Dec. 12, 1972 E. A. GOODMAN 3,706,060

SERIES-MULTIPLE TRANSFORMER

Filed May 14, 1971 3 Sheets-Sheet 1

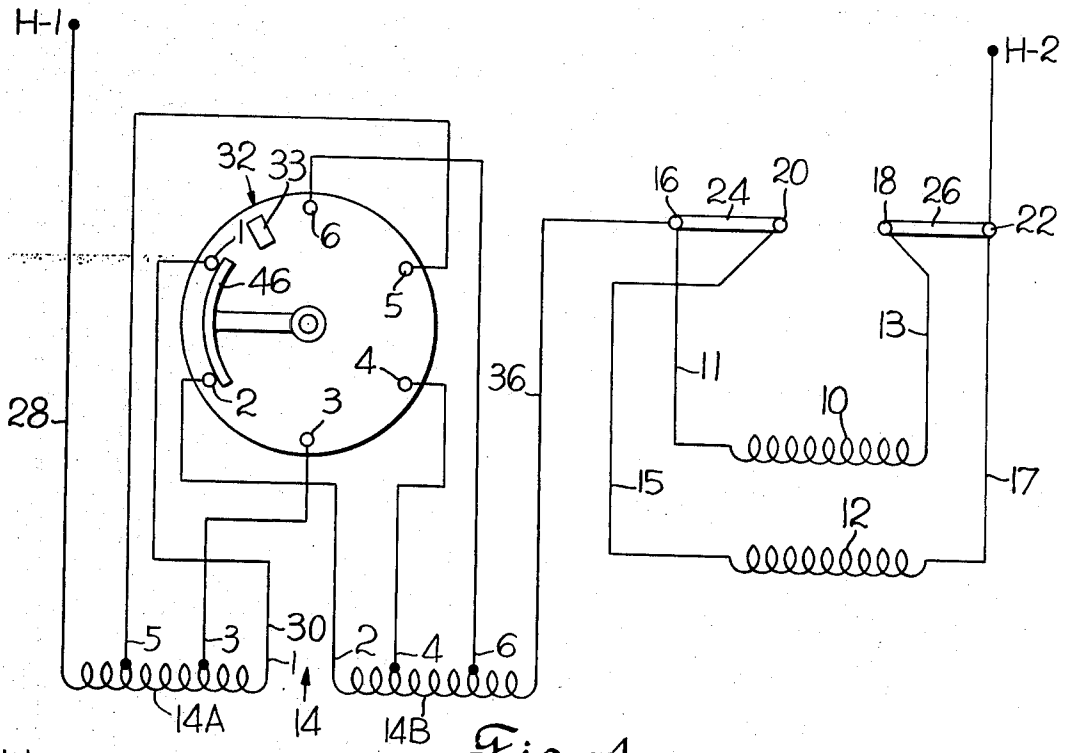


Fig.-1

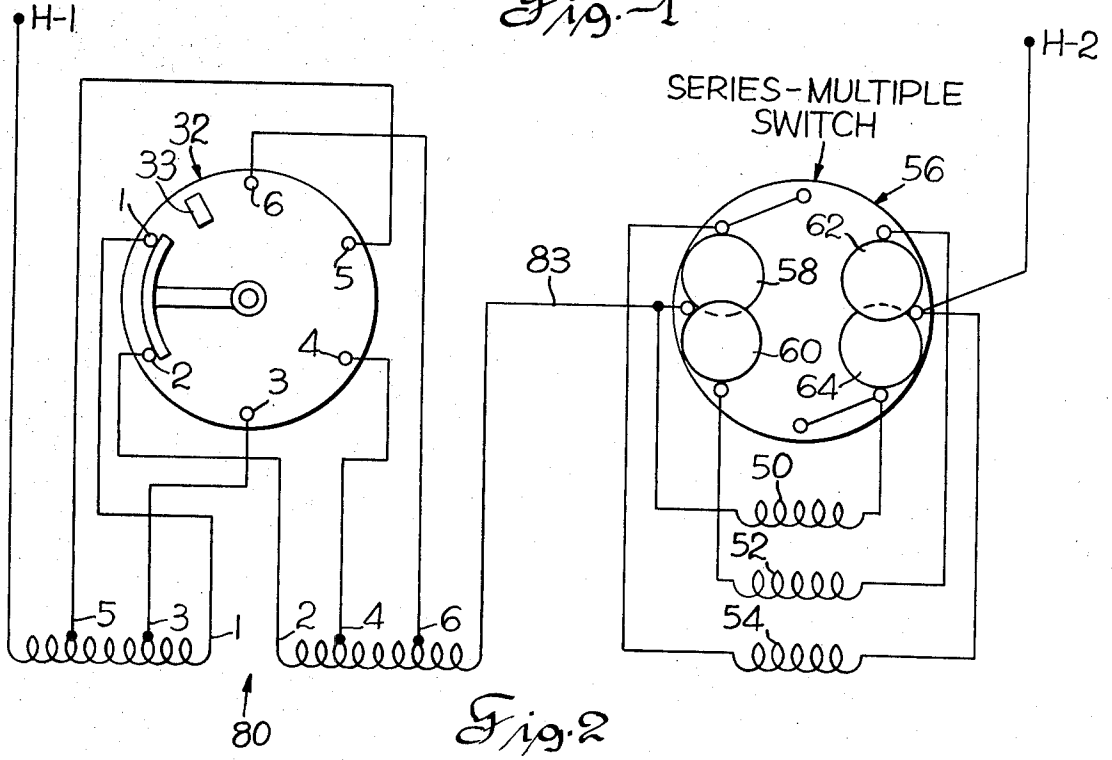


Fig.-2

Inventor
Ernest A. Goodman
By Robert C. Sullivan
Attorneys

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SERIES-MULTIPLE TRANSFORMER

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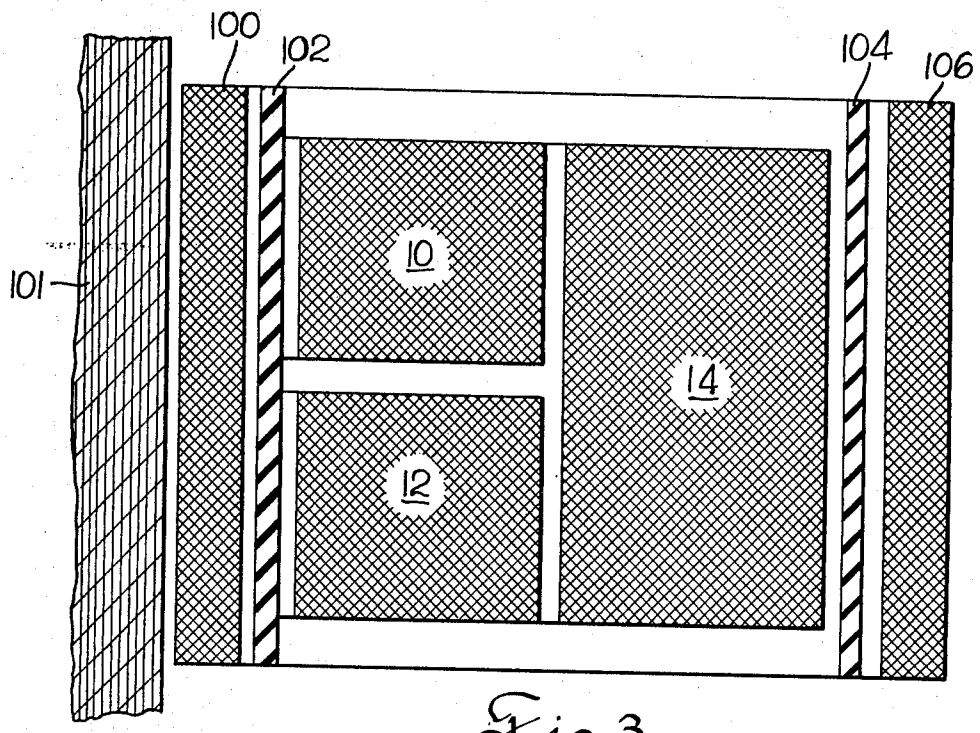


Fig. 3

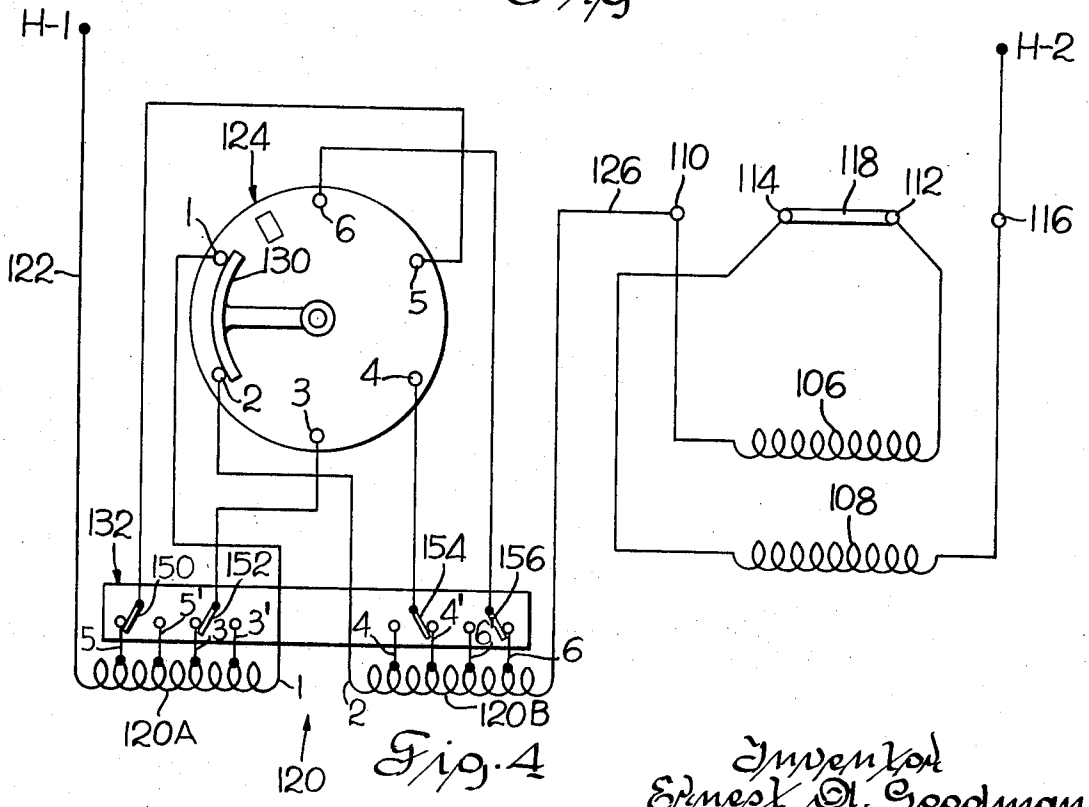


Fig. 4

Inventor
Ernest A. Goodman
By Robert C. Sullivan
Attorneys

Dec. 12, 1972 E. A. GOODMAN 3,706,060

SERIES-MULTIPLE TRANSFORMER

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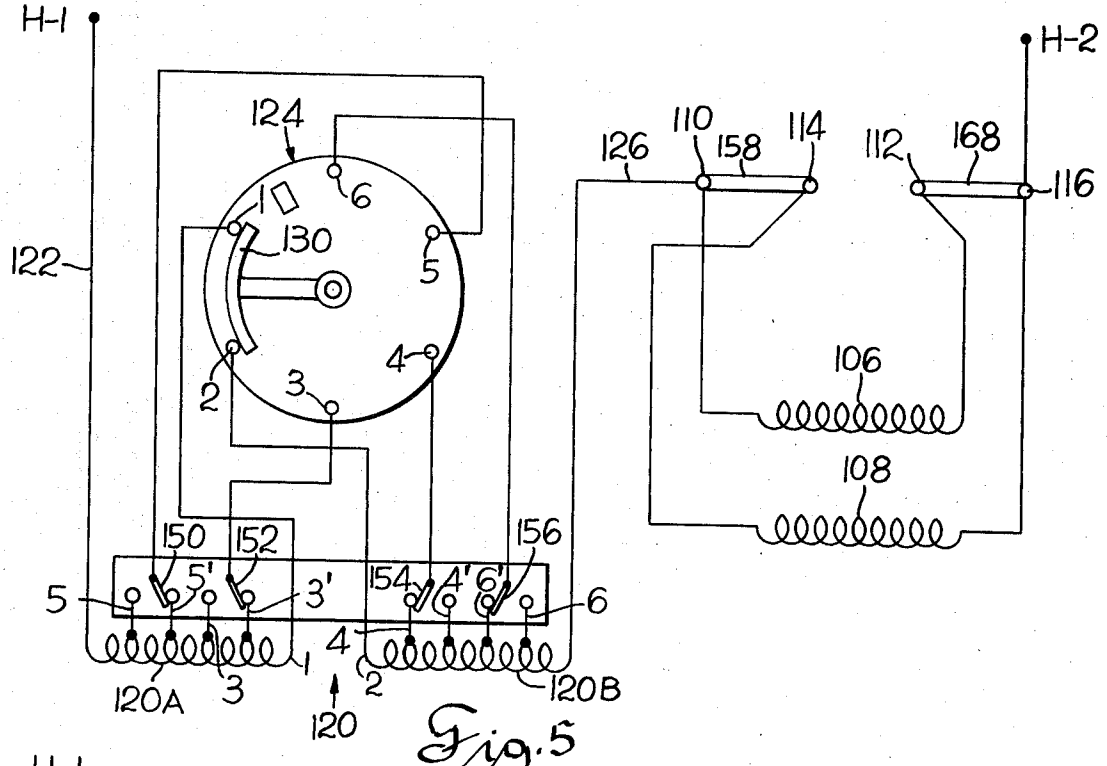


Fig. 5

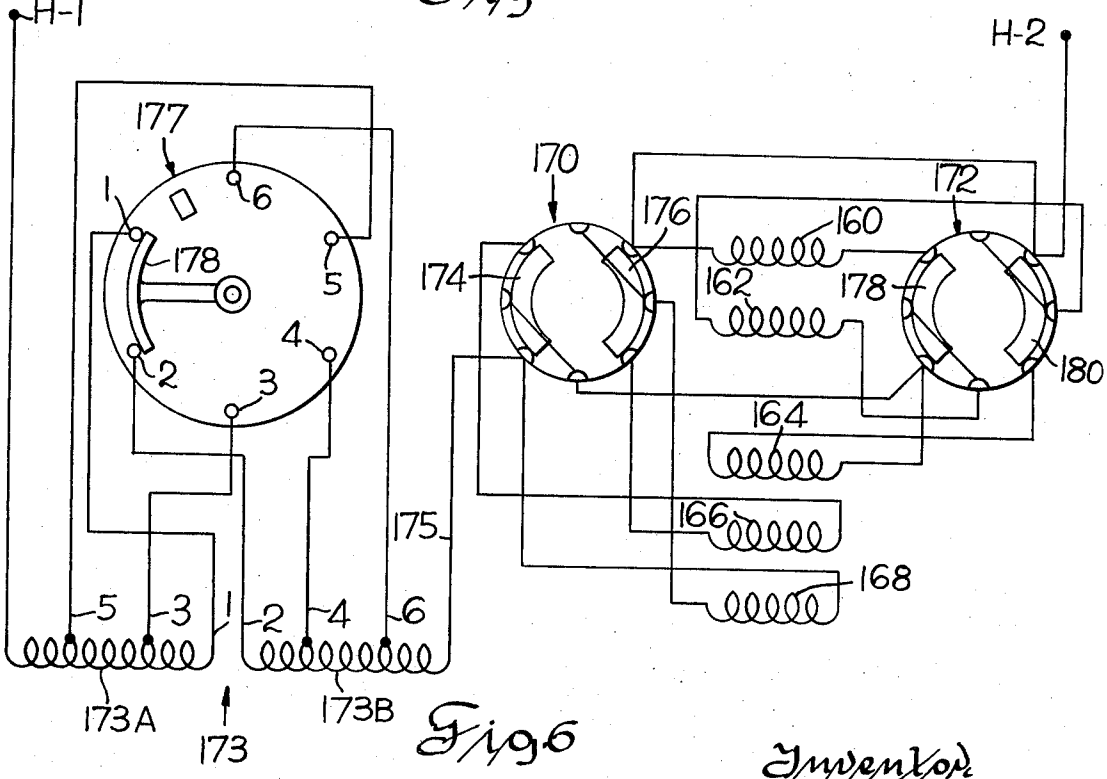


Fig. 6

Inventor
Ernest A. Goodman
By Robert C. Sullivan
Attorney

United States Patent Office 3,706,060
Patented Dec. 12, 1972

3,706,060

SERIES-MULTIPLE TRANSFORMER

Ernest A. Goodman, Pittsburgh, Pa., assignor to Allis-Chalmers Manufacturing Company

Filed May 14, 1971, Ser. No. 143,317
Int. Cl. H01f 21/12
U.S. Cl. 336—147 11 Claims

ABSTRACT OF THE DISCLOSURE

An electrical transformer having a plurality of untapped primary winding sections connectable in either series or in parallel for alternatively either a higher primary voltage rating or a lower primary voltage rating, a tapped primary winding section connected in series with the plurality of untapped winding sections in both the series and in the parallel connection thereof and permitting adjustment by a tap changer switch of the effective number of primary turns, whereby to adjust alternatively either the higher primary voltage rating or the lower primary voltage rating of the transformer.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to electrical transformers having dual voltage ratings—i.e., higher and lower primary voltage ratings.

Description of the prior art

It is known in the transformer art to provide an electrical transformer having a dual voltage rating which is accomplished by connecting primary winding sections in either series to provide a higher primary voltage rating or in parallel (multiple) to provide a lower primary voltage rating. Such series or parallel connection of the primary winding sections may be effected by either a terminal board or a series-multiple switch. For example, a transformer may have a plurality of 2400 volt primary winding sections. When these winding sections are connected in parallel, the voltage rating of the transformer will be 2400 volts. However, when the winding sections are connected in series, the transformer will have a voltage rating which depends on the number of primary winding sections, for example, when three such winding sections are connected in series the voltage rating of the transformer would be 7200 volts.

It is also known in the prior art to provide means for adjusting the higher primary voltage rating when the primary winding sections are connected in series. Such adjustment is usually effected by providing a primary winding section with taps connected to fixed contacts of a tap changer switch so that the number of effective turns in the tapped primary winding section may be adjusted by the tap changer switch to regulate the higher primary voltage rating of the transformer. Such an arrangement is disclosed in U.S. Pat. 3,213,223 to Kenneth H. Sickler. However, in transformers arranged for series-multiple connection for higher or lower primary voltage ratings as shown in U.S. Pat. 3,212,223, a serious disadvantage is that the tap changer switch may only be used when the primary winding sections are connected in series for the higher primary voltage rating and may not be used for adjustment of the lower primary voltage rating when the primary winding sections are connected in parallel. Movement of the tap changer switch when the primary winding sections are connected in parallel may cause the tapped winding section to have an incorrect voltage rating, and induce a short circuit in the transformer that could damage or cause destruction of the transformer.

It is for this reason that the transformer of U.S. Pat. 3,213,223 requires an interlock which holds the tap changer switch in one position wherein the winding sections are connected in parallel for the lower primary voltage rating.

If adjustment of the lower primary voltage rating of a prior art transformer was desired when the primary winding sections were connected in parallel, it was necessary to provide taps in each of the primary winding sections and a tap changer switch for each such tapped winding section. Such arrangement is cumbersome, space-consuming, and subject to error in manufacture (a one-turn error in any winding section is serious) and in operation (mechanical interconnection of the plurality of tap changer switches is almost a necessity).

SUMMARY OF THE INVENTION

Accordingly, it is an object of the invention to provide a dual rated electrical transformer having higher and lower primary voltage ratings and tap changer switch means for adjusting either the higher primary voltage rating or of the lower primary voltage rating of the transformer.

It is another object of the invention to provide a transformer having primary winding sections adapted to be connected for either a higher primary voltage rating or a lower primary voltage rating, and means for changing the transformer turns ratio in either the higher voltage or lower voltage connection of the winding sections.

It is another object of the present invention to provide a transformer having a plurality of untapped (or series-multiple) primary winding sections connectable in either series or in parallel and a tapped primary winding section connected in series with the plurality of untapped winding sections in both the higher voltage connection and lower voltage connection and permitting adjustment of either the higher primary voltage rating or of the lower primary voltage rating of the transformer.

It is a further object of the invention to provide such a transformer having a plurality of taps which are so arranged as to permit constant percentage tap changing at both the higher and lower primary voltage connections of the series-multiple primary winding sections.

It is a still further object of the invention to provide such a series-multiple transformer having means to adjust both the higher and lower primary voltage ratings and wherein the tap sections are distributed across the entire axial height of the coil in order to minimize electrical unbalance between the primary and secondary windings and thus minimize the short circuit forces on the windings.

In achievement of these objectives there is provided a transformer having a plurality of untapped series-multiple primary winding sections which may be connected in either series or in multiple for alternatively either a higher primary voltage rating or a lower primary voltage rating, a tapped primary winding section which is connected in sereis with said plurality of untapped winding sections in both the series and in the multiple connection with the taps connected to a tap changer switch to permit change of the effective number of primary turns, whereby to adjust alternatively either the higher primary voltage rating or the lower primary voltage rating of the transformer.

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

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a transformer embodying the invention having two untapped primary wind-

ing sections adapted to be connected either in series or in parallel by a terminal board and a tapped primary winding section connected in series with the untapped winding sections in both the series and in the parallel connection thereof and having taps connected to a tap changer switch to permit adjustment of either the higher or lower primary voltage rating of the transformer;

FIG. 2 is a schematic diagram of a transformer similar to FIG. 1 except that three untapped primary winding sections may be alternatively connected in series or parallel by a series-multiple switch;

FIG. 3 represents a radial cross section through the transformer of FIG. 1 showing the physical arrangement of the winding sections;

FIGS. 4 and 5 illustrate an alternative embodiment of the invention which provides constant ratio change for each tap change at both the higher and lower primary voltage ratings, with FIGS. 4 and 5 respectively representing the higher and lower voltage rating positions; and

FIG. 6 is a schematic wiring diagram of an alternative embodiment of the invention in which five series-multiple primary winding sections may be connected in either series or multiple and in series with a tapped winding section.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 of the drawing, a transformer embodying the invention has a pair of untapped primary winding sections **10** and **12** arranged to be connected either in series or in parallel together with a tapped winding section **14** connected in series with the pair of untapped, or series-multiple primary winding sections **10** and **12**. Tapped winding section **14** includes four tap sections **1–3**, **2–4**, **3–5** and **4–6** between taps **1** and **3**, **2** and **4**, **3** and **5**, and **4** and **6** respectively. Tap sections **1–3** and **2–4** are isolated from each other and divided tapped wining section **14** into two halves **14A** an **14B** which are electrically connected through the bridging movable contact **46** of a tap changer switch **32**. Tap sections **1–3** and **3–5** are connected in series with an untapped portion in one half **14A** of winding section **14** which is connected by a conductor **28** to primary winding terminal **H–1**, and tap sections **2–4** and **4–6** are connected in series with an untapped portion in the other half **14B** of winding section **14** which is connected by conductor **36** to terminal **16** of a terminal board. Tap changer **32** may be provided with a mechanical stop **33** to prevent the movable contact **46** from bridging stationary contacts **1** and **6**. The primary winding sections **10**, **12** and **14** are each of equal voltage rating and may each have a rating of 2400 volts. The windings **10** and **12** in the embodiment of FIG. 1 are arranged to be connected in either series or in parallel by a terminal board. However, the connection of the windings **10** and **12** in either series or parallel (multiple) may be accomplished by a series-multiple switch as is well known in the art. Opposite ends of winding section **10** are connected to terminals **16** and **18** on the terminal board, and opposite ends of winding section **12** are connected to terminals **20** and **22** on the terminals **16** and **20**, a conducting jumper **26** is connected between the terminals **18** and **22**, and terminal **22** is connected to primary winding input terminal **H–2** so that as shown in FIG. 1 the two untapped winding sections **10** and **12** are connected in parallel and the lower primary voltage rating of the transformer is 2400+2400=4800 volts. If jumpers **24** and **26** are manually moved so that both connect terminals **18** and **20**, the winding sections **10**, **12** and **14** will be connected in series corresponding to the higher primary voltage rating of 2400+(2×2400) =7200 volts.

The taps **1**, **2**, **3**, **4**, **5** and **6** are connected to the corresponding stationary contacts of tap changer switch **32**. Tap changer switch **32** is provided with a movable bridging contact **46** which may be indexed to successive positions in which it bridges adjacent stationary contacts **1–2**, **2–3**, **3–4**, **4–5** or **5–6**.

In FIG. 1 the movable contact **46** is shown bridging contacts **1** and **2** of tap changer switch **32** and is thereby effective to connect all of the turns of tapped winding section **14** in series with the winding sections **10** and **12**. A predetermined percentage of the turns of tapped winding section **14** is removed from the circuit for each indexing step of bridging contact **46** in a counterclockwise direction from the 100 percent winding position shown in FIG. 1, whereby the lower rated primary voltage of the transformer is reduced by a predetermined percentage, such as 2½ percent, for each successive tap change to a maximum, for example, of 10 percent of the rated voltage. The taps **1**, **2**, **3**, **4**, **5** and **6** may be at points on winding section **14** such that each tap change in a counterclockwise direction will subtract 12 volts from the rated lower primary voltage of the transformer up to a maximum of 480 volts. This assumes that each winding section **10**, **12** and **14** has a rating of 2400 volts.

If the taps **1**, **2**, **3**, **4**, **5** and **6** are at positions which provide a primary voltage change of 120 volts for each tap change, each tap change will represent a change of 2.5 percent in the lower primary voltage rating of 4800 volts. However, the same 120 volt change would only represent a change of 1.66 percent of higher primary voltage rating if the winding sections **10** and **12** are connected in series to provide the higher primary voltage rating of 7200 volts. In other words, tap changer **32** as shown in FIG. 1 has "constant voltage" taps which represent the same numerical change in voltage regardless of the series or parallel connection of the untapped winding sections **10** and **12**. Such "constant voltage" change represents one percentage of change of the lower primary voltage rating when the winding series-multiple sections **10** and **12** are connected in parallel, for example, 2.5 percent per tap change, and represents a different percentage of change of the 720 volt higher primary voltage rating, for example, 1.66 percent of higher primary voltage rating change per tap change, when the winding sections **10** and **12** are connected in series.

It is assumed in FIG. 1 that when movable contact **46** is in bridging relation to tap changer fixed contacts **1** and **2** and all of the turns of tapped winding section **14** are in circuit and in series with parallel-connected winding sections **10** and **12**, the transformer has a lower primary voltage rating of 4800 volts. It is further assumed that actuation of movable contact **46** to successive positions in which it bridges fixed contacts **2–3**, **3–4**, **4–5**, and **5–6** will result in a 2.5 percent decrease in the lower rated primary voltage for each successive indexed step of movable contact **46** in a counterclockwise direction. For example, when movable contact **46** is in bridging relation to contacts **5–6**, the lower primary voltage of the transformer for the parallel connection of the untapped windings sections **10** and **12** will be 4800−(.10×4800)=4800 −480=4320 volts.

However, the number of turns of tapped winding section **14** could be such that when movable contact **46** is in bridging relation to fixed contacts **1** and **2**, a 5 percent increase in transformer voltage above the 4800 volt nominal value would result to thereby provide a primary voltage rating of 4800+(.5×4800)=4800+240=5040 volts. In such alternative arrangement each successive indexed position of movable contact **46** would add or subtract 2.5 percent from the rated lower primary voltage. Thus, when movable contact **46** is in bridging relation to fixed contacts **3** and **4**, the transformer lower primary rated voltage would be 4800 volts, and when the movable contact **46** is in bridging relation to fixed contacts **5** and **6**, the rated lower primary voltage of the transformer would be 4800−(.05×4800)=4800−240=4560 volts. In such "constant voltage" embodiment tap changer **32** would provide an adjustment of plus or minus 5 percent in the nominal lower primary rated voltage for a total voltage change of 10 percent of the nominal rated voltage of 4800 volts (assuming that series-multiple windings **10**

and 12 are connected in parallel as shown in FIG. 1). If the windings 10–12 are connected in series for a 7200 volt nominal rated voltage of the transformer primary winding, then the same "constant voltage" arrangement would provide an adjustment of plus or minus 3.33 percent on either side of the nominal 7200 volts. This permits adjustment from a higher primary voltage rating of 7200−240=6960 volts when movable contact 46 is in bridging relation to tap changer contacts 5–6 and all tap sections are out of circuit to a higher primary voltage rating of 7200+240=7440 volts when the movable contact 46 is in bridging relation to fixed contacts 1–12 and all the tap sections are in circuit.

It will thus be appreciated that if all taps are below "normal," the tapped section voltage is equal to that of each of the series-multiple sections; but if some taps are above "normal," additional turns are added to the tapped section and the voltage of the tapped section is no longer equal to that of the series-multiple sections. Such arrangement is possible with the present invention since the tapped section is in series with the series-multiple sections in both the series and parallel connection thereof, but was impossible in prior art dual-voltage transformers unless an interlock was provided to hold the tap changer switch in the position wherein the voltage across the tapped section was equal to that across the series-multiple sections.

FIG. 2 shows an alternative embodiment in which three untapped primary winding sections 50, 52, and 54 are adapted to be connected either in series or in parallel by a series-multiple switch 56. Each of the series-multiple winding sections 50, 52, and 54 may have a rating, for example, of 3600 volts. Switch 56 may be similar to that disclosed in U.S. Pat. 3,170,048 to Charles E. Glatz and John M. Anderson, and reference is made thereto for a description of the structure and operation of switch 56. In the position of the disk contacts 58, 60, 62, and 64 shown in FIG. 2, the three winding sections 50, 52, and 54 are connected in parallel. Counterclockwise movement of the disk contacts 58, 60, 62, and 64 from the position shown in FIG. 2 to the succeeding position connects the sections 50, 52, 54 in series to provide a higher primary voltage rating of 3600+(3×3600)=14,400 volts. A tapped series-multiple primary winding section 80 is connected in series with the winding sections 50, 52, and 54 by conductor 83 in both the parallel and in the series arrangement of winding sections 50–52–54 in the same manner as described for the embodiment of FIG. 1. Winding section 80 includes four tap sections 1–3, 2–4, 3–5, and 4–6 which are switched by tap changing switch 32 in the same manner as described for the embodiment of FIG. 1. Assume that each of the winding sections 50, 52, 54, and 80 has a rating of 3600 volts. If the winding sections 50, 52, and 54 switched by the series-multiple switch 56 are connected in parallel as shown in FIG. 2, the transformer will have a lower primary voltage rating of 3600+3600=7200 volts. If the three untapped windings 50, 52, and 54 are connected in series by series-multiple switch 56, then the transformer will have a higher voltage primary rating of 14,400 volts. Either the higher or the lower primary voltage rating of the transformer may be adjusted by movement of tap changing switch 32 as explained in the embodiment of FIG. 1.

FIG. 3 illustrates one preferred physical arrangement of the windings of the embodiment of FIG. 1. The inner sheet-wound low voltage winding 100 is positioned radially outwardly of the magnetic core winding leg 101. An insulating barrier 102 is positioned coaxially about and radially outwardly of low voltage winding 100. The high voltage series-multiple winding sections 10 and 12 are superimposed in the same axial plane coaxial with and radially outwardly of insulating barrier 102, and each extends approximately one half of the total winding length in anaxial direction. The tapped high voltage winding section 14 is positioned radially outwardly of the series-multiple winding sections 10 and 12 and extends for the full coil length in an axial direction. Consequently, the short circuit strength of tapped winding section 14 is close to that of a single section, single voltage transformer. Because the tapped winding section 14 is positioned electrically close to terminal H–1 of the primary winding, the impulse voltage across the tap sections of a two-bushing distribution transformer embodying the invention may be greater than it might be in a conventional (i.e. nonseries-multiple) design. A high-low insulating barrier 104 is positioned radially outwardly of tapped high voltage winding section 14, and a second sheet-wound low voltage winding 106 is positioned radially outwardly of high-low insulating barrier 104. Alternatively, such tapped winding section may be radially inward or outward of a low voltage winding or may extend the full axial length of a high-low winding.

FIGS. 4 and 5 show an alternative embodiment of the invention which provides "constant percentage" change of voltage per tap change at both the higher primary voltage rating and the lower primary voltage rating of the transformer. The transformer has a pair of series-multiple primary winding sections 106 and 108 with opposite ends of winding section 106 shown connected to terminals 110 and 112 on a terminal board and with opposite ends of winding section 108 shown connected to terminals 114 and 116 on the terminal board. As shown in FIG. 4, the two winding sections 106 and 108 are connected in series by a conducting jumper 118 which bridges the terminals 112 and 114. Each winding section 106 and 108 may have a voltage rating, for example, of 2400 volts. The transformer also has a tapped primary winding section 120 provided with ten taps 5, 5′, 3, 3′, 1, 2, 3, 4′, 6 and 6′. Taps 1 and 2 are isolated from each other and divide winding section 120 into two halves 120A and 120B which are electrically connected through bridging contact 130 of tap changer switch 124. One set of taps 5, 3, 6, 4 together with taps 1 and 2 are used to provide a selected percentage change of voltage per tap change at the higher voltage primary rating, and another set of taps 5′, 3′, 6′, 4′, together with taps 1 and 2 are used to provide the same percentage change of voltage per tap change at the lower primary voltage rating. As shown in FIG. 4, tapped winding section 120 is connected in series with untapped winding sections 106 and 108 by conductor 126. When the series-multiple winding sections 106 and 108 are connected in series with each other and with tapped winding section 120, the transformer has a primary voltage rating of 2400+(2×2400)=7200 volts (assuming that each of the winding sections 106, 108, and 120 has an individual rating of 2400 volts).

The winding section half 120A containing taps 5, 5′, 3, 3′ and 1 is connected by conductor 122 to high voltage input terminal H–1, and the winding section half 120B containing taps 2, 4, 4′, 6 and 6′ is connected by conductor 126 to terminal 110 on the terminal board.

The embodiments of the invention shown in FIGS. 4 and 5 provide "constant percentage" change of the rated voltage of the transformer regardless of whether series-multiple winding sections 106 and 108 are connected in series for the higher primary voltage rating, as shown in FIG. 4 or, alternatively, are connected in parallel for the lower primary voltage rating as shown in FIG. 5. Tap sections 3–5, 1–3, 2–4, and 4–6 each have a predetermined number of turns which will provide a 2.5 percent change of the higher primary rated voltage (e.g., 2½% of 7200 volts=180 volts) when winding sections 105, 108 and 120 are connected in series. Tap sections 3′–5′, 1–3′, 2–4′, and 4′–6′ each have a predetermined number of turns which will provide a 2.5 percent change in the lower primary voltage rating for tap change (i.e. 2.5% of 4800 volts=120 volts) when untapped winding sections 106 and 108 are connected in parallel with each other and in series with tapped primary section 120 when jumper 158 connects terminal board terminals 110 and 114 together and jumper 168 connects terminals 112 and 116 together

as shown in FIG. 5. Thus, in the example given, the voltage subtracted from the rated higher primary voltage would be 2.5 percent of 7200 volts, or 180 volts for each successive tap change in a counterclockwise direction as seen in FIG. 4.

Double-throw selector switches **150, 152, 154,** and **156** are provided on an auxiliary terminal board **132.** The fixed end of selector switch **150, 152, 154,** and **156** is connected to contact **5, 3, 4,** and **6** respectively of the tap changer switch. In FIG. 4 selector switches **150, 152, 154,** and **156** are shown in the position in which they respectively engage taps **5, 3, 4,** and **6** to provide a change of 180 volts per tap change when winding sections **106** and **108** are connected in series as shown in FIG. 4. This 180 volt change for each index step of bridging contact **130** may be 2.5 percent of the higher primary voltage rating, i.e., of 7200 volts.

FIG. 5 shows untapped winding sections **106** and **108** connected in parallel for the lower primary voltage rating (4800 volts) with the selector switches **150, 152, 154** and **156** in engagement with taps **5', 3', 4',** and **6'** so that tap sections **5'–3', 3'–1, 2–4',** and **4'–6'** are in circuit and each tap change results in a 120 volt change which is 2.5 percent of the lower primary voltage rating (4800 volts) when the series-multiple primary winding sections **106** and **108** are connected in parallel. With selector switches **150, 152, 154,** and **156** in the positions shown in FIG. 5, each successive tap change provides a change in the lower primary voltage rating of the transformer of 2.5 percent of 4800 volts, namely, 120 volts. It will be appreciated that members **150, 152, 154,** and **156** could alternatively be either ganged double throw switches or manually operated connector means such as straps.

FIG. 6 illustrates an embodiment in which five primary series-multiple winding sections **160, 162, 164, 166,** and **168,** each of which may have a voltage rating of 1200 volts, are connected either in series or in multiple by two series-multiple switches **170** and **172.** The connections of the five primary series-multiple winding sections **160, 162, 164, 166,** and **168** and of the two series-multiple switches **170** and **172** which switch these winding sections in either series or in multiple are in accordance with the disclosure of U.S. Pat. 3,440,586 to Ernest A. Goodman and Richmond P. Johnston, and reference is made thereto for a description of the structure and of the operation of the two switches **170** and **172.** The series-multiple switch **170** includes a pair of bridging contacts **174** and **176,** and the series-multiple switch **172** includes a pair of movable bridging contacts **178** and **180.** In the position shown in FIG. 6, the series-multiple primary winding sections **160, 162, 164, 166,** and **168** are connected in parallel for the lower primary voltage rating of the transformer. When the movable contacts **174, 176, 178,** and **180** are indexed to the position shown in FIG. 2 of U.S. Pat. 3,440,586, the winding sections **160, 162, 164, 166,** and **168** are connected in series to provide a higher primary voltage rating of $1200+(5\times1200)=7200$ volts.

The transformer also includes a tapped primary winding section **173** which is similar to that of the embodiments of FIGS. 1–3 and has tap sections which are switched by a tap changing switch **177** in the same manner as previously described. Tapped winding section **173** is connected in series with the five series-multiple winding sections **160, 162, 164, 166,** and **168** by conductor **175.** When the series-multiple winding sections **160, 162, 164, 166,** and **168** are connected in parallel and (assuming that each winding section has a voltage rating of 1200 volts), the lower primary voltage rating of the transformer for the parallel connection of the series-multiple winding sections will be 2400 volts when movable contact **178** bridges contacts **1** and **2** and all of the tap sections **1–3, 2–4, 3–5,** and **4–6** are in circuit. The higher primary voltage rating will be $1200+(5\times1200)=7200$ volts when the series-multiple switches **170** and **172** connect the five series-multiple sections **160, 162, 164, 166,** and **168** in series and movable contact **178** bridges stationary contacts **1** and **2** so that all tap sections of tapped winding **173** are in circuit. Each tap change will provide a "constant voltage" change of the higher primary voltage rating and also of the lower primary voltage rating.

Approximately similar sectional voltage relations may be obtained for a 2400×7620 volt transformer by providing a 1270 volt tapped primary winding section (not shown) and five series-multiple primary winding sections of the same voltage rating. Suitable taps on the tapped winding section could then provide voltages above and below the 2400 volt (parallel) lower primary voltage rating and also provide higher primary voltage ratings below 7620 volts when the series-multiple windings are connected in parallel.

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

1. An electrical transformer having a primary winding and a secondary winding inductively linked with each other and with a magnetic core, said primary winding comprising a plurality of untapped series-multiple primary winding sections and a tapped primary winding section each inductively linked with said secondary winding and with said magnetic core, means for alternatively connecting said plurality of untapped series-multiple primary winding sections either in series for a higher voltage rating for said transformer or in parallel for a lower voltage rating, said tapped primary winding section having tap sections between taps and connected in series with said plurality of untapped primary winding sections in both the series connection and in the parallel connection of said plurality of untapped primary winding sections, and tap changer means for selectively switching said tap sections of said tapped winding section into and out of circuit, whereby to adjust the effective number of primary turns in either the series or in the parallel connection of said plurality of untapped primary winding sections.

2. An electrical transformer as defined in claim **1** in which said means for alternatively connecting said plurality of series-multiple winding sections in either series or in parallel comprises terminal board connection means for said plurality of winding sections.

3. An electrical transformer as defined in claim **1** in which said means for switching the tap sections of said tapped winding section comprises a tap-changer switch.

4. An electrical transformer as defined in claim **1** in which said means for alternatively connecting said plurality of series-multiple winding sections either in series or in parallel comprises a series-multiple switch.

5. An electrical transformer as defined in claim **4** in which said means for alternatively connecting said plurality of series-multiple winding sections in series or parallel comprises a pair of series-multiple switches.

6. An electrical transformer as defined in claim **1** wherein the electrical coil of said transformer is cylindrical and said tapped primary winding section extends substantially the entire axial length of said electrical coil to minimize the short circuit forces on said coil.

7. An electrical transformer having primary and secondary windings, said primary winding comprising a plurality of untapped series-multiple primary winding sections, means for alternatively connecting said plurality of untapped series-multiple winding sections either in series for a higher voltage rating for said transformer or in parallel for a lower voltage rating, a tapped primary winding section having tap sections between taps and connected in series with said plurality of untapped winding sections in both the series connection and in the parallel connection of said plurality of winding sections, and tap changer means for selectively switching said tap sections of said tapped winding section into and out of circuit, whereby to adjust the effective number of primary turns in either the series or in the parallel connection of said plurality of series-multiple primary winding sections, the electrical coil of said transformer being cylin-

drical and having annular secondary winding sections of sheet conductor at the radially inner and radially outer periphery thereof, and said primary winding being annular and being disposed between said radially inner and outer secondary winding sections, said tapped winding section being adjacent to and extending substantially the entire axial length of one of said secondary winding sections to minimize the short circuit forces on said coil, and said untapped primary winding sections being axially superimposed.

8. An electrical transformer having primary and secondary windings, said primary winding comprising a plurality of untapped series-multiple primary winding sections, means for alternatively connecting said plurality of untapped series-multiple winding sections either in series for a higher voltage rating for said transformer or in parallel for a lower voltage rating, a tapped primary winding section having tap sections between taps and connected in series with said plurality of untapped winding sections in both the series connection and in the parallel connection of said plurality of winding sections, and tap changer means for selectively switching said tap sections of said tapped winding section into and out of circuit, whereby to adjust the effective number of primary turns in either the series or in the parallel connection of said plurality of series-multiple primary winding sections, said tapped primary winding section having a plurality of first tap sections with first taps at the ends thereof and a plurality of second tap sections having a different number of turns than said first tap sections and second taps at the ends thereof, and including means for alternatively connecting said first and said second taps to the stationary contacts of said tap changer means.

9. An electrical transformer as defined in claim **8** wherein said means for alternatively connecting said first and said second taps comprises a plurality of manually operable double-throw selector switches.

10. An electrical transformer having primary and secondary windings, said primary winding comprising a plurality of untapped series-multiple primary winding sections, means for alternatively connecting said plurality of untapped series-multiple winding sections either in series for a higher voltage rating for said transformer or in parallel for a lower voltage rating, a tapped primary winding section having tap sections between taps and connected in series with said plurality of untapped winding sections in both the series connection and in the parallel connection of said plurality of winding sections, and a tap changer switch for selectively switching said tap sections of said tapped winding section into and out of circuit, whereby to adjust the effective number of primary turns in either the series or in the parallel connection of said plurality of series-multiple primary winding sections, said transformer having a higher primary voltage rating and a lower primary voltage rating, respectively, when said untapped primary winding sections are connected in series and in

parallel, said tapped winding having a plurality of taps at the ends of each of first tap sections across which the voltage is a predetermined percentage of said higher primary voltage rating and a plurality of taps at the ends of each of second tap sections having a different number of turns than said first tap sections and across which the voltage is said predetermined percentage of said lower primary voltage rating, and means for alternatively connecting said taps at the ends of said first tap sections and said taps at the ends of said second tap sections to the stationary contacts of said tap changer switch.

11. An electrical transformer having primary and secondary windings, said primary winding comprising a plurality of untapped series-multiple primary winding sections, means for alternatively connecting said plurality of untapped series-multiple winding sections either in series for a higher voltage rating for said transformer or in parallel for a lower voltage rating, a tapped primary winding section having tap sections between taps and connected in series with said plurality of untapped winding sections in both the series connection and in the parallel connection of said plurality of winding sections, and a tap changer switch for selectively switching said tap sections of said tapped winding section into and out of circuit, whereby to adjust the effective number of primary turns in either the series or in parallel connection of said plurality of series-multiple primary winding sections, said transformer having a higher primary voltage rating when said untapped primary winding sections are in series and a lower primary voltage rating when they are in parallel, said tapped winding section having a plurality of first tap sections each of which has a predetermined number of turns such that the voltage thereacross is a predetermined percentage of said higher primary voltage rating and a plurality of second tap sections each of which has a predetermined number of turns such that the voltage thereacross is said predetermined percentage of said lower primary voltage rating, and means for alternatively connecting the taps at the ends of said first and said second tap sections to the stationary contacts of said tap changer switch.

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