# United States Patent

[11] 3,611,228

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**Pittsburgh, Pa.**

[54] **ELECTRICAL TRANSFORMER**
**5 Claims, 9 Drawing Figs.**

[52] **U.S. Cl.** .......... **336/70,** 336/147
[51] **Int. Cl.** .......... **H01f 15/14**
[50] **Field of Search** .......... 336/145, 146, 147, 150, 69, 70; 323/43.5, 48, 49

[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 742,926 | 11/1903 | Stuant .......... | 336/146 |
| 879,252 | 2/1908 | Fortescue .......... | 336/145 |
| 1,873,824 | 8/1932 | Cole et al. .......... | 336/145 |
| 3,452,311 | 6/1969 | Beck et al. .......... | 336/70 |

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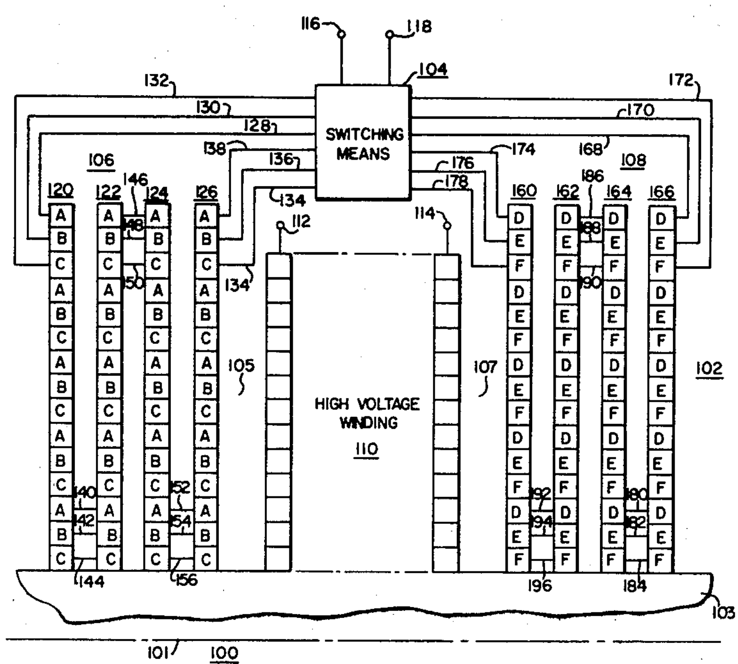
**ABSTRACT:** An electrical transformer including first and second windings, and a switch connected to the first winding for selectively providing a plurality of different output voltage ratings, such as required by mobile transformers. The first winding includes a plurality of discrete or separate electrical paths constructed to provide a substantially equal leakage reactance from each electrical path to the adjacent winding. The plurality of electrical paths are connected in various series-parallel arrangements by the switch, with each arrangement providing maximum KVA per pound of electrical conductor, and reduced oscillatory voltage magnitudes, by actively utilizing each electrical path in each switching arrangement.



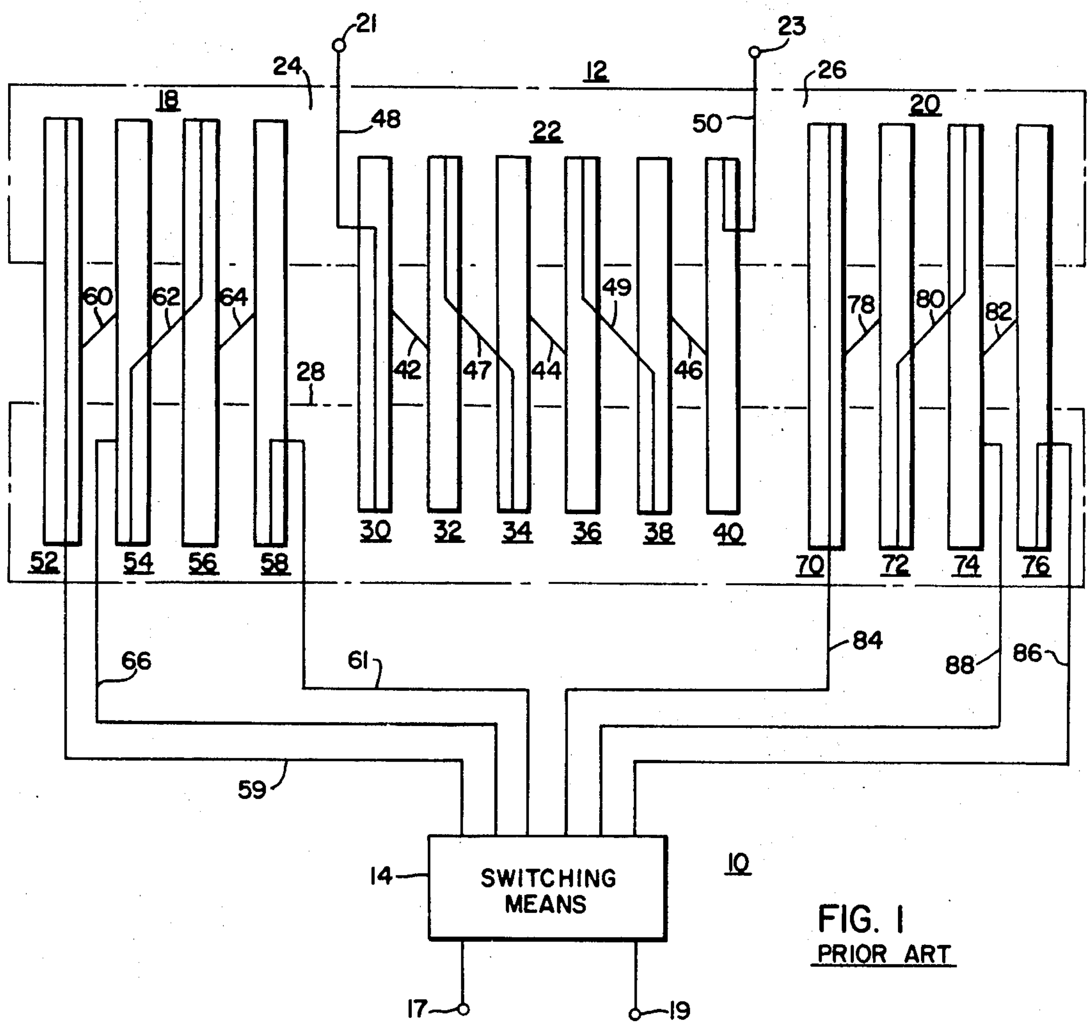
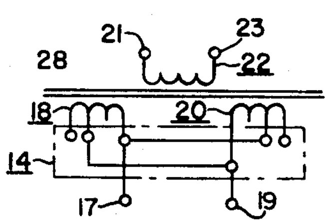
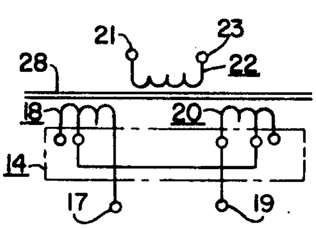


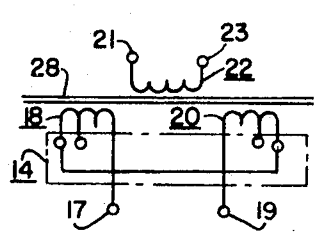

FIG. 1
PRIOR ART




PRIOR ART
FIG. 2A




PRIOR ART
FIG. 2B




PRIOR ART
FIG. 2C

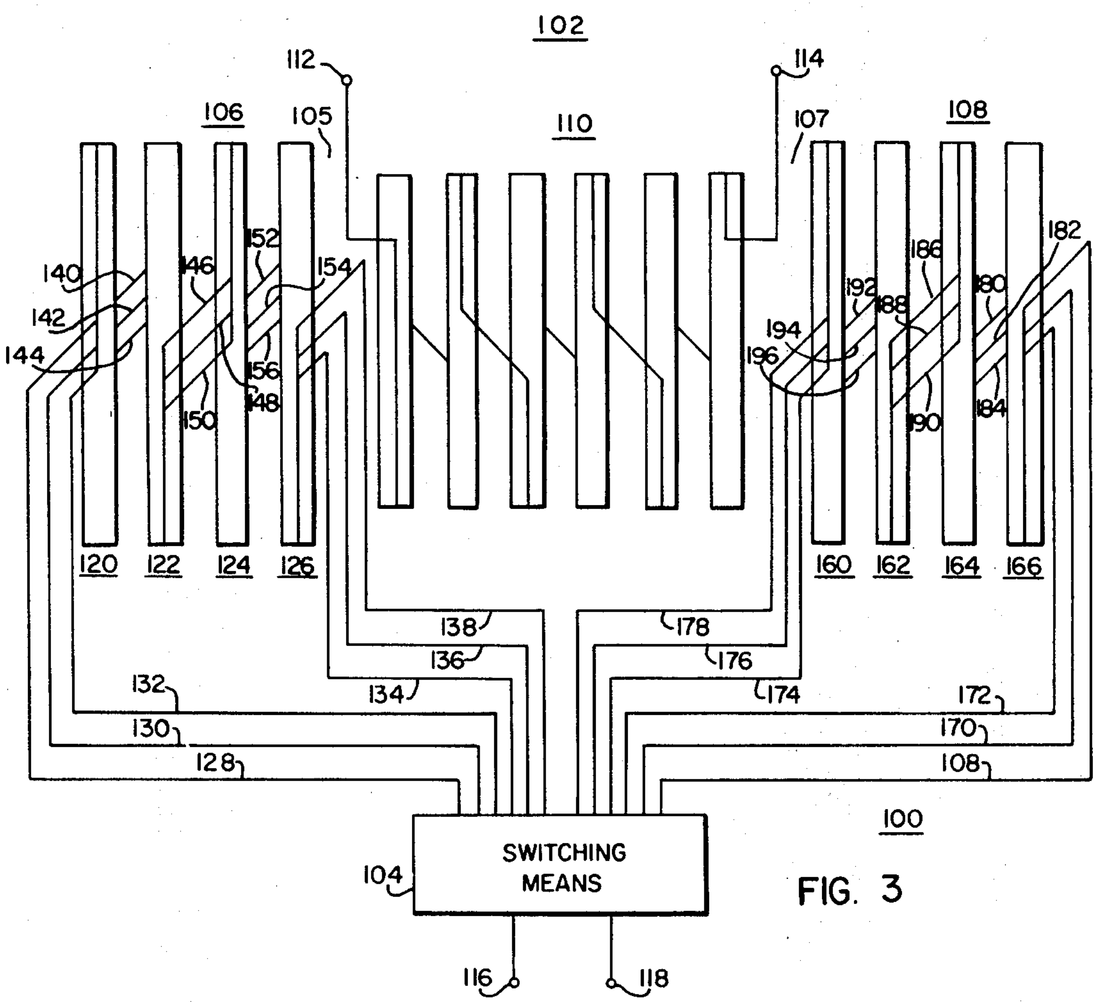



FIG. 3

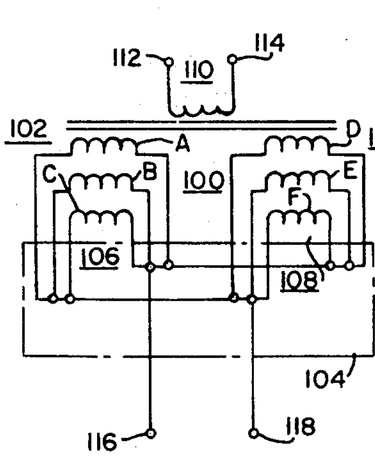



FIG. 5A

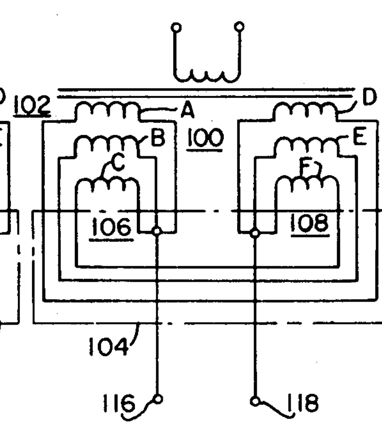



FIG. 5B

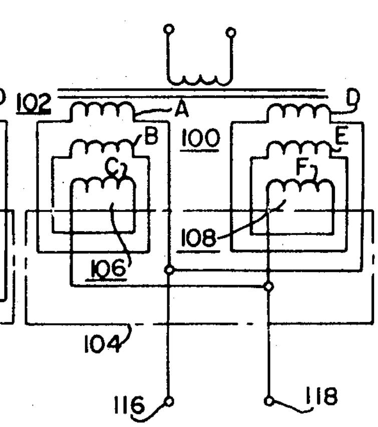



FIG. 5C

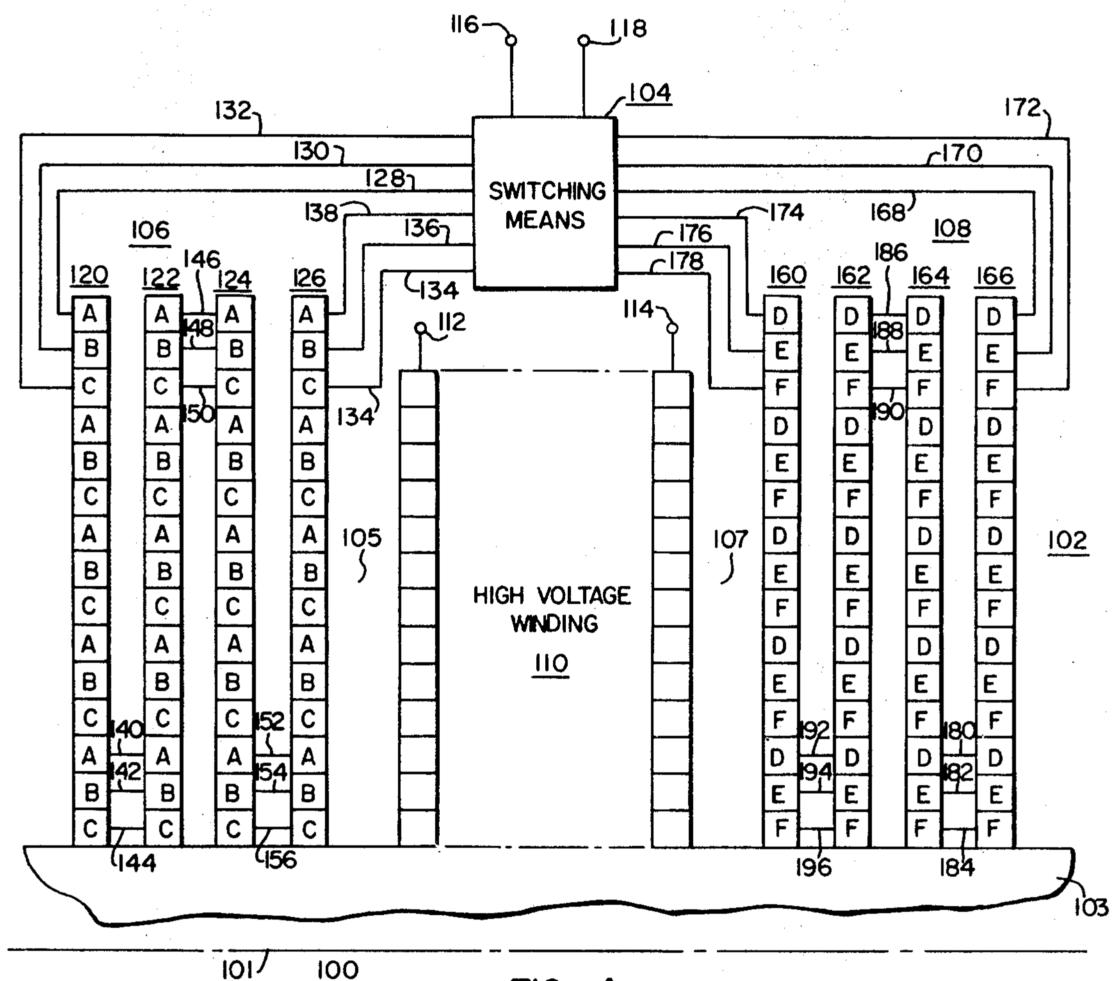

116
118
104
132
130
128
172
170
168
SWITCHING MEANS
138
136
134
174
176
178
106
108
146
186
120
122
124
126
160
162
164
166
148
150
188
190
112
114
105
107
102
HIGH VOLTAGE WINDING
110
140
142
152
154
192
194
180
182
144
156
196
184
103
101
100

FIG. 4

# ELECTRICAL TRANSFORMER

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates in general to electrical power transformers, and more specifically, to electrical transformers of the type suitable for mobile operation, having a winding connectable to provide a plurality of different convention voltage ratings.

2. Description of the Prior Art

Electrical power transformers of the type which have at least one of their windings constructed for series-parallel connection via suitable switching means, should be constructed to have equal leakage reactance from each parallel winding path to the outer windings, in every position of the switch, in order for the parallel paths to equally divide the load current. Mobile transformers, i.e., those which are used to temporarily take the place of other transformers in a power system, are usually designed for series-parallel operation to make them applicable to distribution systems of different voltage ratings. Since the mobile transformer is moved to the desired operating site by a truck, it is important to obtain the maximum KVA rating per pound of transformer, at all voltage ratings, to provide the desired flexibility at minimum weight and cost.

Conventional shell-form transformer construction, wherein the high- and low-voltage windings are axially spaced, offers the greatest flexibility from the impedance standpoint, when one or more of the transformer windings are connectable through series-parallel switching means, to provide a plurality of different voltage ratings, However, where shell-form construction is used for mobile transformers, it is desirable to limit the number of high-low spaces, i.e., the space between axially adjacent high- and low-voltage winding portions, in order to provide the largest KVA rating per pound of transformer. Increasing the number of high-low spaces increases the axial length of the stack of pancake coils which make up the high- and low-voltage windings, which increases the size of the magnetic core, resulting in an overall increase in the size, weight and cost of the apparatus.

Using construction techniques of the prior art, obtaining substantially equal leakage reactances from the plurality of electrical paths to the adjacent windings, in the winding connected to the series-parallel switch, requires increasing the number of high-low spaces, resulting in deleteriously affecting the size, weight and cost of the transformer. On the other hand, limiting the number of high-low spaces to a number such as two, may result in unequal leakage reactances from the parallel paths to the adjacent windings, and may create other undesirable arrangements, in one or more positions of the series-parallel switch, such as creating "floating" or unconnected ends of certain of the winding portions, which oscillate at high-voltage magnitudes during a surge or impulse voltage, and creating idle winding portions which result in added weight for the KVA transformed.

It would be desirable to provide a new and improved shell-form transformer arrangement for transformers having a winding connectable to provide any one of a plurality of different voltage ratings, through a series-parallel switch, which arrangement provides substantially equal leakage reactances from the parallel paths of the switched winding to the adjacent windings, in all portions of the series-parallel switch, while limiting the number of high-low spaces, eliminating "floating" ends, and eliminating idle winding portions.

## SUMMARY OF THE INVENTION

Briefly, the present invention is a new and improved transformer having a first winding connectable through a series-parallel switch to provide a plurality of different voltage ratings, and a second winding. The first and second windings are axially adjacent one another, with the first winding having first and second spaced winding sections, and with the second winding being disposed between the spaced sections of the first winding. The first and second sections of the first winding each have a plurality of different electrical paths, with the electrical paths proceeding completely through their associated winding section, to provide a substantially equal leakage reactance from each path to the second winding. The ends of the electrical paths, of both the first and second winding sections, are connected to a series-parallel switch. The series-parallel switch utilizes all of the winding paths in each position of the switch, to transform the maximum KVA per pound of electrical conductor, as well as eliminating floating or unconnected windings which may oscillate upon surge impulse voltages.



## BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be more readily understood and its advantages more apparent, when considered in view of the following detailed description of exemplary embodiments thereof, taken in connection with the accompanying drawings, in which:

FIG. 1 is a plan view of a transformer constructed according to the teachings of the prior art;

FIGS. 2A, 2B and 2C are schematic diagrams of the transformer switch arrangement shown in FIG. 1, illustrating three different series-parallel switching arrangements;

FIG. 3 is a plan view of a transformer-switch arrangement constructed according to the teachings of the invention;

FIG. 4 is a fragmentary elevational view, in section, of the transformer-switch arrangement shown in FIG. 3; and

FIGS. 5A, 5B and 5C are schematic diagrams of the transformer-switch arrangement shown in FIGS. 3 and 4, illustrating three different series-parallel switching arrangements.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, and FIG. 1 in particular, there is shown a plan view of a transformer-switching arrangement 10 constructed according to the teachings of the prior art. Transformer-switching arrangement 10 includes a transformer 12 and switching means 14, interconnected to provide a plurality of different transformer ratios, such as required by mobile transformers. Transformer 10 may be of conventional shell-form construction, and may be single or polyphase. Since each phase of a polyphase system would be similar, only a single phase is illustrated in FIG. 1 to simplify the drawings.

Transformer 12 includes a first or low-voltage winding having first and second axially spaced winding sections 18 and 20, respectively, and a second or high-voltage winding 22 disposed in the space between the first and second winding sections, providing first and second high-low spaces 24 and 26, respectively. Winding 22 has terminals 21 and 23 adapted for connection to a source of alternating potential, and sections 18 and 20 of the first winding are connected to terminals 17 and 19 via switching means 14, with terminals 17 and 19 being adapted for connection to an electrical distribution system.

Sections 18 and 20 of the first winding, and the second winding 22, each have a plurality of pancake or disc-type coils, usually having the outer configuration of a round cornered square, with all of the pancake coils being stacked with their openings in alignment on a winding leg of a suitable magnetic core, such as winding leg 28 shown in dotted outline. Each pancake coil has a plurality of conductor turns formed by winding an insulated conductor having one or more conductive strands, about a winding mandrel. The high-voltage winding 22 has plurality of pancake coils, such as pancake coils 30, 32, 36, 38 and 40 which are interconnected in series with start-start, finish-finish connections. A start-start connection is a connection between the innermost turns of adjacent pancake coils, while a finish-finish connection is an interconnection between the outermost turns of adjacent pancake coils. Thus, alternate pairs of pancake coils may be connected with start-start connections 42, 44 and 46, while the remaining adjacent pancake coils are interconnected with finish-finish connections 47 and 49. The outermost ends of the pancake coils located at opposite ends of the winding **22** are connected to terminals **21** and **23** via conductors **48** and **50**, respectively.

The first section **18** of the first or low voltage winding includes a plurality of pa pancake coils, such as pancake coils **52**, **54**, **56** and **58**, which are serially connected with start-start, finish-finish connections, Pancake coils **52** and **54** are interconnected with start-start connection **60**, pancake coils **54** and **56** are interconnected with finish-finish connection **62**, and pancake coils **56** and **58** are interconnected with start-start connection **64**. The pancake coils **52** and **58** located at the ends of the first winding section **18** are connected to switching means **14**, via conductors **59** and **61**, and a tap lead **66** is connected from a predetermined point intermediate the ends of the first winding section, to the switching means **14**.

The second section **20** of the first winding includes a plurality of pancake coils, such as pancake coils **70**, **72**, **74** and **76**, which are serially connected with start-start, finish-finish connections. Pancake coils **70** and **72** are interconnected with a start-start connection **78**, pancake coils **72** and **74** are interconnected with a finish-finish connection **80**, and pancake coils **74** and **76** are interconnected with a start-start connection **82**. The pancake coils **70** and **76** located at the ends of the second winding section **20** are connected to switching means **14** via conductors **84** and **86**, and a tap lead **88** is connected from a predetermined point intermediate the ends of the second winding section **20**, to the switching means **14**.

The transformer switching arrangement **10** shown in FIG. **1** may be connected to provide three standard output voltages, for example 2.4 kv. 4.8 kv. and 7.2 kv., according to the position selected by switching means **14**. For example, the lowest voltage rating may be achieved by connecting the portion of winding section **18** between leads **66** and **61**, and the portion of winding section **20** between leads **84** and **88**, in parallel. The intermediate voltage rating may be achieved by connecting these same two sections in series, and the highest voltage rating may be achieved by connecting the complete winding sections **18** and **20** in series, as shown in the schematic diagrams of FIGS. **2A**, **2B** and **2C**, respectively. The disadvantages of this prior art arrangement are readily apparent by observing the schematic diagrams shown in FIGS. **2A** and **2B**, as in both of the arrangements shown in these figures there are unconnected winding portions, having floating ends which may oscillate during impulse voltage conditions, as well as resulting in added weight per KVA transformed, due to the idle winding portions.

FIG. **3** is a plan view of a transformer-switching arrangement **100**, constructed according to the teachings of the invention, which overcomes the disadvantages of the prior art arrangement shown in FIG. **1**. The transformer-switching arrangement **100** shown in FIG. **3** includes a transformer **102** and switching means **104**, interconnected to provide a plurality of different transformer ratios, suitable for use as a mobile transformer. Transformer includes a first winding having first and second axially divided or spaced sections **106** and **108**, and a second winding **110** which is disposed between the spaced sections of the first winding. The first and second windings each have a plurality of pancake-type coils, with the pancake coils being disposed with their openings in alignment on a common leg of a magnetic core (not shown) with the winding arrangement either being a single-phase transformer, or a single phase of a polyphase transformer Winding **110**, which may be the high-voltage winding, is connected to terminals **112** and **114**, which are adapted for connection to a source of alternating potential. Winding **110** may be constructed and arranged similar to the winding **22** shown in FIG. **1**, and hereinbefore described.

The first and second winding sections **106** and **108** of the first winding, however, are constructed in an entirely different manner than the first and second winding sections of the transformer shown in FIG. **1**, with each of the pancake coils of the first and second winding sections being constructed of a plurality of conductors, with the number of conductors being equal to, or some fraction of, the desired series to multiple ratio. If the series to multiple ratio is three to one, then three conductors will be used to construct each pancake coil of each winding section. This construction of the pancake coils of the first and second winding sections **106** and **108** may be more readily understood by referring to FIG. **4**, which is a fragmentary elevational view of transformer **102** shown in FIG. **3**. Only a portion of the pancake coils are shown in FIG. **4**, as they would be symmetrical about centerline **101**.

As illustrated in FIG. **4**, three conductors, referenced A, B and C, may be radially wound together to provide each of the pancake coil has three electrical paths therethrough. The three electrical paths of the pancake coils of the first winding section **106** are connected in series, to provide three series paths which extend completely through the first winding section **106**. For example, pancake coils **120** and **122** have their A, B and C paths interconnected via start-start connections **140**, **142 144**, respectively, the A, B and C paths of pancake coils **122** and **124** are interconnected via finish-finish connections **146**, **148** and **150**, respectively, and the A, B and C paths of pancake coils **124** and **126** are interconnected via start-start connections **152**, **154** and **156**, respectively. The ends of the A, B and C electrical path at one end of winding section **106** are connected to switching means **104** via conductors **132**, **130** and **128**, respectively, and the ends of the A, B and C paths at the other end of winding section **106** are connected to switching means **104** via conductors **138**, **136** and **134**, respectively.

In like manner, winding section **108** has a plurality of pancake coils, such as pancake coils **160 162**, **164** and **166**, with each of these pancake coils being constructed to have three separate paths therethrough, and the three electrical paths through each pancake coil are serially connected to provide three series paths throughout the complete winding section **108**. For example, the three electrical paths through winding section **108** may be termed the D, E and F paths, with the D, E and F paths of pancake coils **166** and **164** being interconnected with start-start connections **180**, **182** and **184**, respectively, the D, E and F paths of pancake coils **164** and **162** interconnected with finish-finish connections **186**, **188** and **190**, respectively, and the D, E and F paths of pancake coils **162** and **160** interconnected with start-start connections **192**, **194** and **196**, respectively. The ends of the D, E and F paths at one end of winding section **108** are connected to switching means **104** via conductors **168**, **170** and **172**, respectively, and the ends of the D, E and F paths at the other end of winding section **108** are connected to switching means **104** via conductors **174**, **176** and **178**, respectively. Thus, all of the electrical paths of each of the winding sections **106** and **108** are coextensive with one another, each completely extending through its associated winding section, and thus providing substantially the same leakage reactance from each electrical path to the high-voltage winding **110**.

In addition to providing a substantially equal leakage reactance from each of the paths of each winding section **106** and **108** to the high-voltage winding **110**, high-voltage oscillations are eliminated, and maximum KVA per pound of conductor is obtained, by switching arrangements which utilize all of the winding paths, in every position of the switching means. For example, assuming that voltage ratings of 2.4 kv., 4.8 kv. and 7.2 kv. are required, the lowest voltage rating may be achieved by a position of switch **104** which connects each electrical path of the first and second winding sections **106** and **108** directly between the output terminals **116** and **118**. FIG. **5A** is a schematic diagram of the transformer-switching arrangement **100**, illustrating the connection of the electrical paths by switching means **104** to obtain the lowest voltage rating.

The intermediate voltage position of switching means **104** connects the electrical paths of the first and second winding sections **106** and **108** in serially connected pairs, with each pair including an electrical path, from each of the first and second winding sections, **106** and **108** respectively and then connects each serially connected pair directly between the output terminals **116** and **118**. Thus, as illustrated in the schematic diagram of FIG. **5B**, one end of path A may be connected to terminal **116**, the other end may be connected to one end of path B, and the other end of path B and may be connected to terminal **118**. In like manner paths B and E are serially connected between terminals **116** and **118**, and paths C and F are serially connected between terminals **116** and **118**.

The highest voltage rating is achieved by connecting the electrical paths of each of the first and second winding sections **106** and **108** in series, respectively, and connects each of the two groups of serially connected electrical paths directly between the output terminals **116** and **118**. More specifically, as shown in FIG. **5C**, this arrangement may be achieved by connecting one end of path A to terminal **116**, the other end of path A to an end of path B, the other end of path B to one end of path C, and the other end of path C to terminal **118**. In like manner, the paths of winding section **108** are serially connected, with one end of path D being connected to terminal **116**, its other end being connected to one end of path E, the other end of path E being connected to one end of path F, and the remaining end of path F being connected to terminal **118**. The switching arrangement shown in FIGS. **5A**, **5B** and **5C** provide three common voltage ratings, while actively using each path of each winding section, eliminating idle winding portions and floating winding ends.

In addition to providing a substantially equal leakage reactance from each electrical path of each winding section to the adjacent winding **110**, the interleaving of the paths in each pancake coil increases the series capacitance of the pancake coils and the winding sections, which distributes surge potentials more uniformly across the pancake coils and winding sections.

While the invention has been described with the plurality of paths in each pancake coil being radially disposed, it would also be suitable in certain applications to wind the pancake coils such that the paths are side-by-side, i.e., axially instead of radially disposed.

In summary, there has been disclosed a new and improved transformer-switching arrangement suitable for mobile transformers, which provides a plurality of voltage ratings while utilizing only two high-low spaces, and which forces an equal distribution of lead current between parallel connected paths, since all of the parallel connected paths have a substantially equal leakage reactance to the high-voltage winding **110**. Further, the disclosed switching arrangement actively utilizes every electrical path in every switching arrangement, eliminating high-voltage oscillations which may occur with prior art arrangements, such as due to switching or lightning surges. Still further, since all of the conductor material is actively utilized each position of the series-parallel switch, maximum KVA transformed per pound of conductor is achieved, resulting in reduced size, weight and cost of the apparatus, compared with certain prior art arrangements.



I claim as my invention:

**1.** An electrical transformer comprising:

a magnetic core including a leg portion,

a first winding portion disposed about said leg portion having first and second axially spaced winding sections,

a second winding portion disposed about said leg portion, between said first and second winding sections,

each of said first and second winding sections having a plurality of electrical paths which proceed completely through their associated winding sections,

first and second terminals,

and switching means connected to said first and second winding sections and to said first and second terminals, said switching means having a plurality of positions, including a position which connects each electrical path of said first and second winding sections directly between said first and second terminals, a position which connects the electrical paths of said first and second winding sections in serially connected pairs, with each pair including an electrical path from each of said first and second winding sections, and connects each serially connected pair directly between said first and second terminals, and a position which connects the electrical paths of each of said first and second winding sections in series, respectively, and connects each of the resulting two groups of serially connected electrical paths directly between said first and second terminals.

**2.** The electrical transformer of claim **1** wherein each of the first and second winding sections have a like numbered plurality of electrical paths.

**3.** The electrical transformer of claim **1** wherein the first and second winding sections each include a plurality of axially spaced pancake coils each having a plurality of conductor turns, with each pancake coil having conductor turns from all of the electrical paths associated with the winding section of which the pancake coil is part.

**4.** The electrical transformer of claim **3** wherein the conductor turns of the plurality of electrical paths in each pancake coil are radially interleaved.

**5.** The electrical transformer of claim **1** wherein each of the first and second winding sections include three electrical paths.