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BUCK BOAST TRANSFORMER VOLTAGE CONTROLLER WITH TAP CHANGING TRANSFORMER SYSTEM

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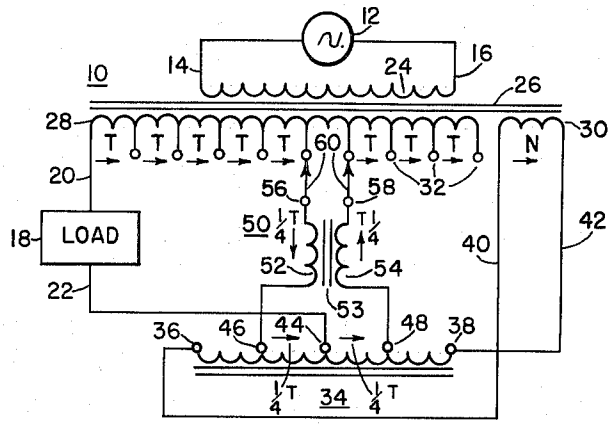


Fig. 1.

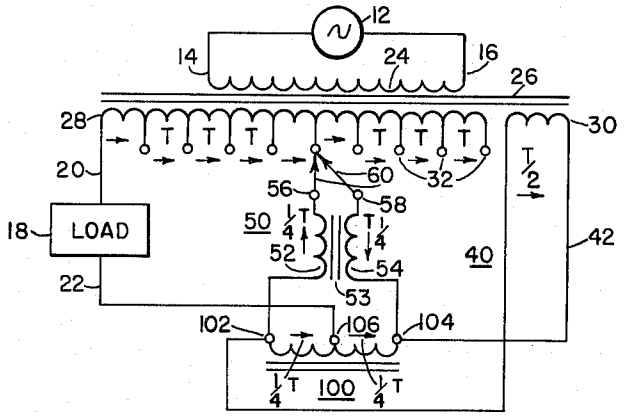


Fig. 2.

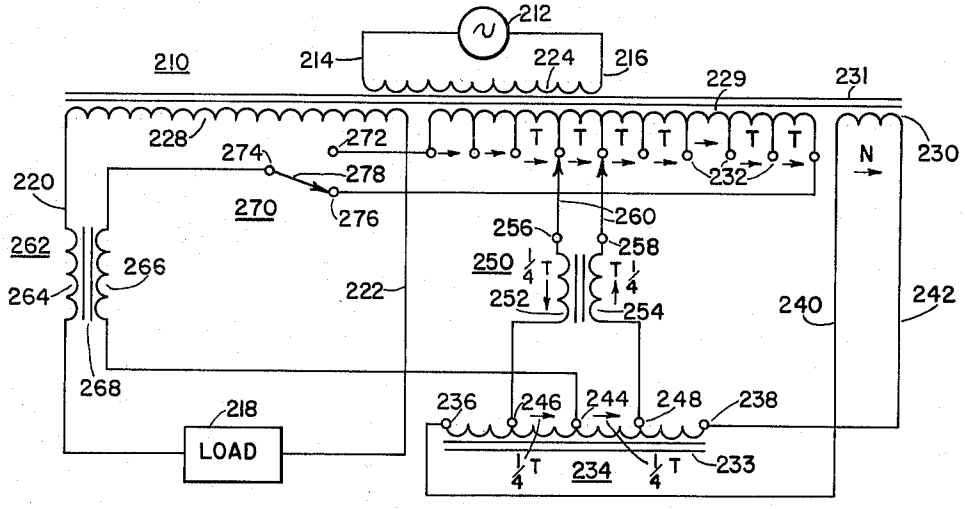


Fig. 3.

WITNESSES

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BUCK BOOST TRANSFORMER VOLTAGE CONTROLLER WITH TAP CHANGING TRANSFORMER SYSTEM

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This invention relates to apparatus for adjusting or regulating the voltage of alternating current electric circuits, and more particularly, to transformer tap changing systems.

Tap changing under load in voltage regulating or adjusting apparatus, such as step-type voltage regulators and tap changing transformers, must provide a continuous flow of power to the load while the tap is being changed. This means that two taps must be bridged some time during the tap change. To prevent excessive current flow between taps during the bridging sequence, it is common practice to utilize a split or mid-tapped bridging reactor, such as a preventive autotransformer, to permit the transition from one tap position to another tap position of the equipment. The bridging reactor is normally short circuited when the associated tap changing equipment is on certain positions, while on other positions of said tap changing equipment, the bridging reactor, as its name implies, bridges two transformer tap connections. When in the bridging position, the reactor presents a high reactance to circulating currents, thus protecting the transformer winding, while its low impedance to load current permits operation on the bridging position to obtain voltages which are substantially midway between the transformer tap connections.

To reduce the kva. rating of the bridging reactor and also introduce a substantially constant reactive load into the system for all positions of the associated tap changing equipment, tap changing systems of the prior art, such as those disclosed in U.S. Reissue Patent 21,854 and U.S. Patent 3,015,057, provide various means for impressing a half-tap voltage across the bridging reactor. This half-tap voltage divides across the bridging reactor and is in opposition to the full tap voltage impressed upon the reactor when the tap changing equipment is in the bridging position. Since the full tap voltage also divides evenly across each half of the bridging reactor or preventive autotransformer, the result is that each half of said reactor has a one-fourth tap voltage impressed across it. When the tap changing equipment short circuits the reactor, the full tap voltage no longer opposes the one-half tap voltage across the bridging reactor. However, each half of the bridging reactor still has one-fourth tap voltage impressed across it, but of opposite polarity. Therefore, the reactive load is the same for all tap positions and the kva. requirement of the bridging reactor has been reduced, because the voltage across said reactor has been reduced by one-half.

The above-mentioned systems, however, are impractical on many designs of step regulators and tap changing transformers, as they require that the number of turns between successive taps of the regulating winding be divisible by four. For example, in U.S. Reissue Patent 21,854, auxiliary windings are used which develop a one-fourth tap voltage. The full tap winding thus must have four times the turns of the auxiliary winding. U.S. Patent 3,015,057, uses a portion of the main transformer winding to develop a one-half tap voltage, and since said portion of winding is mid-tapped, to obtain proper balance it must contain an even number of turns. The number of turns between taps on the regulating winding is thus twice an even number, which produces a product divisible by four. It is, therefore, desirable to provide a transformer tap changing system which has all the advantages of the tap changing systems of the above-mentioned patents, as well as the additional advantage of eliminating the requirement that the number of turns between successive taps on the regulating winding be divisible by four.

It is an object of this invention to provide a new and improved transformer tap changing system.

Another object of this invention is to provide a transformer tap changing system in which the kva. of the bridging reactor is reduced.

A further object of this invention is to provide a transformer tap changing system in which the reactive load introduced by the bridging reactor included in said system is substantially the same for all positions of the associated tap changing equipment.

Another object of this invention is to provide a tap changing system in which the kva. of the bridging reactor is reduced and the reactive load introduced by said reactor is substantially the same for all positions of the tap changing equipment, without the requirement that the number of turns between successive taps of the regulating winding be divisible by four.

Briefly, the present invention accomplishes the above cited objects by providing an auxiliary reactor or autotransformer connected across an additional regulating transformer winding section to provide a source of a one-half tap voltage for the bridging reactor or preventive autotransformer, plus a midpoint of said one-half tap voltage. More specifically, by connecting an auxiliary reactor or autotransformer across an additional regulating winding, the turns of said auxiliary reactor or autotransformer can be chosen to provide a voltage which is equal to one-half of the voltage between successive taps on the regulating winding, plus a midpoint of said one-half tap voltage, thus allowing the number of turns between successive taps of the regulating winding to be any desired number. The use of the preventive autotransformer or bridging reactor is thus extended to make its use practical on substantially all step-regulator and tap-changing transformer designs.

Further objects and advantages of the invention will become apparent as the following description proceeds and features of novelty which characterize the invention will be pointed out in particularity in the claims annexed to and forming a part of this specification.

For a better understanding of the invention, reference may be had to the accompanying drawings, in which:

FIGURE 1 is a schematic diagram of circuits and apparatus in a transformer tap changing system showing one embodiment of the invention;

FIG. 2 is a schematic diagram of circuits and apparatus in a transformer tap changing system showing another embodiment of the invention; and

FIG. 3 is a schematic diagram of circuits and apparatus in a transformer tap changing system showing still another embodiment of the invention.

Referring now to the drawings, and FIG. 1 in particular, a transformer **10** is illustrated which is connected to be supplied with electrical energy or power from a suitable source of alternating current, as indicated at **12**, through primary power circuit conductors **14** and **16**, and to deliver electric energy or power to a secondary or load circuit, including a load **18**, through the secondary circuit conductors **20** and **22**.

In particular, the transformer **10** includes primary winding **24**, secondary winding **28**, and an additional regulating winding **30**. The secondary winding **28** has a plurality of tap connections **32** which are electrically spaced apart from one another to provide substantially the same potential, as indicated at T, and the same number of turns

between each adjacent pair of tap connections 32. The primary winding 24 is connected to the source of alternating potential 12 through primary line conductors 14 and 16, and the secondary winding 28 is connected to the load 18 through secondary line conductors 20 and 22. The primary and secondary winding sections 24 and 28, and the regulating winding section 30 are inductively disposed on a magnetic core structure 26, which may be of any conventional type.

Auxiliary autotransformer 34 is connected across additional regulating winding 30. More specifically, winding 30, which may have any desired number of turns, is connected to terminals 36 and 38 of auxiliary autotransformer 34 through line conductors 40 and 42. Auxiliary autotransformer 34 includes tap connections 44, 46 and 48. Tap connections 46 and 48 are located a certain number of turns on each side of the tap connection 44, with the number of turns selected to provide a voltage across tap connections 46 and 48 equal to one-half of the voltage T between successive taps 32 on the secondary winding 28. Therefore, tap 44 may be arbitrarily selected just as long as there are sufficient turns on each side of tap 44 for taps 46 and 48 to be selected to give a voltage of one-fourth T between taps 46 and 44 and between taps 44 and 48. Tap connections 46 and 48 of auxiliary autotransformer 34 are connected to bridging reactor or split preventive autotransformer 50. Bridging reactor 50 includes coil sections 52 and 54 and magnetic core 53, with tap connection 46 of auxiliary autotransformer 34 being connected to coil section 52 and tap connection 48 being connected to coil section 54. The turns of said coil sections 52 and 54 are substantially equal, so that the voltage across each section is substantially the same. Bridging reactor 50 is connected to terminals 56 and 58 of switching means or mechanism 60, which may be of any suitable type. Switching means 60 selectively connects the same or adjacent tap connections 32 of secondary winding 28 in circuit relation with the bridging reactor or preventive autotransformer 50. The switching means 60 is shown in the bridging position with respect to the tap connections 32 in FIG. 1.

As hereinbefore mentioned, the number of turns in additional regulating winding 30 may be any desired value. If the number of turns exceeds one-half the number of turns between successive taps 32 of the regulating winding 28, the connections of winding 30 to auxiliary autotransformer 34 and the connections of preventive autotransformer or bridging reactor 50 to said auxiliary autotransformer are substantially as shown in FIG. 1. In other words, winding 30 is connected across the entire winding of transformer 34 at terminals 36 and 38 and bridging reactor or preventive autotransformer 50 is connected to tap connections 46 and 48. Tap connections 46 and 48 are located to produce one-fourth of the voltage T between successive taps 32 across each of the two sections 52 and 54 of bridging reactor or autotransformer 50. On the other hand, if the number of turns in winding 30 is less than one-half the number of turns between successive taps, then the split reactor or preventive autotransformer 50 will be connected across the whole auxiliary autotransformer 34, with winding 52 being connected to terminal 36 and winding 54 being connected to terminal 38. Lines 40 and 42 from the additional regulating winding 30 will be connected to tap connections 48 and 46 respectively, with tap connections 46 and 48 being so located that the voltage applied to each of the coil sections 52 and 54 of bridging reactor 50 is equal to one-fourth of the voltage T between successive taps 32 of secondary winding 28.

In summary, the number of turns between adjacent taps 32 on secondary winding 28 may be chosen to be of any desired value, odd or even, and the number of turns N on additional regulating winding 30 may also be any desired value. A voltage equal to one-half the voltage T between successive tap connections 32 on secondary winding 28, with a tap providing a voltage equal to one-fourth of the voltage T on each side of said tap, is provided by auxiliary autotransformer 34.

In the operation of the transformer tap changing system shown in FIG. 1, when the switching means 60 is in the bridging position as shown in FIG. 1, the potential equal to one-half the voltage produced across adjacent tap connections 32 is provided by auxiliary autotransformer 34 and impressed across coil sections 52 and 54 of bridging reactor or preventive autotransformer 50, and opposes the potential T between the adjacent pair of tap connections 32 to which the switching means 60 is connected. The total potential across the bridging reactor or preventive autotransformer 50 is, therefore, equal to the difference between the potential T between the adjacent pair of tap connections 32 of the secondary winding 28, to which the switching means 60 is connected, and the potential equal to one-half the voltage T produced by auxiliary autotransformer 34, or a total potential of one-half T. Since the potential across bridging reactor 50 divides in a substantially equal manner across coil sections 52 and 54, the potential across each of said coil sections is substantially equal to one-fourth the potential T produced between the adjacent pair of tap connections 32 of secondary winding 28. In addition, since the total potential applied to bridging reactor 50 is substantially equal to one-half the potential between the adjacent pair of tap connections 32 of secondary winding 28, the kva. rating of the bridging reactor 50 is reduced to substantially one-half that of a conventional bridging reactor, which is subjected to the total potential between the adjacent tap connections.

On the other hand, when the switching means 60 connects coil section 52 of bridging reactor 50 to same tap connection 32 as coil section 54 of bridging reactor 50, as shown in FIG. 2, the potential applied to bridging reactor 50 is due solely to that produced by auxiliary autotransformer 34, or one-half the potential T. Since the potential across the bridging reactor 50 in the non-bridging position of switching means 60 is still one-half T, or the same as it was for the bridging position of tap changing means 60, the potential across each coil section 52 and 54 of bridging reactor 50 is therefore substantially equal to one-fourth the potential between each pair of adjacent tap connections 32 of the secondary 28. Since the circulating current and the potential across coil sections 52 and 54 of bridging reactors 50 is of the same magnitude for both the bridging and non-bridging positions of the switching means 60, the reactive load introduced by the transformer tap changing system due to the bridging impedance 50 is the same for all positions of the switching means 60, thus substantially eliminating the inequalities in line reactive current between bridging and non-bridging positions of the switching means 60, which would otherwise be introduced by alternately exciting and short circuiting the bridging reactor 50.

FIG. 2, which was referred to earlier to show the non-bridging position of switching means 60, is a schematic diagram of another embodiment of the invention, with like reference numerals in FIG. 2 referring to like components in FIG. 1. When the number of turns between tap connections 32 on secondary winding 28 is even, it is possible for the regulating winding 30 to have one-half the number of turns that exist between tap connections 32, and still have an integral number of turns. This allows a less complex auxiliary autotransformer to be used as shown at 100. This auxiliary autotransformer develops the half-tap voltage which is applied to the bridging reactor 50.

More specifically, when the number of turns between successive taps 32 is even, the additional regulating winding 30 may be wound with one-half said even number of turns and produce a voltage equal to one-half the voltage T produced between adjacent tap connections 32 of secondary winding 28. Therefore, to obtain a one-half tap

voltage with a mid-point, an auxiliary autotransformer **100** may be used with a tap **106**. In this instance, lines **40** and **42** from regulating winding **30** are connected across the auxiliary autotransformer **100** at terminals **102** and **104**. The windings **52** and **54** of bridging reactor **50** are also connected to terminals **102** and **104**, respectively. The tap **106** of auxiliary autotransformer **100** is connected to the load **18** through line **22**. Therefore, when the number of turns between successive taps **32** on secondary winding **28** are even, an auxiliary autotransformer **100** may be used which has a single tap **106**, with additional tap connections as shown in the auxiliary autotransformer **34** of FIG. 1 being unnecessary. Or, if an autotransformer similar to the autotransformer **34** of FIG. 1 is used, taps **36** and **46** would coincide, as would taps **38** and **48**.

FIG. 3 shows a schematic diagram of the basic circuit of FIG. 1 incorporated in voltage regulating system. In particular, a transformer **210** is illustrated which is connected to be supplied with electrical energy from a source of alternating current, as indicated at **212**, through primary power circuit conductors **214** and **216**, and to deliver electric energy to a secondary or load circuit, including a load **218**, through the secondary circuit conductors **220** and **222**.

In particular, the transformer **210** includes primary winding **224**, secondary winding **228**, main regulating winding **229**, and an additional regulating winding **230**. The regulating winding **229** has a plurality of tap connections **232** which are electrically spaced apart from each other to provide substantially the same potential, as indicated at T, and the same number of turns between each adjacent pair of tap connections **323**. The primary winding **224** is connected to the source of alternating potential **212** through the primary line conductors **214** and **216**, and the secondary winding **228** is connected to the load **218** through secondary line conductors **220** and **222**. The primary and secondary sections **224** and **228** and the regulating winding sections **229** and **230** are inductively disposed on a magnetic core structure **231** which may be of any conventional type.

Auxiliary autotransformer **234** is connected across additional regulating winding **230**. More specifically, winding **230**, which may have any desired number of turns, is connected to terminals **236** and **238** of auxiliary autotransformer **234** through line conductors **240** and **242**. Auxiliary autotransformer **234** includes tap connections **244**, **246** and **248**. Tap connections **246** and **248** are located a certain number of turns on each side of tap **244**, with the number of turns selected to provide a voltage across tap connections **246** and **248** substantially equal to one-half the voltage T between successive taps **232** on main regulating winding **229**. Tap connections **246** and **248** of auxiliary autotransformer **234** are connected to bridging reactor **250**. Bridging reactor **250** includes coil sections or portions **252** and **254** and magnetic core structure **253**, tap **246** being connected to coil section **252** and tap connection **248** being connected to coil section **254**. The turns of said coil sections **252** and **254** are substantially equal so that the voltage across each section is also substantially the same. Bridging reactor **250** is connected to terminals **256** and **258** of switching means or mechanism **260**, which may be of any suitable type. Switching means **260** selectively connects the same or adjacent tap connections **232** of main regulating winding **229** in circuit relation with bridging reactor or preventive autotransformer **250**. The switching means **260** is shown in the bridging position with respect to the tap connections **232**.

In order to regulate the electric potential supplied to load **218** through secondary line conductors **220** and **222**, a series transformer **262** may be used. A series transformer provides regulation and also isolation of the tap switching means **260** from the transformer secondary winding **228**. The series transformer **262** makes it unnecessary to design special tap changing switches that will withstand the high current or high voltages present in some transformer secondary circuits. Furthermore, the voltage and current ratings of a patricular tap changing switch may be met by simply selecting the proper turn ratio of the series transformer. Series transformer **262** includes windings **264** and **266**, which are inductively disposed on magnetic core **268**, with winding **264** being connected in a series circuit relationship with secondary winding **228** and load **218**. Variable excitation for the series transformer **262** is obtained by connecting winding **266** in a series circuit relationship with regulating winding **229**. Reversing switch **270**, having terminals **272**, **274** and **276** and current carrying member **278**, is used to connect regulating winding **229** with winding **266** of series transformer **262** in a manner that either bucks or boosts the voltage produced in secondary winding **228**. Thus, reversing switch **270** allows the secondary voltage applied to load **218** to be regulated in steps either above or below the voltage produced in secondary winding **228**, effectively doubling the regulating range of the tap changing system.

As previously mentioned, the number of turns in the additional regulating winding **230** may be any desired value. If the number of turns exceeds one-half the number of turns between successive taps **232** of the regulating winding **229**, the connections of winding **230** to auxiliary autotransformer **234** and the connections of bridging reactor **250** to said auxiliary autotransformer are substantially as shown in FIG. 3. In other words, winding **230** is connected across the entire winding of autotransformer **234** at terminals **236** and **238**, and bridging reactor or preventive autotransformer **250** is connected to taps **246** and **248**. Tap connections **246** and **248** are located to produce one-fourth of the voltage T between successive tap connections **232** across each of the two coil sections **252** and **254** of bridging reactor or autotransformer **250**. On the other hand, if the number of turns in winding **230** is less than one-half the number of turns between successive taps **232**, then the bridging reactor **50** will be connected across the whole auxiliary autotransformer **234**, with coil section **252** being connected to terminal **236** and coil section **254** being connected to terminal **238**. Lines **240** and **242** from the regulating winding **230** will be connected to tap connections **248** and **246** respectively, with tap connections **246** and **248** being so located that the voltage applied to each of the coil sections **252** and **254** of bridging reactor **50** is equal to one-fourth of the voltage T between successive tap connections **232** of regulating winding **229**.

In summary the number of turns between adjacent tap connections **232** on regulating winding **229** may be chosen to be any desired value, odd or even, and the number of turns N on additional regulating winding **230** may also be any desired value. A voltage equal to one-half the voltage T between successive tap connections **232** on regulating winding **229**, with a tap providing a voltage equal to one-fourth of the voltage T on each side of said tap, is provided by auxiliary autotransformer **234**.

In the operation of the transformer tap changing system shown in FIG. 3, when the switching means **260** is in the bridging position as shown in FIG. 3, a potential equal to one-half the potential T between successive tap connections **232** is produced by auxiliary autotransformer **234** and impressed across coil sections **252** and **254** of bridging reactor **50** and opposes the potential T between the adjacent pairs of tap connections **32** to which the switching means **260** is connected. The total potential across the bridging reactor **250** is, therefore, equal to the difference between the potential T between adjacent pairs of tap connection **232** of the regulating winding **229**, to which the switching means **260** is connected, and a potential equal to one-half the voltage T produced by auxiliary autotransformer **234**, or a total potential equal to one-half the potential between adjacent tap connection **232**. Since the potential across coil sections **252** and **254** of bridging reactor **250** is substantially the same,

the potential across each of said coil sections in substantially equal to one-fourth the potential T between the adjacent pairs of tap connections 232 of regulating winding 229. In addition, since the total potential applied to bridging reactor 50 is substantially equal to one-half the potential between adjacent pairs of tap connections 232 on regulating winding 229, the kva. rating of the bridging reactor 50 is reduced to substantially one-half that of the conventional bridging reactor which is subjected to the total potential between adjacent tap connections.

On the other hand, when switching means 260 connects coil section 252 of bridging reactor to the same tap connection 232 as coil section 254 of bridging reactor 250, the potential applied to bridging reactor 250 is due solely to that produced by auxiliary autotransformer 234 and is equal to one-half the potential T between adjacent tap connections 232 of regulating winding 229. Since the potential across bridging reactor 250 in the non-bridging position of the switching means 260 is still equal to one-half T, the same as it was for the bridging position of tap switching means 260, the potential across each coil section 252 and 254 of bridging reactor 50 is therefore substantially equal to one-fourth the potential between each pair of adjacent tap connections 232 of regulating winding 229. Since the circulating current and the potential across coil sections 252 and 254 of bridging reactor 250 is of the same magnitude for both the bridging and non-bridging positions of switching means 260, the reactive load introduced by the transformer tap changing system due to the bridging reactor 250 is the same for all positions of the switching means 260, thus eliminating the inequalities in reactive load between the different tap connections 232 of regulating winding 229, which would otherwise by introduced by bridging reactor 250.

It is of course obvious, that the circuit shown in FIG. 3 can be modified to be used with an autotransformer similar to the one shown in FIG. 2 (autotransformer 100) in the instances where the turns between adjacent tap connections 232 are an even number.

It is to be understood that a transformer-tap changing system as disclosed may be employed with autotransformers as well as with isolated winding transformers as illustrated, and with three-phase transformers rather than the single-phase units illustrated.

It will, therefore, be apparent that the circuits and apparatus embodying the teachings of this invention have the advantages of reducing the kva. rating of the bridging impedance and of maintaining the reactive load substantially constant for all positions of the switching means, without the disadvantage of requiring the number of turns between adjacent tap connections on the regulating winding to be divisible by 4. Therefore, the use of the bridging reactor or preventive autotransformer has been extended to transformer designs where it has heretofore been impractical because of core and coil design restrictions.

Since numerous changes may be made in the above-described apparatus and circuits and different embodiments of the invention may be made without departing from the spirit and scope thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

We claim as our invention:

1. In a tap changing system for transformers, a first transformer winding connected to a source of alternating potential, a second transformer winding having a plurality of tap connections with substantially the same potential difference between adjacent tap connections, a bridging reactor having first and second coil sections, autotransformer means having a plurality of tap connections, a third transformer winding connected to tap connections of said autotransformer means, switching means for selectively and sequentially connecting one end of each of said first and second coil sections of said bridging reactor to the same or adjacent tap connections of said second transformer winding, the other ends of said first and second coil sections of said bridging reactor being connected to taps on said autotransformer means such that a potential is applied to said bridging reactor that is substantially one-half the potential between adjacent tap connections of said second transformer winding and of such polarity as to limit the total potential across said bridging reactor to substantially one-half the potential between adjacent tap connections of said second transformer winding, independently of whether said switching means connects said first and second coil sections of said bridging reactor to the same or adjacent tap connections of said second transformer winding.

2. In a tap changing system for transformers, a first transformer winding connected to a source of alternating potential, a second transformer winding having one end connected to a load circuit and a plurality of tap connections with an even number of turns and the same potential difference between adjacent tap connections, a bridging reactor having first and second coil sections, an autotransformer having a tap substantially dividing said autotransformer into two equal sections and connected to said load circuit, a third transformer winding having one-half the number of turns as are between adjacent tap connections on said second transformer winding and connected across said autotransformer, switching means for selectively and sequentially connecting one end of each of the first and second coil sections of said bridging reactor to the same or adjacent tap connections of said second transformer winding, the other ends of said first and second coil sections of said bridging reactor being connected across said autotransformer such that a potential is applied to said bridging reactor that is substantially one-half the potential between adjacent tap connections of said second transformer winding and of such polarity as to limit the total potential across said bridging reactor to substantially one-half the potential between adjacent tap connections of said second transformer winding, independently of whether said switching means connects said first and second coil sections of said bridging reactor to the same or adjacent tap connections of said second transformer winding.

3. In a tap changing system for transformers, a first transformer winding connected to a source of alternating potential, a second transformer winding having a plurality of tap connections arranged to have substantially the same potential between each adjacent pair thereof, a bridging reactor having first and second coil portions, an autotransformer, a third transformer winding connected in circuit relation with said autotransformer, switching means for selectively connecting one end of each of said first and second coil portions of said bridging reactor to the same or adjacent tap connections of said second winding, the other ends of said first and second coil portion of said bridging reactor being connected in circuit relation with said autotransformer such that the potential applied to said bridging reactor is substantially one-half the potential between the tap connections of said second winding and of such polarity as to limit the potential across each portion of said bridging reactor to one-fourth of the potential between adjacent tap connections of said second transformer winding, independently of the position of said switching means.

4. In a tap changing system for transformers, a first transformer winding connected to a source of alternating potential, a second transformer winding having one end connected to a secondary circuit and a plurality of tap connections arranged to have substantially the same potential between each adjacent pair thereof, a bridging reactor having first and second coil portions each having substantially the same number of turns, a mid-tapped reactor, a third transformer winding connected in circuit relation with said mid-tapped reactor such that the potential across said mid-tapped reactor is substantially bal-

anced with respect to its mid-point, switching means for selectively connecting one end of each of said first and second coil portions of said bridging reactor to the same adjacent tap connections of said second transformer winding, the other ends of said first and second coil portions of said bridging reactor being connected in circuit relation with said mid-tapped reactor such that the potential applied to said bridging reactor is substantially one-half the potential between the tap connection of said second winding and of such polarity as to limit the potential across each portion of said bridging reactor to one-fourth of the potential between adjacent tap connections of said second winding independently of the position of said switching means, the mid-tap of said mid-tapped reactor being connected to said secondary circuit.

5. In a tap changing system for transformers, a power circuit comprising a pair of conductors, first, second and third transformer windings disposed on a magnetic core, said first transformer winding being energized by said power circuit, said second transformer winding having a plurality of tap connections spaced from one another to provide substantially the same potential between adjacent tap connections, a bridging reactor having first and second coil portions disposed on a second magnetic core, switching means for selectively connecting one end of each of said first and second portions of said bridging reactor to the same or adjacent tap connections of said second transformer winding, an autotransformer connected in circuit relation with said third transformer winding, said bridging reactor connected in circuit relation with said autotransformer, wth the ends of said first and second coil portions of said bridging reactor connected to said autotransformer so that the potential across said bridging reactor is substantially one-half the potential between the adjacent tap connections of said second transformer winding and of such polarity to limit the total potential across said bridging reactor to substantially one-half the potential between adjacent tap connections of said second transformer winding.

6. In a tap changing system for transformers, a first transformer winding connected to a source of alternating potential, a second transformer winding connected to a secondary circuit, a third transformer winding having a plurality of tap connections arranged to have the same potential difference between adjacent tap connections, a fourth transformer winding, a bridging reactor having first and second coil sections, switching means for selectively connecting one end of each of said first and second coil sections of said bridging reactor to the same or adjacent tap connections of said second transformer winding, an autotransformer having a plurality of taps connected

across said fourth transformer winding, the other end of said first and second coil sections of said bridging reactor being connected to said autotransformer such that a potential is applied to said bridging reactor that is substantially equal to one-half the potential between the tap connections of said third transformer winding and of such polarity to limit the potential across each section of said bridging reactor to one-fourth the potential between adjacent tap connections of said third transformer winding, independently of the position of said switching means, a series transformer including a first winding connected in a series circuit relationship with said second transformer winding in said secondary circuit and a second winding connected between said autotransformer and one end of said third transformer winding.

7. In a tap changing system for transformers, a first transformer winding connected to a source of alternating potential, a second transformer winding connected to a secondary circuit, a third transformer winding having a plurality of tap connections arranged to have the same potential difference and an even number of turns between adjacent tap connections, a fourth transformer winding having one-half the number of turns as between adjacent tap connections on said third transformer winding, a bridging reactor having first and second coil sections, each coil section having substantially the same number of turns, switching means for selectively connecting one end of each of said first and second coil sections of said bridging reactor to the same or adjacent tap connections of said second transformer winding, a mid-tapped reactor connected across said fourth transformer winding, the potential across said mid-tapped portion being substantially balanced with respect to its mid-tap, the other ends of said first and second coil sections of said bridging reactor being connected across said mid-tapped reactor, the potential applied to said bridging reactor being substantially equal to one-half the potential between the tap connections of said third transformer winding and of such polarity to limit the potential across each section of said bridging reactor to one-fourth the potential between adjacent tap connections of said third transformer winding independently of the position of said switching means, a series transformer including a first winding connected in a series circuit relationship with said second transformer winding in said secondary circuit and a second winding connected between the mid-tap of said mid-tapped reactor and one end of said third transformer winding.

No references cited.

LLOYD McCOLLUM, *Primary Examiner.*