Oct. 21, 1969 C. J. LAMBERTON 3,474,326

TAP CHANGING APPARATUS FOR INDUCTIVE WINDINGS

Filed Jan. 27, 1967 2 Sheets-Sheet 1

Fig. 1. (PRIOR ART)

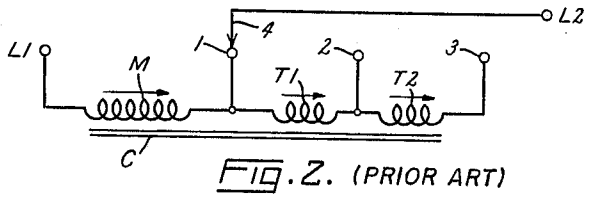


Fig. 2. (PRIOR ART)

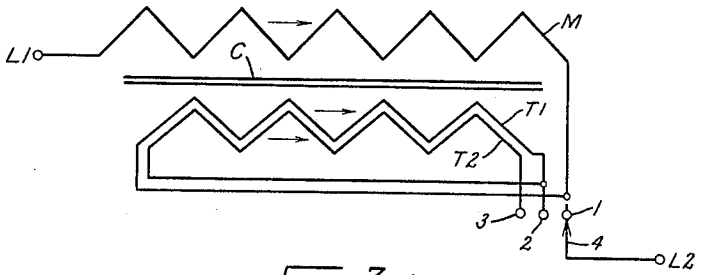


Fig. 3. (PRIOR ART)

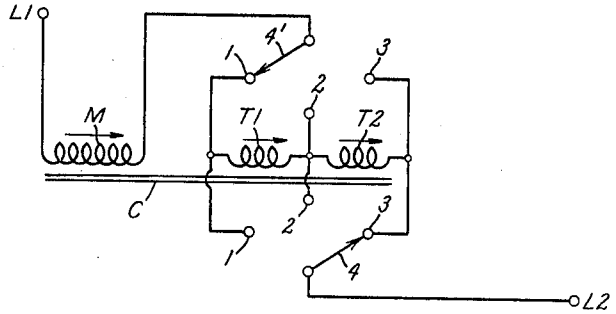
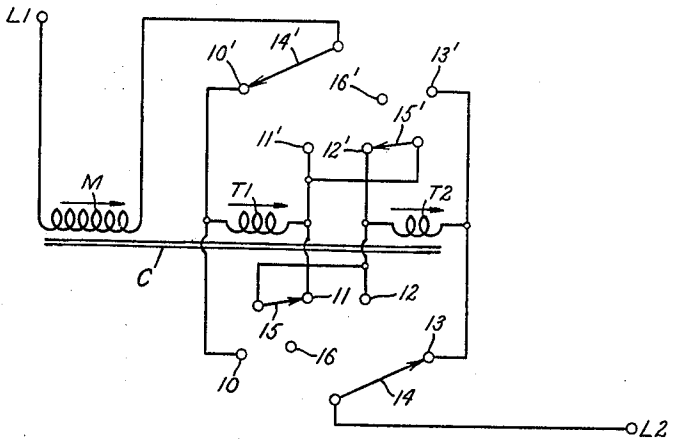


Fig. 4.



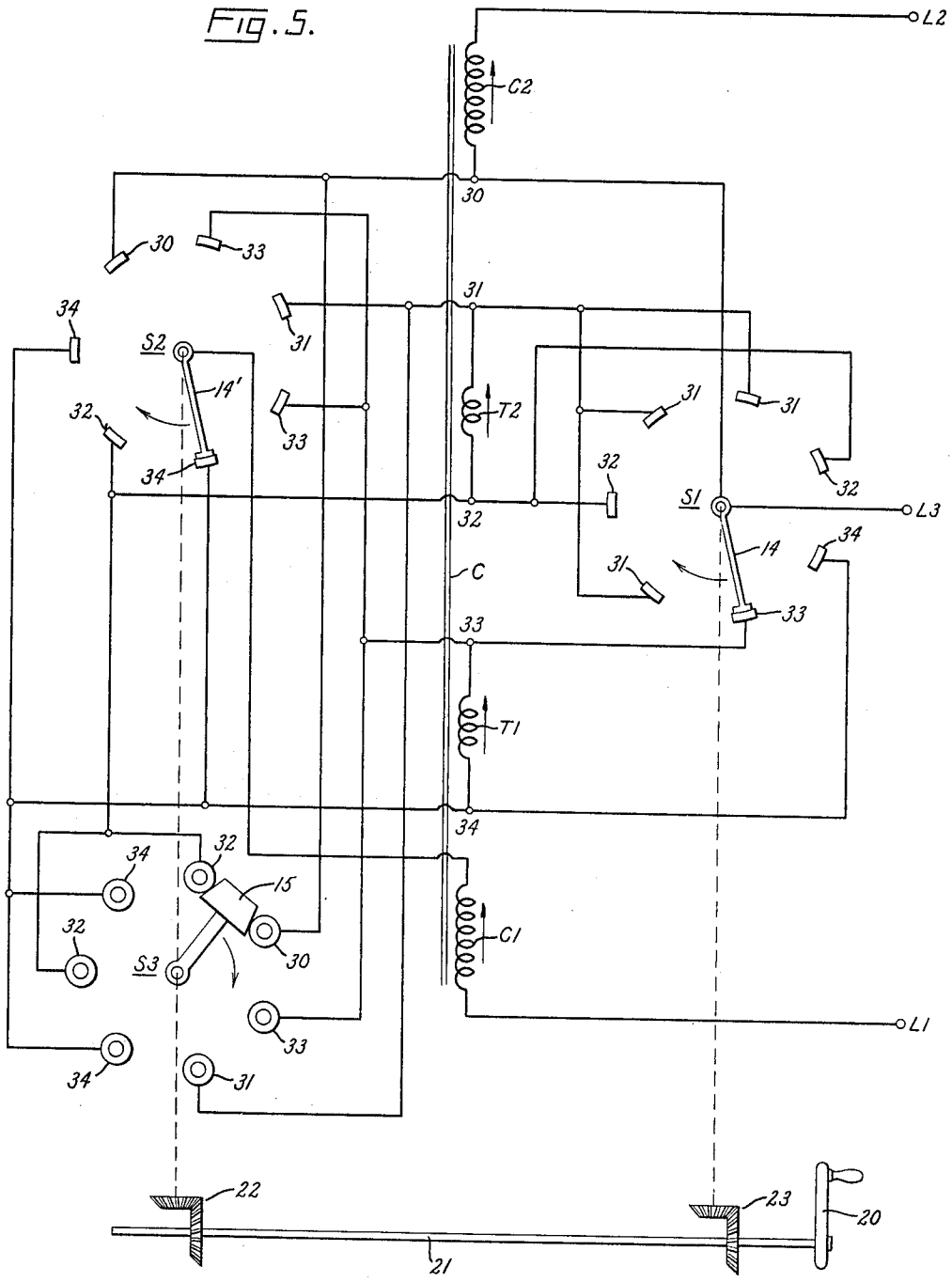
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TAP CHANGING APPARATUS FOR INDUCTIVE WINDINGS

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Fig. 5.



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3,474,326

TAP CHANGING APPARATUS FOR INDUCTIVE WINDINGS

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U.S. Cl. 323—43.5
11 Claims

ABSTRACT OF THE DISCLOSURE

A tap changing apparatus for an inductive electric winding in which one or more pairs of tap sections providing unequal incremental voltages are switched in a variety of buck and boost series circuit relations to provide voltage variation in small steps measured by the voltage difference between tap sections of each pair.

BACKGROUND

My invention relates to electric induction apparatus, and particularly to inductive windings provided with tap sections for voltage variation. The invention concerns selectable connection of such tap sections, and is especially applicable to variable ratio transformers of either the isolated secondary or autotransformer type.

While my invention is applicable to both disk type and layer type windings, it is convenient to illustrate the objectives and advantages of the invention by considering briefly the prior practice in winding and connecting tap sections of a helical layer-type winding. In such a winding to sections, whether they be at one end or immediate the ends of the winding, are commoniy interwound in one or more winding layers. By this is meant that the tap sections in any layer are wound in physically parallel relation with each other, the ends of each tap section being brought out of the winding by leads to tap contacts. In such a winding the tap sections are commonly connected permanently in series circuit relation so that unused taps are left open-circuited at one end. Because of the interwound positioning of the tap sections, voltage difference between electrically remote but physically adjacent ends of such sections is considerably greater than the turn-to-turn voltage of the main winding turns. This voltage difference and the consequent stress on turn insulation increases in proportion to the number of interwound tap sections. Also, by simple cut out of series-connected tap sections, the unused sections are left to contribute to inductive energy loss in the winding.

It is therefore desirable to minimize the number of tap sections and to utilize each section in a current conducting circuit disposition to the fullest extent possible. This has been done to some extent in the past by utilizing some or all of the tap sections selectably in buck or boost relation of the main winding. In this way the number of tap sections required is reduced to about half of that required in a single-ended series connection. In some cases, however, it is desirable to provide for very small incremental tap voltages, such as voltage variations measured in terms of a single winding turn. To provide such fine adjustment by even buck-boost use of tap sections would require a large number of sections, tap leads and tap contacts. To provide a large number of single-turn tap sections is bulky and expensive, and single-turn tap sections are difficult to wind. By my invention such fine voltage variation is obtainable from a smaller number of larger tap sections.

It will be understood from the foregoing that when I refer herein to a "tap section" of an inductive winding I

mean to identify a portion of the winding extending electrically between immediately adjacent tap contact leads or connections, there being no intermediate tap lead or tap contact connected to such "section." An electrically adjacent pair of such tap sections, of course, ordinarily has one tap lead and associated tap contact in common therebetween.

SUMMARY

Accordingly, it is a principal object of my invention to provide an improved tap changing apparatus for inductive electric winding.

It is a more particular object of my invention to provide a tap changing system and apparatus for inductive windings which permit voltage variation in incremental steps smaller than any single tap section, and employs a minimum number of tap sections for any predetermined range of voltage variation.

In carrying out my invention in one preferred embodiment, I provide a transformer comprising a magnetizable core and winding, the winding including a main winding portion and at lesat two interwound tap sections and the tap sections having unequal numbers of turns. Preferably, the turns of the two tap sections differ by only a single turn, and each tap section itself has only a small number of turns, as two turns and three turns, respectively. Each tap section is electrically separable from the other and is provided with discrete tap leads at each end thereof. By suitable switching means a variety of connections is made available so that each of the two tap sections may be separately connected in series with the main winding in either aiding or opposing voltage relation, the tap sections may be connected in mutually opposing voltage relation in either net-aiding or net-opposing voltage relation with the main winding, both tap sections may be connected in mutally aiding voltage relation to provide either a net-aiding or a net-opposing voltage relation with the main winding, or both tap sections may be bypassed entirely.

My invention will be more fully understood and its various objects and advantages further appreciated by referring now to the following detailed specification taken in conjunction with the accompanying drawing in which:

DRAWINGS

FIG. 1 is a schematic circuit diagram of any inductive electric winding provided with two series-connected tap sections;

FIG. 2 is a diagrammatic representation of a layer-type winding having interwound tap sections electrically connected as in FIG. 1;

FIG. 3 is a schematic circuit diagram of an inductive electric winding having two tap sections selectably connectable in either aiding or opposing voltage relationship with the main winding;

FIG. 4 is a schematic circuit diagram of an inductive winding having a pair of unequal tap sections variously connectable in aiding or opposing voltage relation to provide a range of voltage variation in substantially uniform, small incremental steps in accordance with my invention; and

FIG. 5 is a schematic circuit diagram of a tapped inductive winding similar to that shown at FIG. 4 and including interconnected switching means for accomplishing the tap connections principally characteristic of my invention.

DESCRIPTION

Referring now to the drawing, I have shown at FIG. 1 a schematic representation of an inductive electric winding, such as a transformer winding, connected between a pair of line terminals L1 and L2 and comprising a main

winding section M and two series-connected tap sections T1 and T2 wound upon a magnetizable core C. In a manner well known to the prior art, the tap sections T1 and T2 are permanently connected in series circuit relation with each other and with the main winding, and tap leads from the end of each section are brought out to tap contacts 1, 2 and 3, the center contact 2 being common to the connected ends of the tap sections T1 and T2. A movable tap selector contact 4 is provided to connect the line terminal L2 to any selected one of the tap contacts.

At FIG. 2, I have illustrated diagrammatically the manner in which a tap winding, such as that shown at FIG. 1, may be wound in layer configuration on the core C. At FIG. 2 the tap sections are shown axially interwound in one layer of the winding and the main winding portion M is in an adjacent layer. Correspondence of the parts of FIG. 3 to those of FIG. 2 is indicated by use of the same reference numerals. It is of course possible, if desired, to interwind the tap sections both mutually and in one or more main winding layers.

At FIG. 3, I have illustrated a previously known arrangement in which an inductive winding M, provided with a pair of incremental voltage tap sections T1 and T2 and wound on a magnetizable core C, may be connected to utilize either or both of the tap sections in either aiding or opposing relation with respect to the main winding portion M. The tap sections T1 and T2 of FIG. 3 are permanently connected in series circuit relation with each other, and two multi-position tap selector contacts 4 and 4' are provided. The selector contact 4 connects the tap sections to the line terminal L2 as in FIGS. 1 and 2. The selector contact 4' is interposed between the tap sections and the main winding portion M. To this end two sets of tap contacts 1, 2 and 3 are provided, one set cooperating with the movable contact 4, and the other cooperating with the movable contact 4'.

It will be understood by those skilled in the art that, if desired, the movable tap selector contacts 4 and 4' of FIG. 3 may be interconnected for simultaneous stepping movement in opposite directions from the positions shown in the drawing. Alternatively, movable contacts 4 and 4' may be independently actuated to connect the tap sections T1 and T2 in a variety of selectable combinations between line terminal L2 and main winding portion M. For example, in the position of that selector contacts 4 and 4', shown at FIG. 3, both tap sections T1 and T2 are connected in series circuit relation with the winding portion M. As indicated by directional arrows, the sections T1 and T2 when connected may be assumed to be in voltage-aiding relation with winding M and with each other. If the contact member 4 is now moved to tap contact 2, the tap section T2 is bypassed or cut out of the circuit, while the tap section T1 remains in circuit. By now moving the switch member 4' to its associated tap contact 2, both of the tap sections are disconnected from the series circuit between L1 and L2. If now the switch member 4 is moved from its tap contact 2 to its tap contact 1, the tap section T1 is re-inserted in the series circuit in an opposite sense so that it is in opposing voltage relation with the main winding portion M. Finally, if the switch member 4' is now moved to its tap contact 3, both of the tap sections T1 and T2 are again in circuit in aiding voltage relation with each other but in voltage opposition to the main winding portion M.

It will now be evident that the tap circuit of FIG. 3 may be utilized to connect either one or both of the tap sections in either aiding or opposing voltage relationship with the main winding M. As this circuit of FIG. 3 has been previously known and used, however, both of the tap sections T1 and T2 provide equal incremental voltages so that no voltage steps are obtainable in a magnitude less than the voltage magnitude of a single tap section.

Referring now to FIG. 4, I have illustrated an embodiment of my invention wherein an inductive winding on the core C comprising a main portion M and a pair of tap sections T1 and T2 may be selectably connected between line terminals L1 and L2 in a variety of series circuit combinations such that the tap sections are utilized in either aiding or opposing voltage relation with respect to the main winding portion M. These tap sections are so proportioned relative to each other that substantially equal incremental voltage steps having a magnitude less than the voltage of either tap section are obtainable over a range of voltage both above and below the voltage of the main winding portion itself. For this purpose the tap sections T1 and T2 are wound with different numbers of turns or are otherwise arranged to provide between their ends unequal incremental voltages. Each tap section is connected at each end to discrete tap contacts, so that neither tap section is permanently connected to the other tap section or to the main winding portion.

At FIG. 4, one end of tap section T1 is connected to a pair of electrically connected contacts 10, 10', and the other end of tap section T1 is connected to a pair of electrically connected tap contacts 11 and 11'. Similarly, one end of tap section T2 is connected to a discrete pair of electrically connected tap contacts 12, 12' and the other end of the tap section T2 is connected to a discrete pair of electrically connected tap contacts 13, 13'. A movable selector contact 14, connected to the line terminal L2, is arranged selectably to engage any one of the tap contacts 10, 11, 12 or 13, while a movable selector contact 14', connected to one end of the main winding M, is arranged selectably to engage any one of the tap contacts 10', 11', 12' or 13'. In addition, a movable contact arm 15, connected to the tap contacts 12, 12', is arranged selectably to engage the tap contacts 10 or 11 or to be left in open circuit position 16. Similarly, a movable contact arm 15', connected to the tap contacts 11, 11', is arranged selectably to engage either the tap contact 12' or the contact 13' or to be left in open circuit position 16'. Thus it may be observed that the movable selector contact 14' connects the tap sections to the main winding, the movable selector contact 14 connects the tap sections to the line terminal L2, and the movable contact members 15 and 15' connect the tap sections T1, T2 to each other, each in a variety of selectable combinations. If desired, the movable contact members shown at FIG. 4 may be interconnected for simultaneous stepping operation in predetermined sequence, but for the purpose of illustration it may be assumed that each of these contact members is independently operable, to accomplish, for example, the sequence described below.

In the position of the several switch members shown at FIG. 4, the tap sections T1 and T2 are both connected in series circuit relation with the main winding portion M and in aiding voltage relation with the main winding, as indicated by the directional arrows on the drawing. If it is assumed that the tap section T1 has three turns and the tap section T2 has only two turns, this circuit connection is effective to add five turns, i.e., the incremental voltage of five turns, to the voltage of the main winding portion M. If now the switch member 14 is moved from its contact 13 to its contact 12, the tap section T2 is bypassed, so that the remaining included tap section T1 adds three turns to the voltage of the main portion M. If now the switch member 14 is returned to its contact 13 and the switch member 14' moved to its contact 11', the tap section T1 is removed from the series circuit and the tap section T2 included, thereby to add only two turns to the voltage of the main winding M. The incremental voltage added to the main winding portion M may be now reduced to a single turn by returning switch member 14' to its contact 10', moving switch member 15' to its contact 13', moving switch member 14 to its contact 12, and moving switch member 15 to its open circuit position. In this connection the tap section T1

is connected in aiding relation with the main winding M, and the tap section T2 connected in bucking or opposing relation so that a net incremental voltage equivalent to a single tap turn is added to the main winding voltage. To reduce the incremental voltage of the tap sections to zero, it is only necessary to leave the switch members 15 and 15' in the positions shown on the drawing, and to move the switch members 14 and 14' to their contacts 11 and 11' respectively. It will now be evident to those skilled in the art that by a similar program of switch connections the tap sections T1 and T2 may be utilized to oppose the main winding voltage in steps of −1, −2, −3, and −5 tap turns.

For simplicity and clarity of illustration, I have shown at FIGS. 1–4 examples wherein the tap sections are serially connected at one end of a single main winding portion. It will, of course, be evident to those skilled in the art that between the tap windings shown and the line terminal L2 an additional main winding portion may be connected in the series circuit, so that the tap sections are electrically between separate portions of the main winding. Physically such separate main winding portions may comprise coil layers positioned to sandwich the tap coil layers therebetween. I wish to have it understood that in the appended claims I intend to comprehend all such plural as well as single main winding arrangements.

To further illustrate a preferred embodiment of my invention in more specific detail, I have shown at FIG. 5 a schematic circuit diagram of an autotransformer connection between primary line terminals L1 and L2, and a variable voltage secondary line terminal L3. In the embodiment of the invention shown at FIG. 5, the several switching means illustrated diagrammatically at FIG. 4 are shown in physically interconnected, synchronously operable step-by-step relation, and connected to effect incremental voltage variations over only that portion of buck and boost voltage ranges characterized by step voltages smaller in magnitude than the magnitude of either tap section.

In the embodiment of the invention shown at FIG. 5, an autotransformer winding connected between primary line terminals L1 and L2 comprises a pair of main or common portions C1, C2 and a pair of intermediate tap sections T1 and T2 wound on a common core C, the tap sections being provided with three turns and two turns respectively, as indicated on the drawing. A variable voltage secondary line terminal L3 is shown connected to one end of the main winding portion C2, thereby to constitute an autotransformer connection. The tap sections T1 and T2 are arranged to be connected selectably in series with the common portion C1 between terminals L3 and L1. It will, of course, be understood by those skilled in the art that the inductive winding comprising the portions C1, C2, T1 and T2 may, if desired, be variously connected between the terminals L1 and L2 in the manner to be described without providing any intermediate tap terminal L3, and may thus be utilized as the primary or secondary winding of an isolated secondary type transformer.

Referring now more particularly to the several switch members shown at FIG. 5, it will be observed that a tap selector switch S1 has a movable selector contact 14 connected to line terminal L3 and to the main winding portion C2, and is provided with tap contacts connected to the several discrete ends of tap sections T1 and T2. Similarly, a second tap selector switch S2 having a movable selector contact 14' connected to main winding C1 is provided with tap contacts connected also to the several ends of the tap sections. Finally, a third selector switch S3, having a movable bridging contact 15, cooperates with the tap selector switches S1 and S2 to connect or bypass the tap sections in various selectable series circuit connections between the main winding portions C1, C2. The movable contact arms of the several selector switches S1, S2 and S3 are diagrammatically illustrated as being simultaneously actuated in synchronous step-by-step relation by means of a manually operable hand wheel 20 connected through a shaft 21 and suitable gearing 22 and 23 to the several contact arms.

Each of the tap selector switches S1, S2 is provided with seven tap contacts, all of which are connected to the four discrete ends of the tap sections T1, T2. On the drawing at FIG. 5, these four discrete tap section ends are identified by reference numerals 31, 32, 33 and 34, and the tap contacts on switches S1 and S2 to which they are connected are similarly identified. It will be noted that in each case several tap contacts of the same switch are connected together for purposes which will appear hereinafter. The intermediate selector switch S3 is also provided with seven tap contacts, but its movable switch arm 15 is of the bridging type adapted in the several step positions of the switch to effect engagement between adjacent tap contacts. The tap contacts of the switch S3 are also variously connected to the tap section terminals 31, 32, 33 and 34 in the manner indicated on the drawing by like reference numerals on the associated tap contacts. One of the tap contacts of the switch S3 is connected to the terminal 30 of the main winding portion C2.

In the position of the several synchronously operated step-by-step tap switches shown at FIG. 5, the three-turn tap section T1 is connected in aiding voltage relation with the main winding portions C1 and C2 (indicated by the directional arrows on the drawing), while the tap section T2 is bypassed or disconnected from the series circuit. In the embodiment of the invention shown at FIG. 5, this is the maximum boosting, or aiding, tap voltage connection provided, and the circuit may be followed from line terminal L1 through the main winding section C1, contact 34 of the tap switch S2, the tap section T1, contact 33 of the tap switch S1, and the main winding portion C2 to the line terminal L2.

The operation of the tap changing apparatus shown at FIG. 5 may now be observed by assuming a clockwise step-by-step movement of the several interconnected selector switches S1, S2 and S3. The initial or maximum boost position shown in the drawing was described in the preceding paragraph. If it is now assumed that each of the selector switches progresses one step in a clockwise direction, it will be found that the tap section T2 is connected in circuit in a voltage-aiding relation and the tap section T1 bypassed, i.e., disconnected from the series circuit. This circuit may be followed from the line terminal L1, through the main winding section C1, contact 32 of the tap switch S2, tap section T2, contact 31 of the tap switch S1, and thus through the main winding portion C2 to the line terminal L2. In this connection the voltage of the main winding sections is boosted by the two turns of tap section T2. If now the several selector switches S1, S2 and S3 are moved a second step in a clockwise direction from the position shown, both of the tap sections T1 and T2 are connected in circuit in voltage opposition to each other, so that a net incremental voltage equal to that of one tap section turn is added to the main winding. This may be observed by following the series circuit from the line terminal L1 through the main winding section C1, through the contact 34 of tap switch S2, through the three-turn tap section T1 in the boosting direction, through the tap contacts 33–31 of the selector switch S3, then through the two-turn tap section T2 in the bucking direction, through the tap contact 32 of the tap switch S1, and finally through the main winding section C2 to the line terminal L2. The incremental voltage may now be reduced to zero by making a neutral connection in which no voltage is added to or subtracted from the main winding portion. This is accomplished by moving the several interconnected selector switches clockwise to a third step position from that shown on the drawing. In this posi-

tion it will be found that both tap sections T1 and T2 are bypassed and thus omitted from the series circuit. This circuit may be followed from the line terminal L1, through the main winding section C1, through the contact 30 of the tap switch S2 and thus directly to the main winding portion C2 and through it to the line terminal L2.

It will now be evident to those skilled in the art by reference to FIG. 5 that by progressively moving the several selector switches S1, S2 and S3 through their remaining fourth, fifth and sixth clockwise positions of advancement, the differential tap sections T1 and T2 are first connected in voltage opposition to each other with a net one-turn bucking effect upon the main winding portions, and are then separately connected in opposing voltage relation to the main winding portions to provide minus 2 and minus 3 turn bucking positions respectively. Upon completing rotation of the tap switches to the position shown in the drawing, the circuit connection is restored to a plus 3 turn boosting connection as first described.

By my invention, means are provided whereby a minimum number of tap sections of an inductive coil may be utilized in an optimum manner to effect incremental voltage variations both above and below the voltage of the main coil portion and in steps less than the voltage of any single tap section. The invention comprehends at least two tap sections of unequal voltage, but is not limited to only two sections. It will be apparent that additional tap sections of predetermined equal incremental voltage values may be added and also utilized selectably in buck-boost relation. By appropriate switching connections, these added sections may be so combined in series circuit with the unequal pair of sections that the small differential voltage steps are extended over a wider range. If desired, also, there may be provided more than one pair of differential voltage sections, and these may be so arranged that the differential voltage of each pair is the same, while the absolute but unequal voltages of each pair are different. For example, a pair of coils having two turns and three turns, respectively, may be utilized along with a second pair of tap sections having four turns and five turns respectively. Many similar combinations will occur to those skilled in the art, and it will be obvious that switching means similar to those described may be connected to extend the small differential voltage steps over substantially the entire attainable range of voltage variation.

As suggested throughout the specification, my invention is applicable to any inductive coil in which tap sections are provided to make incremental voltage changes in the total number of turns of the coil. While disclosed as a transformer winding, which may be either an autotransformer or an isolated secondary type, it is evident that the invention is applicable also to reactors connected in circuit as load or compensating devices.

Therefore while I have disclosed only certain preferred embodiments of my invention by way of illustration, many modifications will occur to those skilled in the art. Accordingly, I wish to have it understood that I intend herein to cover all such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In an electric tap changing apparatus, an inductive winding comprising a main winding portion and at least two tap sections, each said tap section having a pair of immediately adjacent tap contact connections at opposite ends thereof and no intermediate tap connections and said tap sections providing unequal incremental voltages between their respective ends, a first line terminal connected to one end of said main winding portion, a second line terminal, and switching means for selectably connecting either or both said tap sections in any one of several predetermined series circuit relations between the other end of said main winding portion and said second line terminal, said switching means providing at least one connection of both said tap sections in said series circuit relation and in mutually opposing voltage relation with each other.

2. A tap changing apparatus according to claim 1 wherein said switching means provides two selectable connections of both said tap sections in said series circuit relation with said tap sections in mutually opposing voltage relation, and the differential voltage therebetween selectably in aiding or opposing voltage relation with said main winding portion.

3. A tap changing apparatus according to claim 1 in which said switching means provides also for selectable connection of each said tap section separately in said series circuit relation.

4. A tap changing apparatus according to claim 3 in which said switching means provides also for bypassing both said tap sections in connecting said main winding portion to said second line terminal.

5. A tap changing apparatus according to claim 2 in which said switching means provides also for selectable connection of each said tap section separately in said series circuit relation in either aiding or opposing voltage relation with said main winding portion.

6. A tap changing apparatus according to claim 1 wherein said switching means provides also for connecting both said tap sections in said series circuit relation and in mutually aiding voltage relation.

7. A tap changing apparatus according to claim 2 wherein said switching means provides also for connecting both said tap sections in said series circuit relation and in mutually aiding voltage relating in either aiding or opposing relation with said main winding portion.

8. A tap changing apparatus according to claim 7 wherein said switching means provides also for selectable connection of each said tap section separately in said series circuit relation in either aiding or opposing voltage relation with said main winding portion.

9. An inductive winding according to claim 1 wherein said winding is provided with a core and said unequal tap sections are wound on a common portion of said core and have different numbers of turns.

10. An inductive winding according to claim 9 wherein the numbers of turns of said tap sections differ by approximately one turn.

11. An inductive winding according to claim 1 wherein said unequal tap sections are mutually interwound and have unequal numbers of turns.

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U.S. Cl. X.R.

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