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McGill

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[54] **DISTRIBUTED TAPPED TRANSFORMER WINDING AND METHOD OF WINDING SAME**

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[52] **U.S. Cl.**..... **336/150,** 29/605, 336/180, 336/192

[51] **Int. Cl.**..... **H01f 21/12,** H01f 15/10

[58] **Field of Search**..... 336/150, 180, 192, 336/182; 29/605

[56] **References Cited**

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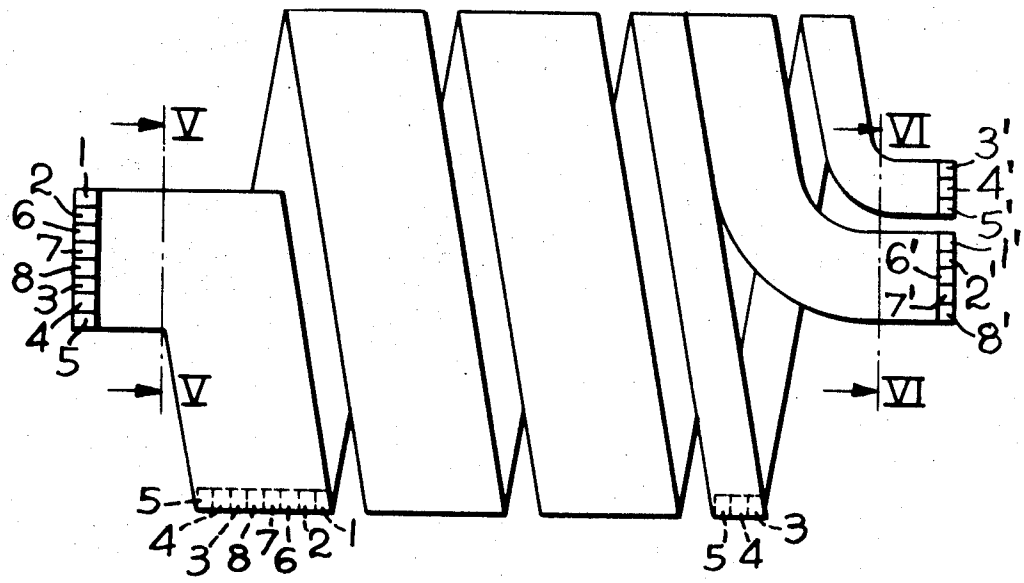
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Attorney—Robert C. Sullivan et al.

[57] **ABSTRACT**

A distributed tapped transformer winding in which some tap sections have $n+1$ winding turns while the remaining tap sections have n winding turns, and a method of winding said distributed tapped transformer winding which avoids undesirable cross-overs in bringing out the finish ends of the tap sections having n winding turns. In accordance with an embodiment of the invention, the conductors forming the tap sections having $n+1$ turns are positioned in the most "lagging" part of the winding bundel, relative to the direction of winding, and the conductors forming the tap sections having n winding turns are positioned in the "leading" part of the winding bundle. This arrangement permits the finish ends of the tap sections having n winding turns to be brought out for connection to a terminal board on the transformer without crossing over the turns of the tap sections having $n+1$ winding turns.

6 Claims, 6 Drawing Figures



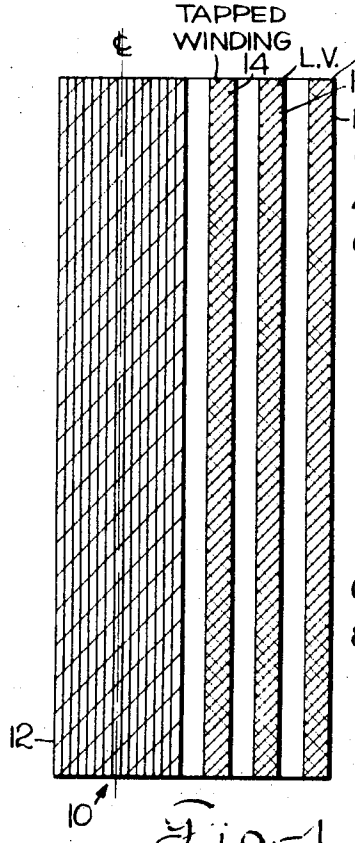


Fig. 1

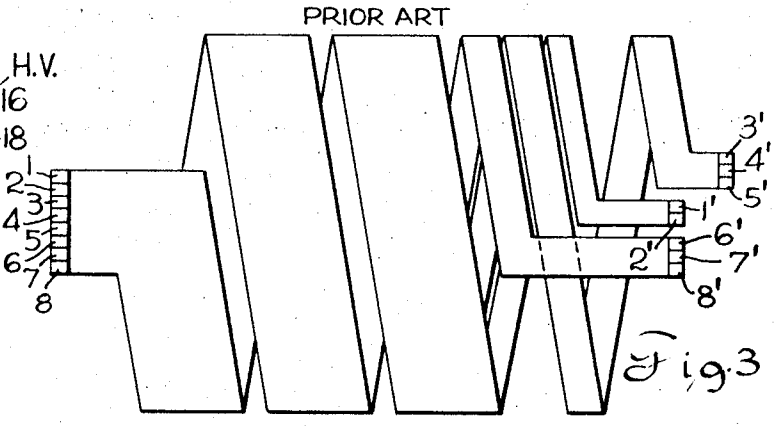


Fig. 3

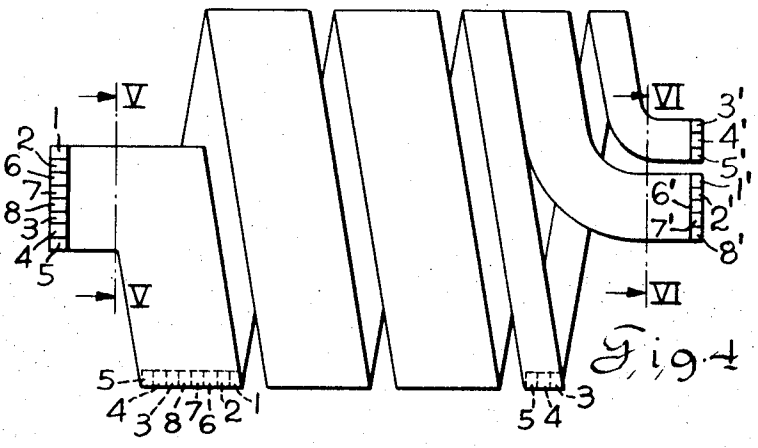


Fig. 4

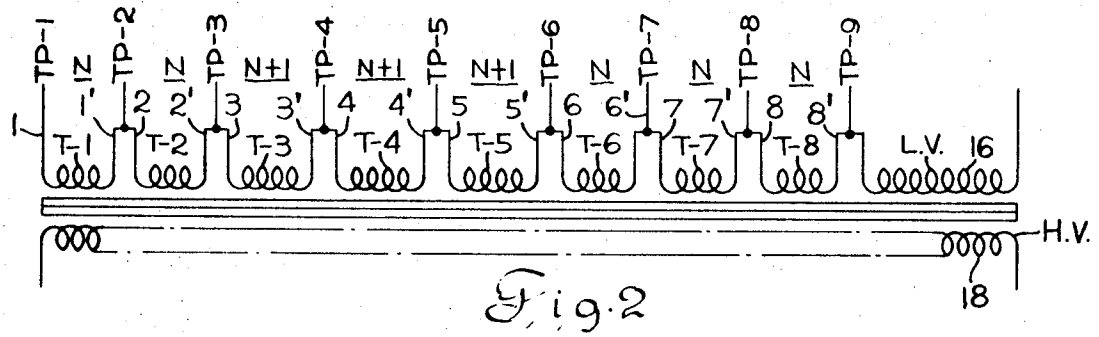


Fig. 2

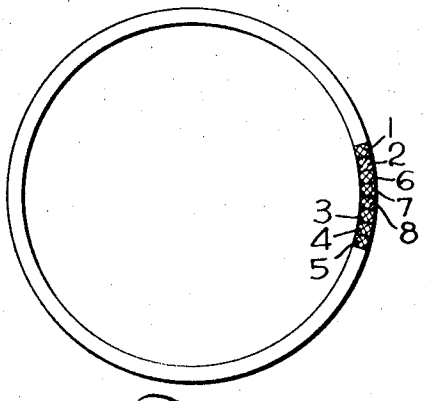


Fig. 5

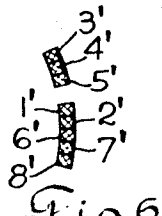


Fig. 6

DISTRIBUTED TAPPED TRANSFORMER WINDING AND METHOD OF WINDING SAME

FIELD OF THE INVENTION

This invention relates to distributed tapped transformer windings of the type in which some of the tap sections have one more turn than other tap sections, and to a method of winding such distributed tapped windings.

DESCRIPTION OF THE PRIOR ART

In distributed tapped transformer windings it is sometimes desirable that one or more of the tap sections of the tapped winding have one more winding turn than other tap sections of the same tapped winding. In the prior art constructions and methods of winding distributed tapped transformer windings, if the conductor or conductors corresponding to the tap section or sections having one less turn than other tap sections were located at what might be called a "lagging" position in the winding bundle relative to the conductors having one more winding turn, then the problem was presented that the conductors in the "lagging" position in the winding bundle and having one less turn were required to cross over the "leading" conductors in the winding bundle and having one more turn in order to be brought out for connection to a terminal board on the transformer. This cross-over by the conductors of the winding of the tapped winding sections having one less turn in undesirable for several reasons, including the fact that the cross-over undesirably increases the radial build of the transformer winding. Furthermore, the prior art practice required that the "cross-over" portions of the conductors having one less turn be cut and brazed to their corresponding conductors since the conductors are generally too thick to be bent into the "cross-over" position. This step adds to the cost and complexity of the prior art construction and method.

STATEMENT OF THE INVENTION

Accordingly, it is an object of the present invention to provide an improved winding arrangement and method of winding a distributed tapped transformer winding in which one or more of the tap sections of the distributed winding have one more winding turn than other tap sections of the distributed winding; or, conversely, in which one or more of the tap sections has one less winding turn than other tap sections of the tapped winding, and without undesirable cross-over of the conductors having n winding turns relative to the conductors having $n+1$ winding turns, as has occurred in the prior art practice.

It is another object of the invention to provide an improved winding arrangement and method of winding a distributed tapped transformer winding in which one or more of the tap sections have one more winding turn than other tap sections of the distributed winding and which winding arrangement and method is less complicated and less costly than the prior art winding arrangement and method.

In achievement of these objectives, there is provided in accordance with an embodiment of the invention a distributed tapped transformer winding in which some tap sections have $n+1$ winding turns while the remaining tap sections have n winding turns, and a method of winding said distributed tapped transformer winding which avoids undesirable cross-overs in bringing out the finish ends of the tap sections having n winding turns. In accordance with an embodiment of the invention, the conductors forming the tap sections having $n+1$ turns are positioned in the most "lagging" part of the winding bundle, relative to the direction of winding, and the conductors forming the tap sections having n winding turns are positioned in the "leading" part of the winding bundle. This arrangement permits the finish ends of the tap sections having n winding turns to be brought out for connection to a terminal board on the transformer without crossing over the turns of the tap sections having $n+1$ winding turns.

BRIEF DESCRIPTION OF THE DRAWINGS

Further objects and advantages of the invention will become apparent from the following description taken in conjunction with the accompanying drawing in which:

FIG. **1** is a diagrammatic view of a typical transformer having a distributed tapped winding, showing the orientation of the tapped winding relative to the transformer and to the other windings of the transformer;

FIG. **2** is a diagrammatic view of the tapped winding showing the electrical relation of the plurality of tap sections of the winding relative to each other; the windings shown in FIG. **2** could represent the windings of a single phase transformer, or alternatively, one phase of a three-phase transformer;

FIG. **3** is a diagrammatic view showing the prior art practice method of winding a tapped winding of the type in which some of the tap sections have one more turn than other of the tap sections;

FIG. **4** is a diagrammatic view showing the method of the present invention of winding a distributed tapped winding in which one or more of the tap sections have one more turn than other tap sections;

FIG. **5** is a view taken along section line V—V of FIG. **4** showing the "start" ends of the tap sections being brought out for connection to a terminal board on the transformer; and

FIG. **6** is a view taken along section line VI—VI of FIG. **4** showing the "finish" ends of the tap sections being brought out for connection to a terminal board on the transformer.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. **1**, there is a diagrammatic cross section of a transformer generally indicated at **10** including a magnetic core **12**, and a tapped winding generally indicated at **14** coaxially positioned about and radially outwardly of the magnetic core **12**. Suitable insulating spacers (not shown) are interposed between the tapped winding **14** and the magnetic core **12**. A low voltage winding **16** is coaxially positioned about and radially outwardly of the tapped winding **14**, and a high voltage winding **18** is coaxially positioned about and radially outwardly of the low voltage winding **16**. Suitable insulating spacers (not shown) are positioned between the tapped winding **14**, the low voltage winding **16** and the high voltage winding **18**.

It will be noted that the tapped winding **14** extends for the entire axial length of the transformer windings. The tapped winding **14** in the illustrated embodiment is part of the low voltage windings and is connected in

series with the untapped low voltage winding **16** at the transformer terminal board.

Distributed tapped windings of the type herin described are normally connected in series with the low voltage winding; however, if properly insulated and having other proper parameters, a distributed tapped winding could be connected in series with an untapped high voltage winding.

While not restricted thereto, the winding and method of winding hereinbefore described would be used primarily on a core-form transformer, single phase or three phase. If applied to a three-phase transformer the windings shown in FIGS. **1** and **2** would be repeated for each of three phases.

The tapped winding **14** is a single layer winding helically wound on suitable support such as an insulating cylinder and includes a plurality of tap sections, each of which is wound along the entire axial length of the tapped winding **14** with the exception that certain of the tap sections, as will be explained hereinafter, may have one more winding turn than the other tap sections.

As best seen in the schematic diagram of FIG. **2**, it is assumed for purposes of illustration that there are eight tap sections respectively identified as **T-1**, **T-2**, **T-3**, etc., through **T-8** inclusive. It is assumed also that tap sections **T-1**, **T-2**, **T-6**, **T-7** and **T-8** each have *n* winding turns; whereas tap sections **T-3**, **T-4** and **T-5** have *n*+1 turns. As best seen in FIG. **2**, each of the tap sections is provided with a start end and finish end, thus tap section **T-1** has a start end **1** and a finish end **1'**; tap section **T-2** has a start end **2** and a finish end **2'**; and similarly, each of the other tap sections has a start end and a finish end such as **3-3'** respectively, **4-4'** respectively, through **8-8'**, respectively, the unprimed number being the start end of each respective tap section and the primed number being the finish end of each respective tap section. The plurality of tap sections **T-1** through **T-8**, inclusive, are connected in series with each other at a terminal board provided on the transformer. Thus, at the transformer terminal board finish end **1'** of tap section **T-1** is connected to start end **2** of tap section **T-2**, and finish end **2'** of tap section **T-2** is connected to start end **3** of tap section **T-3** and so forth. The plurality of tap sections **T-1** through **T-8**, inclusive, are connected in series with each other in numerical order as best seen in the schematic diagram of FIG. **2**, and the finish end **8'** of tap section **T-8** is connected to start end of the low voltage winding **16** as seen in FIG. **2**. Taps connected to the stationary contacts of a tap changer switch or the like are provided as shown in the schematic diagram of FIG. **2**. Thus, the start end **1** of tap section **T-1** becomes tap lead **TP-1**; a second tap lead **TP-2** is connected to a junction between the finish end **1'** of tap section **T-1** and the start end **2** of tap section **T-2**; a tap lead **TP-3** is connected to a junction between the finish end **2'** of tap section **T-2** and the start end **3** of tap section **T-3**, etc. Thus a total of nine tap leads identified as **TP-1** through **TP-9** inclusive appear in the diagrammatic sketch of FIG. **2**.

Refer now to FIG. **3** which shows the problem presented by the prior art distributed tapped winding arrangement and method of winding where it is desired that certain of the tap sections such as tap sections **T-3**, **T-4** and **T-5** have one more winding turn than the other tap sections. In the assumed embodiment in which there are eight separate tap sections, the winding bundle from which the tap sections are wound consists of eight conductors numbered **1** through **8** inclusive. In the example of FIG. **3** which is illustrative of the prior art practice the conductors **1** through **8**, inclusive, which correspond to the tap sections **T-1** through **T-8**, inclusive, are arranged in numerical order within the winding bundle. That is, conductor No. **1** which ultimately becomes tap section **T-1** is in what might be defined as the "leading" position in the winding bundle with respect to the direction of winding, and the conductor No. **8** which ultimately becomes tap section **T-8** is at what might be defined as the most "lagging" position in the bundle relative to the direction of winding, with all of the conductors **1** through **8**, inclusive, being arranged in numerical sequence in the winding bundle. It is assumed that the direction of winding starts from the left-hand end of the view of FIG. **3** at which point all of the start ends **1** through **8**, inclusive, begin at substantially the same angular winding position, with the winding progressing toward what might be defined as the "finish" end at the right-hand end of the view of FIG. **3** at which certain of the conductors namely **3**, **4** and **5** corresponding to tap sections **T-3**, **T-4** and **T-5** respectively, have been wound one more turn than the remaining conductors **1**, **2**, **6**, **7** and **8** corresponding to the similarly numbered tap sections.

To simplify the assignment of reference numerals, the conductors which form the various tap sections will be referred to by the same reference numerals as the numeral for the start end of the respective tap section. Thus, for example, tap section **T-1** is formed by conductor **1** having start end **1** and finish end **1'**.

It will be noted from an examination of FIG. **3** that due to their "lagging" position in the winding bundle of numerically arranged conductors in accordance with the prior art practice, the conductors **6**, **7** and **8** which have *n* turns must, in having their "finish" ends **6'**, **7'** and **8'** brought out at the finish end of the tapped winding structure for connection to a terminal board, of necessity, cross over and thus radially overlay the conductor turns **3**, **4** and **5** which are carried through one additional winding turn. The finish ends **1'** and **2'** of conductors **1** and **2** which have *n* turns due to their "leading" position in the winding bundle do not cross over the turns **3**, **4** and **5**.

It can be seen that the cross-over by the conductors **6**, **7** and **8** relative to the conductors **3**, **4** and **5** in bringing the finish ends of conductors **6**, **7** and **8** out to the terminal board is undesirable since it increases the radial build of the distributed tapped winding structure and thus of the transformer, and also requires cutting and brazing of the ends of the conductors which cross over, as previously explained.

Referring now to FIG. **4**, there is diagrammatically shown the winding arrangement for distributed tapped windings in accordance with the present invention in which some of the tapped winding sections have one more turn than other winding sections. Thus, referring to FIG. **4**, there is shown a bundle of conductors which are helically wound in side-by-side relation in a single layer about an insulating drum or the like, and including conductors **1–8**, inclusive, which respectively correspond to the tap sections **T-1** through **T-8** inclusive, of the view of FIG. **2**. As in the previous example of FIG. **3**, tap sections **3**, **4** and **5** are to have *n*+1 turns each and tap sections **1**, **2**, **6**, **7** and **8** are each to have *n* turns. In accordance with the present invention, the

conductors which form the tap sections having $n+1$ turns, namely conductors **3, 4** and **5,** are placed in the most "lagging" position in the winding bundle and the conductors which are to form the tap sections having n turns are positioned in the "leading" part of the winding bundle relative to the direction of winding. As in the previous example in FIG. **3,** it is assumed that the tapped winding is wound starting at the left-hand end of the view of FIG. **4** at which all of the start ends of the tap sections **T-1** through **T-8,** inclusive, start at substantially the same angular position (within the limits imposed by having the plurality of conductors, together with any necessary insulation, lie in side-by-side relation in a one-layer winding; and the expression "substantially the same angular position" as used in the specification and claims is to be interpreted in this light). The winding terminates at the right-hand end of the view of FIG. **4** in which certain of the tap sections and the "finish" ends thereof have advanced through one additional turn, namely finish ends **3'**, **4'** and **5'**, as compared to certain of the other tap sections which have only n turns, namely, tap sections **T-1, T-2, T-6, T-7** and **T-8.**

Thus, in examining FIG. **4,** it will be noted that the conductors are arranged in the following order reading from the most "leading" end of the winding bundle (the right-hand end in FIG. **4**) to the most "lagging" end thereof (the left-hand end in FIG. **4**): **1, 2, 6, 7, 8, 3, 4, 5.** Thus it will be noted that conductors **3, 4** and **5** which when wound from the tap sections **T-3, T-4** and **T-5** having one more winding turn are positioned at the most "lagging" end of the winding bundle relative to the direction of winding.

After the completion of n winding turns, the group of conductors having the "finish" ends **1'**, **2'**, **6'**, **7'** and **8'** — that is, the group of conductors having n turns, is "peeled off" without the necessity of crossing over the remaining conductors **3, 4** and **5** and the conductors **3, 4** and **5** can continue for one more winding turn to thereby complete $n+1$ turns without any cross-overs of the conductors having $n+1$ turns by the conductors having n turns having occurred as occurs in the case of the prior art embodiment of FIG. **3.** The reason the cross-overs are avoided by the present invention is the fact that the conductors which have n turns are positioned at the "leading" part of the winding bundle and thus can be "peeled off" without crossing over any of the conductors having $n+1$ turns, the conductors having $n+1$ turns being positioned in a "lagging" position in the bundle relative to the direction of winding.

The "start" and "finish" ends of the various tap sections **TP-1** through **TP-8,** inclusive, as wound in accordance with the method shown in FIG. **4** are then brought out in a generally axial direction to a terminal board on the transformer and the plurality of tap sections are connected in series relation with each other in the same manner as shown in the diagrammatic sketch of FIG. **2.** The avoidance of cross-overs by the winding arrangement and method of winding of the present invention has various advantages, including the fact that the avoidance of the cross-overs of the prior art such as illustrated in the prior art illustration of FIG. **3,** permits the transformer to be built with a smaller radial build than in the case of the prior art arrangement and method and without the necessity of cutting and brazing the ends of the conductors which cross over, thereby providing a less complicated and less expensive construction and method than the prior art.

In winding the distributed winding of the present invention, it is necessary to place additional insulation between conductors **2** and **6** and between conductors **8** and **3** of the illustrated embodiment along the entire length of the winding, due to the voltage difference between those conductors. However, the distributed tapped winding of the prior art also required insulation between certain conductors.

It might be noted that, particularly in the end turns of the distributed winding, such as the finish turns of the tap sections **3, 4** and **5** which have $n+1$ winding turns, that such winding turns while a complete "electrical turn" are not necessarily a complete 360° mechanical turn, since a complete "electrical turn" is defined as a winding turn which has completed the magnetic circuit through the magnetic core, as would be obvious to one skilled in the art. Hence the term "winding turn" as used in the claims or in the specification is intended to include complete "electrical turns" which may not necessarily be complete 360° mechanical turns.

While the distributed tapped transformer winding has been described and illustrated as being embodied in a single layer winding, it is within the scope of the invention to provide a distributed tapped transformer winding having a plurality of radially superposed winding layers, with one or more layers being wound in accordance with the principles hereinbefore described where it is desired that some tap sections in a certain layer or layers have n winding turns and that other tap sections in the given layer or layers have $n+1$ winding turns. The particular conductors having n turns and $n+1$ turns may vary in the different winding layers.

From the foregoing detailed description of the invention it has been shown how the objects of the invention have been obtained in a preferred manner. However, modifications and equivalents of the disclosed concepts such as readily occur to those skilled in the art are intended to be included within the scope of this invention.

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

1. A distributed tapped transformer winding comprising a plurality of tap sections each comprising winding turns distributed along a substantial part of the axial length of the tapped winding, at least one of said tap sections having one more winding turn than other tap sections, each tap section being wound from a corresponding conductor, the plurality of conductors corresponding to the plurality of tap sections being arranged in a winding bundle, said winding bundle being wound from one end of said tapped winding toward the opposite end of said tapped winding to form a single layer winding in which the conductor turns within the winding bundle are arranged in accordance with a predetermined sequence which differs from the sequence in the distributed tapped winding of the tap sections to which the respective conductors correspond, all of the conductor turns of the bundle starting at substantially the same angular position at said one end and progressing toward an opposite end at which the said at least one conductor corresponding to said at least one of said tap sections is wound through one more winding turn than the remaining conductors, the at least one conductor

corresponding to the at least one tap section have one more winding turn being positioned at the "lagging" position in the bundle relative to said direction of winding, the remaining conductors corresponding to the remaining tap sections being positioned at the "leading" end of the bundle, whereby the ends of said remaining conductors may be brought out at said opposite end for connection to a terminal board or the like without crossing over the said at least one conductor corresponding to said at least one tap section having one more winding turn.

2. A distributed tapped transformer winding as defined in claim **1** in which said plurality of tap sections are connected in series with each other at a terminal board.

3. A distributed tapped transformer winding as defined in claim **1** which is part of the low voltage windings of the transformer and is connected in series with an untapped low voltage winding.

4. A distributed tapped transformer winding as defined in claim **1** which is part of the high voltage windings of the transformer and is connected in series with an untapped high voltage winding.

5. A distributed tapped transformer winding as defined in claim **1**, comprising a plurality of radially superposed winding layers, at least one of said winding layers being wound in the manner of the single layer winding described in claim **1**.

6. The method of winding a single layer distributed tapped transformer winding of the type having a plurality of tap sections and in which at least one of said tap sections has $n+1$ winding turns while the remainder of said tap sections each respectively have n winding turns, comprising the steps of:

a. arranging a plurality of electrical conductors in a winding bundle, with each of said conductors corresponding to and forming when wound a particular one of said tap sections; said conductors being positioned in a sequence in said bundle which differs from the sequence in the distributed tapped winding of the tap sections to which the respective conductors correspond;

b. positioning the at least one of said conductors corresponding to the at least one of said tap sections having $n+1$ winding turns at the most lagging part of the winding bundle relative to the direction of winding;

c. positioning the conductors corresponding to the remainder of said tap sections which have n winding turns at the leading part of the winding bundle relative to the direction of winding;

d. winding said bundle helically from one end of said distributed winding at which the ends of said plurality of tap sections all start at substantially the same angular position toward an opposite end at which the said at least one conductor corresponding to the said at least one tap section having $n+1$ winding turns is wound through one more winding turn than the said remaining conductors;

e. at the end of n winding turns from said one end "peeling" off from said winding bundle for connection to the terminal board of the transformer the conductors corresponding to the remainder of said tap sections which have n winding turns;

f. at the end of n winding turns from said one end, continue to wind through one additional winding turn the said at least one conductor corresponding to the said at least one tap section having $n+1$ winding turns.

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