construction requirements become more complicated as the number of strands increases. For this reason, use of interleaved arrangements with multiple-strand windings is somewhat restrained by the higher cost to construct such windings.

Two and three strand interleaved windings are relatively common and are being used in a variety of applications. Four-strand interleaved windings seem to approach the "trade-off" point between impulse strength and construction costs. Although a number of four-strand interleaved winding arrangements are known, there are particular disadvantages associated with each arrangement. A four-strand interleaved winding which offers improved impulse strength over conventional windings is disclosed in British Patent Specification No. 1,099,403. This winding requires the winding of eight strands simultaneously and a large number of lead bends and splices to interconnect the strands in various coil disks.

U.S. Pat. No. **3,299,385** discloses a four-strand interleaved winding which requires the winding of only four strands simultaneously. However, in some winding applications, it is desirable to have most of the leads, which interconnect the various coil disks, located on the inside of the winding near the winding tube rather than on the outside of the winding. Therefore, it is desirable and it is an object of this invention, to provide a four-strand interleaved winding which is relatively simple to construct and which has most of the interleaving connections located on the inside of the winding.

SUMMARY OF THE INVENTION

There are disclosed herein new and useful fourstrand interleaved windings which can be constructed by winding with only four conductor spools and which have the connections, which connect together non-adjacent coil disks, located on the inside of the winding.

The coil disks of each winding are connected together in such a manner that four conduction paths direct current through each winding. Two conduction paths begin at the outer turn of an upper disk and spiral inwardly through the upper coil disk. These conduction paths are then transferred to the inner turn of an adjacent coil disk where they spiral outwardly through the adjacent coil disk. The conduction paths then proceed

to other coil disks in the winding and spiral therethrough in a similar manner.

Two additional conduction paths begin at the inner turn of the adjacent coil disk, or first coil disk from the upper coil disk, and spiral outwardly through the adjacent coil disk. These conduction paths are then transferred to the outer turn of the upper coil disk where they spiral inwardly through the upper coil disk. These conduction paths are then transferred to other coil disks in the winding and spiral therethrough in a similar manner.

A conductor from one of the conduction paths is positioned radially between the conductors which form other conduction paths to provide the high series capacitance. In one embodiment, one conduction path begins at the outermost conductor location in the upper coil disk. In another embodiment, one conduction path begins at the conductor location which is radially adjacent to the outermost conductor location in the upper coil disk.

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 view of a four-strand interleaved-turn winding constructed according to one embodiment of this invention;

FIG. **2** is a view of a four-strand interleaved-turn winding constructed according to another embodiment of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

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

Referring now to the drawing, and to FIG. **1** in particular, there is shown a four-strand winding **10** of the interleaved-turn type. In this specific embodiment, the winding **10** is positioned around the insulated low-voltage winding **12** and the magnetic core leg **14.** The winding **10** may be represented in various other embodiments without departing from the scope of the invention. For example, the winding **10** could be a low-voltage winding located adjacent to a magnetic core leg rather than being a high-voltage winding.

The winding **10** consists of the strands or conductors **16, 18, 20** and **22** which form turns within the winding **10.** The turn **24** is an outer turn and the turn **26** is an inner turn. The conductors which form the turns **24** and **26** are grouped in the manner illustrated since all of the conductors of that turn are wound at the same time. This should not be confused with the electrical turns which progress through the winding **10.**

The conductors **16, 18, 20** and **22** are spirally disposed around the winding axis **28** to form the coil disks **30, 32, 34** and **36.** The winding **10,** including the portion not illustrated in FIG. **1,** is constructed by winding the four strand simultaneously on a suitable winding tube, "breaking down" and "rebuilding" every other coil disk, and making the proper interconnections and crossovers between the coil disks. Each conductor is individually insulated with conductor insulation to reduce eddy currents, such as the insulation **38** around the conductor **16.**

The coil disks **30, 32, 34** and **36** are interconnected by the finish-finish connections **40, 42** and **44,** and by the start-start connections **46, 48** and **50.** The interleaved pattern provided thereby can be determined by following the conduction paths which progress through the coil disks. The letters A, B, C and D are used to designate the four conduction paths through the winding **10.** The numbers associated with the letters at the conductor locations indicate the number of turns the conductor has made around the axis **28** and, therefore, the relative voltage induced therein. This identifying technique permits rapid observation about the theoretical potential difference between various conductor locations.

A first path A begins at location A1 and progresses inwardly to location A2. The identifying nomenclature is established assuming that the coil disks are wound with only two complete four-strand turns. It is emphasized that normally more turns would be included and that the invention is not limited to just two turns. The first path then proceeds across the lead **52** of the start-start connection **46** to the location A3 and then outwardly to the location A4. After the first path proceeds across the lead **54** of the finish-finish connection **42** to the location A5, the pattern of progression of the first path in the coil disks **34** and **36** is similar to that in the coil disks **30** and **32.**

A second conduction path C begins at location C1 and progresses inwardly to location C2. The second conduction path then proceeds across the lead **56** of the start-start connection **46** to the location C3 and then outwardly to the location C4. After the second conduction path proceeds across the lead **58** of the finish-finish connection **42** to the location C5, the pattern of progression of the second path in the coil disks **34** and **36** is similar to that in the coil diks **30** and **32.**

A third conduction path B begins at location B1 and progresses outwardly to location B2. The third path then proceeds across the lead **60** of the finish-finish connection **40** to the location B3 and then inwardly to the location B4. After the third conduction path proceeds across the lead **62** of the start-start connection **46** to the location B5 in the coil disk **36,** the pattern of progression of the third path in the coil disks **34** and **36** is similar to that in the coil disks **30** and **32.**

A fourth conduction path D begins at location D1 and progresses outwardly to location D2. The fourth path then proceeds across the lead **64** of the finish-finish connection **40** to the location D3 and then inwardly to the location D4. After the fourth conduction path proceeds across the lead **66** of the start-start connection **46** to the location D5 in the coil disk **36,** the pattern of progression of the fourth path in the coil disks **34** and **36** is similar to that in the coil disks **30** and **32.**

Another embodiment of the invention is illustrated in FIG. **2.** The winding **70** includes the coil disks **72, 74,** 76 and **78.** The coil disks are disposed around the coil axis **80,** the magnetic core leg **82,** and the low-voltage winding **84.** With the exception of the lead connections to and between the coil disks, the physical construction, and the possible variations thereof, are similar to those mentioned in describing FIG. **1.**

In the winding **70,** a first conduction path A begins at location A1 and progresses inwardly to location A2. The first path then proceeds across the lead **86** of the start-start connection **88** to the location A3 and then outwardly to the location A4. After the first path proceeds across the lead **90** of the finish-finish connection **92** to the location A5, the pattern of progression of the first path in the coil disks **76** and **78** is similar to that in the coil disks **72** and **74.**

A second conduction path C begins at location C1 and progresses inwardly to location C2. The second path then proceeds across the lead **94** of the start-start connection **88** to the location C3 and then outwardly to the location C4. After the second conduction path proceeds across the lead **96** of the finish-finish connection **92** to the location C5, the pattern of progression of the second path in the coil disks **76** and **78** is similar to that in the coil disks **72** and **74.**

A third conduction path D begins at the location D1 and progresses outwardly to the location D2. The third conduction path then proceeds across the lead **98** of the finish-finish connection **100** to the location D3 and then inwardly to the location D4. After the third conduction path proceeds across the lead **102** of the finish-finish connection **104** to the location D5 in the coil disk **78,** the pattern of progression of the third path in the coil disks **76** and **78** is similar to that in the coil disks **72** and **74.**

A fourth conduction path B begins at location B1 and progresses outwardly to location B2. The fourth path then proceeds across the lead **106** of the finish-finish connection **100** to the location B3 and then inwardly to the location B4. After the fourth conduction path proceeds across the lead **108** of the start-start connection **104** to the location B5 in the coil disk **78,** the pattern of progression of the fourth path in the coil disks **76** and **78** is similar to that in the coil disks **72** and **74.**

The interleaved windings disclosed herein exhibit high series capacitance together with large current carrying capability. The number of strands which must be wound simultaneously is less than that of many prior art arrangements. In addition, interleaving connections between non-adjacent coil disks are made on the inside of the winding where they can be conveniently located on the winding tube underneath the winding, thereby providing a strong and compact winding structure.

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. An interleaved winding for electrical inductive apparatus, comprising:

at least first and second coil disks disposed axially adjacent to each other, with each coil disk containing a plurality of conductors spirally disposed around a common axis to form at least inner and outer turns of the conductors;

start-start and finish-finish connections located between the coil disks to provide at least first, second, third and fourth conduction paths through the coil disks, said conduction paths being directed in a first radial direction when progressing towards said axis and in a second radial direction when progressing away from said axis;

said first and second conduction paths beginning at the outer turn of the first coil disk and progressing in the first direction through the first coil disk and

then in the second direction through the second coil disk;

said third and fourth conduction paths beginning at the inner turn of the second coil disk and progressing in the second direction through the second coil disk and then in the first direction through the first coil disk;

with said third conduction path being radially positioned, in the coil disks, between the first and second conduction paths;

said first coil disk being connected to a third coil disk in the winding by a start-start connection which is positioned under the inner turn of the second coil disk, said third coil disk being axially located in the winding with two coil disks between the first and third coil disks.

2. The interleaved winding of claim **1** wherein the first conduction path begins at the outermost conductor location in the first coil disk.

3. The interleaved winding of claim **1** wherein the fourth conduction path begins at the innermost conductor location in the second coil disk.

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