Jan. 9, 1940. M. SCHWAIGER 2,186,211

REGULATING TRANSFORMER

Filed March 5, 1938 2 Sheets-Sheet 1

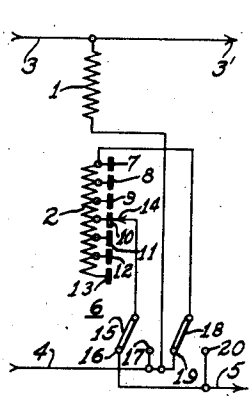


Fig. 1.

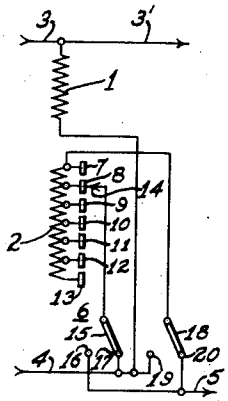


Fig. 2.

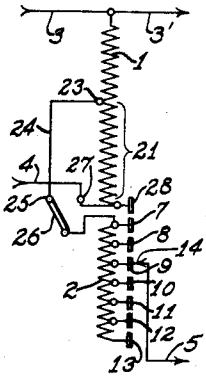


Fig. 3.

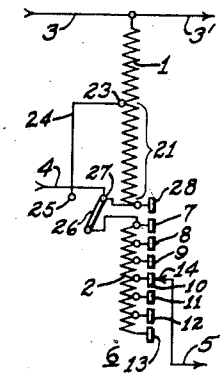


Fig. 4.

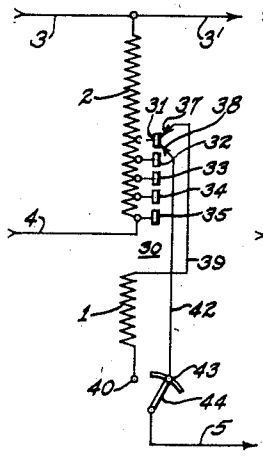


Fig. 5.

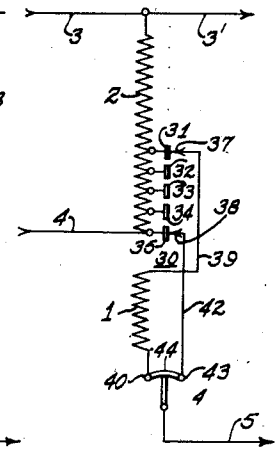


Fig. 6.

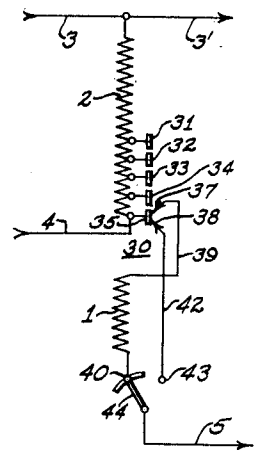


Fig. 7.

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REGULATING TRANSFORMER

Filed March 5, 1938 2 Sheets-Sheet 2

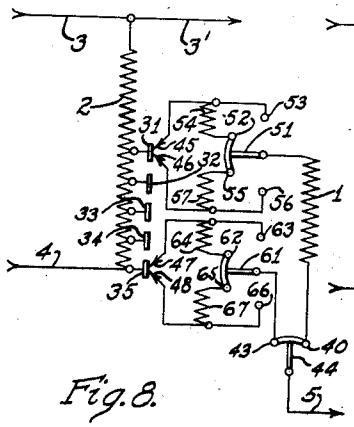


Fig. 8.

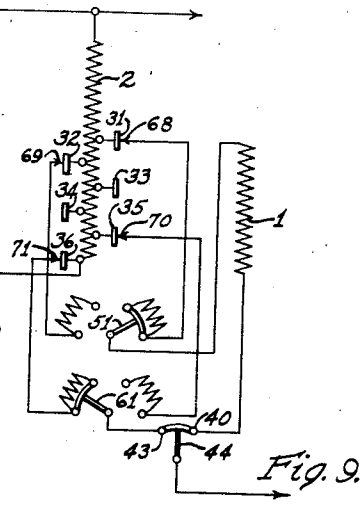


Fig. 9.

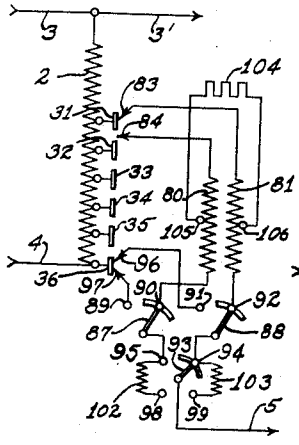


Fig. 10.

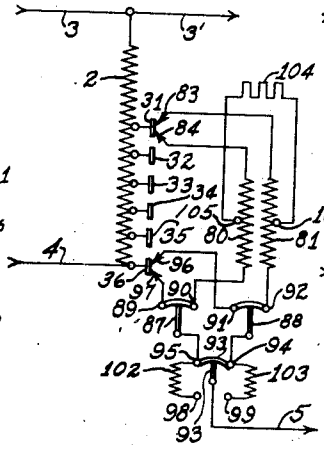


Fig. 11.

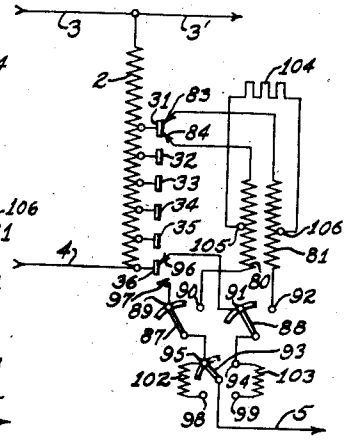


Fig. 12.

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2,186,211

UNITED STATES PATENT OFFICE

2,186,211

REGULATING TRANSFORMER

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Application March 5, 1938, Serial No. 194,117
In Germany April 7, 1937

6 Claims. (Cl. 171—119)

My invention relates to regulating transformers in which transformer taps and tap switches are provided for varying the voltage ratio between the primary and secondary circuits.

It is customary in transformers of this character to provide a fixed or unregulated winding portion and a variable or regulated winding portion, the two portions together forming an autotransformer in which the regulated portion boosts or bucks the voltage of the unregulated portion to control the secondary or output voltage in steps above and below the voltage of the supply or primary voltage. The fixed winding portion of a transformer may remain continuously energized from the primary circuit and the regulated winding portion may be included in the secondary circuit to provide a controlled increase or decrease in the voltage applied to that circuit.

Should a short circuit occur on the secondary circuit of the transformer when the regulated winding portion is connected in voltage opposition to the unregulated portion, the short circuit current may be very large due to the lowered effective reactance of the transformer.

To overcome this undesirable condition, a portion only of the unregulated winding portion may be used in series with selected parts of the regulated winding portion which is provided with taps to control the voltage in steps over a given range in voltage. After the tap selecting switch has operated throughout one range of voltage steps, a different part of the unregulated portion of the transformer winding may be connected in series with the regulated portion to provide an extended or different range of regulated voltage steps. During the changeover from one range of voltage steps to another range of voltage steps, certain switching operations are necessary which render this arrangement undesirable.

It is an object of my invention to provide a tap changing transformer in which the above enumerated disadvantages are overcome.

Other objects and advantages of my invention will be apparent from the following description of certain preferred embodiments thereof, reference being had to the accompanying drawings, in which:

Figures 1, 2, 3 and 4 illustrate prior arrangements of apparatus and circuits providing regulating transformers having a plurality of tap connections; and

Figs. 5 to 12, inclusive, illustrate apparatus and circuits arranged in accordance with several embodiments of the invention.

Referring to the drawings, Figs. 1 and 2 illustrate one known arrangement of providing variable voltage transformers in which a fixed or unregulated winding portion 1 and a variable or regulated winding portion 2 are provided, and connected to receive energy from a primary or supply circuit represented by conductors 3 and 4, and to deliver energy to a secondary or load circuit represented by conductors 3' and 5. The winding portion 1 is connected between conductors 3 and 4 as illustrated to be continuously energized in accordance with the voltage of the primary circuit. The winding portion 2 is provided with a series of taps connected to a row of contacts indicated generally at 6, and including the several contacts 7, 8, 9, 10, 11, 12 and 13 which cooperate with a movable tap selector contact 14 to form a tap changing switch. The contact 14 is connected through a movable switch contact member 15 and contact 16 to the secondary circuit conductor 5 when in the position illustrated in Fig. 1 and through contact members 15 and 17 to the circuit conductor 4 when in the position illustrated in Fig. 2. A switch contact member 18 is provided for connecting the upper end of the winding portion 2 through contact member 19 to conductor 4 when in the position illustrated in Fig. 1 and through contact member 20 to conductor 5 when in the position illustrated in Fig. 2.

When the switch members 15 and 18 are in the positions illustrated in Fig. 1, the variable winding portion 2 is so connected with respect to the fixed winding portion 1 that the voltage applied between the secondary circuit conductors 3'—5 exceeds the primary circuit voltage applied from conductors 3 and 4 to the winding portion 1 by the number of tapped parts of the winding portion 2 included in the circuit, which increases as the contact 14 is moved progressively from engagement with the contact 7 to engagement with the contact 13, in which position the maximum secondary voltage is provided.

When it is desired to supply a voltage to the secondary circuit conductors 3'—5 that is less than the voltage supplied from the primary circuit conductors 3—4 to the unregulated winding portion 1, the switch members 15 and 18 are moved to the positions shown in Fig. 2, in which positions the winding portions 1 and 2 are connected in series in reverse voltage relation, so that as the contact 14 progresses from engagement with the contact 7 along the row of tap contacts 7 to 13, the voltage applied to the secondary circuit is progressively decreased.

While the arrangement shown in Figs. 1 and 2

provides a number of voltage regulating steps in excess of the number of tap connections provided, by employing the same tap contacts both to decrease and to increase the secondary voltage with respect to the primary circuit voltage, and thus to secure a mechanical advantage, it also introduces an undesirable characteristic into the transformer when the winding portions 1 and 2 are connected in voltage opposition, as in Fig. 2, in that if a short circuit occurs on the secondary winding circuit, the reactance of the winding which normally reduces the short circuit current is greatly reduced in effectiveness.

In the circuit arrangement shown in Figs. 3 and 4, this disadvantage is avoided by providing a circuit connection from an intermediate point 23 on the unregulated winding 1 through conductor 24, switch contact members 25 and 26 to the upper end of the unregulated winding portion 2, so that in the position of the switch contact member 26 shown in Fig. 3, that portion only of the unregulated winding 1 between conductor 3 and the point 23 is included in series with parts of the regulated winding portion 2, that part of the unregulated winding indicated by the numeral 21 being excluded from the secondary winding circuit. It will be noted that in Figs. 3 and 4, the primary circuit conductors 3 and 4 are connected to opposite ends of the unregulated winding 1.

In the arrangement shown in Figs. 3 and 4 the voltages in the two sections 1 and 2 are always in the same direction, the voltage steps to provide a secondary voltage below the primary voltage being obtained by moving the contact member 14 along the row of contacts 7 to 13 with the switch contact member 26 in the position illustrated in Fig. 3. In order to obtain secondary voltages higher than the primary circuit voltage, the contact member 26 is moved into engagement with the switch contact member 27 as shown in Fig. 4, so that the secondary circuit includes the whole of the unregulated winding portion 1 together with as many of the steps of the regulated winding portion 2 as may be determined by the position of the contact 14.

When the contact member 14 is moved along the contact row to engagement with contact 13 with the switch 26 in the position illustrated in Fig. 3, the secondary voltage then corresponds to the primary voltage and before the contact member 26 is moved from engagement with the contact member 25 into engagement with the contact member 27, or from the position illustrated in Fig. 3 to the position illustrated in Fig. 4, the contact 14 must first be moved from engagement with contact 13 into engagement with an auxiliary contact 28, so that movement of the contact 26 will not interrupt the secondary winding circuit. This necessitates arranging the contact members 7 to 13 and 28 in a circular position so that the contact 14 may move in sequence from engagement with contact 13 to contact 28 and then to contact 7. This arrangement of the contact row has the disadvantage that the apparatus is not as easily mounted within the transformer tank and must be controlled by more complicated mechanism than when the fixed contact members are arranged in a straight line along which the movable contact 14 may operate.

In order to avoid the above pointed out limitations in the arrangement of the step selector switch construction and operating mechanism, and to provide a rectilinear contact path, while at the same time avoiding the necessity of reversing the direction of current in the regulated winding portion with respect to the direction in the unregulated winding portion, the step switching mechanism provided in accordance with the invention includes at least two movable selector contacts, one of which is connected directly through a changeover switch in one operative position to the secondary winding circuit 5, and the other of which is connected through the unregulated winding portion 1 and the changeover switch in a second operative position to the conductor 5.

This construction is illustrated in Figs. 5, 6 and 7 in which the primary circuit conductors 3 and 4 are connected directly across the entire regulated winding portion 2. The lower part of the winding portion 2 is provided with tap connections between spaced points along the winding and tap contacts 31, 32, 33, 34 and 35 that are arranged to be engaged by movable tap selecting contacts 37 and 38, the contact 36 being connected through conductor 39 and the winding 1 to a contact 40 of a changeover switch, and the selector contact 38 being connected by conductor 42 to a contact 43 of the changeover switch. The changeover switch is also provided with a movable contact member 44 that is permanently connected to the secondary conductor 5 and is adapted to engage one or both of the contact members 40 and 43.

In the position of the various switch members illustrated in Fig. 5, the minimum secondary voltage is provided between conductors 3' and 5. This voltage corresponds to that portion of the primary circuit voltage appearing across that portion of the regulated winding 2 between the tap contact 31 and conductor 3. As the selector contact 38 is moved progressively from engagement with tap contact 31 into engagement with the contacts 32, 33, 34 and 35 in sequence, the voltage applied to the secondary circuit is increased to correspond to the primary circuit voltage. As the selector contact 38 moves from the position illustrated in Fig. 5 to the position illustrated in Fig. 6, the selector contact 37 remains in its initial position in engagement with the fixed contact 31. The portion of the winding 2 connected between contact 31 and contact 35 corresponds in number of turns to the unregulated winding portion 1 wound on the same transformer core, so that as the switch contact member 44 is moved from the position illustrated in Fig. 5 to bridge both contact members 40 and 43, as illustrated in Fig. 6, the two winding portions that are temporarily connected in parallel develop a substantially equal voltage. That is, the voltage appearing between contact members 31 and 35 of the winding portion 2 is the same as the voltage appearing across the winding portion 1, so that as the switch contact member 44 is moved from the position illustrated in Fig. 5 to the position illustrated in Fig. 7, the voltage supplied to the secondary winding circuit of conductors 3'—5 remains unchanged. Also, no circulating current flows between the two winding portions when the member 44 bridges contacts 40 and 43. The position of the switch contact 44 in Fig. 6 is a temporary position which exists only during the transition from the operated position shown in Fig. 5 to the operated position shown in Fig. 7. With the switch contact member 44 in the position shown in Fig. 7, the secondary circuit voltage is increased progressively by moving the selector contact 37 progressively along the tap contacts 32, 33, 34 and 35.

The tap contact train of Figs. 5, 6 and 7, represented generally at 30 and including the contacts 31, 32, 33, 34 and 35, may be arranged either rectilinearly or circularly. The selector contacts 37 and 38 may be sliding or snap contacts and may be actuated either under load or under no load. If it is desired that the tap selector contacts be not operated under load, load switches may be provided and the selector contacts 37 and 38 may be sub-divided into a pair of contacts each, the individual contacts of each pair being operated from engagement with one tap contact to the adjacent tap contact only under no load condition for that selector contact.

Such an arrangement is shown in Fig. 8, in which the selector contact members 45 and 46 acting as a pair, perform an equivalent function to the selector contact 37 of Figs. 5, 6 and 7 and the selector contacts 47 and 48 acting as a pair perform a function corresponding to the selector contact 38 of Figs. 5, 6 and 7.

In the switch positions illustrated in Fig. 8, which corresponds to the switch positions illustrated in Fig. 7, the contact pair 45, 46 connect the winding portion 1 through contacts 40 and 44 of the changeover switch to the conductor 5 in parallel circuit relation to the part of the winding portion 2 connected through the contact pair 47, 48 and contacts 43 and 44 to the conductor 5. In the illustrated positions of the load switch contacts 51 and 61 the circuit divides between the two selector contacts of each pair and through the pair of reactor windings 54 and 57 associated with contact 51, and a pair of reactor windings 64 and 67 associated with the contact 61. When it is desired to move a pair of contacts, for example, the contacts 45 and 46 in a direction to increase the secondary circuit voltage, the contact 44 of the changeover switch is first moved to the right, as viewed in the drawings, out of engagement with the contact 43. The contact 51 is then moved upwardly to bridge contacts 52 and 53, thus interrupting the circuit through selector contact 46. The contact 46 is then moved into engagement with the next tap contact 32. Thereafter, the switch member 51 is moved downwardly to bridge the contact members 55 and 56, the contact member 51 engaging the contact member 55 before separating from the contact member 52, in which position the windings 54 and 57 act as a preventive auto to prevent the short circuit of the transformer winding section between segments 31 and 32 while preventing interruption of the circuit through the switch contact member 51. With the switch member 51 in engagement with the contacts 55 and 56, the selector contact 45 is moved into engagement with the tap contact 32 and the contact member 51 brought back to its normal position bridging contacts 52 and 55. The normal position of the contact 51 maintains while both the contacts 45 and 46 are in engagement with the same tap contact. The windings 54 and 57 which may be differentially related windings on the same magnetic core, to provide a low reactance circuit for current in the winding 1 while at the same time, a high reactance circuit to the circulating current between the selector contacts 45 and 46 when in engagement with adjacent tap contacts during the interval in which the contacts 52 and 55 are bridged by contact 51.

When it is desired to move the pair of contact members 47 and 48 step by step along the row of tap contacts 31 to 35, this may be done in the same sequence as described above with respect to the contacts 45 and 46, the load switch contact member 61 being provided to engage contact members 63 and 62 in its upper position to short circuit the winding 64 and interrupt the circuit through contact 48, and in its lower position to bridge contacts 65 and 66 to short circuit the winding 67 and interrupt the circuit through contact 47. In its mid-position the contact 61 bridges the contacts 62 and 65 while the selector contacts 47 and 48 are in engagement with the same tap selector contact.

In Fig. 9 another embodiment of the invention is illustrated in which the even-numbered tap contacts are connected to one step selecting contact of each pair of contacts, and the uneven numbered tap contacts are connected to the other step selecting contact of each pair. For example, the selector contacts 68 and 70 engage only the tap contacts 31, 33 and 35 and the selector contacts 69 and 71 engage only the tap contacts 32, 34 and 36.

In the arrangement of the circuits shown in Fig. 9, the normal position of the load switches 51 and 61 will be either in the extreme right or extreme left position as shown in the drawings, the middle position being only a transitory position while moving between the one or the other of the two operative positions.

In Figs. 10, 11 and 12, an arrangement is provided in which the unregulated winding portion 1 is subdivided into two halves 80 and 81. In the switching position shown in Fig. 10, the load circuit conductor 5 is connected through the unregulated winding portion 81 to the step selector contact 83, the step selector contact 84 being without current during its changeover position from engagement with tap contact 31 to engagement with contact 32, while the load switch contact member 93 is separated from contact 95 and in engagement with contact 94. In any tap position both selector contact members 83 and 84 are located on the same tap contact member, such as 32, so that the load current divides itself equally through the two tap contact members 83 and 84, and the two winding portions 80 and 81. When the secondary circuit is completed through contacts 83 and 84, the changeover switch contact members 87 and 88 are in the positions illustrated in Fig. 10 in engagement with the contact members 90 and 92, respectively, and the load switch contact member 93 is in position to bridge the contact members 94 and 95.

The selector contact members 96 and 97 are connected respectively to contact members 91 and 89 of the changeover switches. Upon movement of the selector contact members 96 and 97 from engagement with the tap contact members 31 to 36, the changeover switches 87 and 88 are in the positions illustrated in Fig. 12. If the direction of movement of the selector contacts 96 and 97 is downwardly along the tap selector contact row, the switch member 93 will be rotated in a clockwise direction from its central position, as shown in Fig. 11, in which central position it bridges the contact members 95 and 94. When the contact member 93 is moved from engagement with the contact member 95 to interrupt the circuit through the selector contact 97, the selector contact 97 is then moved downwardly to the next tap contact position. After the contact 93 has moved sufficiently to again engage the contact 95 and while out of engagement with the contacts 94 or 99, the selector contact 96 is moved downwardly into engagement with the next lower tap contact member of the row, and the contact

93 is again moved to the position shown in Fig. 11 to bridge the contacts 95 and 94, thus dividing the load current equally between the selector contacts 96 and 97.

During movement of the selector contact members 96 and 97 along the tap contact row, the changeover switches 87 and 88 will remain in the positions illustrated in Fig. 12 until both selector contacts 96 and 97 are in engagement with the lower tap contact 36. With both contacts 96 and 97 in engagement with the tap contact 36 and the load switch contact 93 in its central position bridging contacts 94 and 95, the changeover switches 87 and 88 are simultaneously moved from the positions shown in Fig. 12 through the positions shown in Fig. 11 to the positions shown in Fig. 10. During the transitory or temporary position of the switch contact members 87 and 88 shown in Fig. 11, the unregulated windings 80 and 81 are connected in parallel with that portion of the regulated winding 2 between the tap contact 31 and the tap contact 36. After the changeover contacts 87 and 88 are in the positions illustrated in Fig. 10, further increase of the secondary voltage is effected by rotating the contact member 93 first to the position shown in Fig. 10, out of engagement with the contact member 95, in which position the selector contact member 84 is moved from engagement with the tap contact 31 to the next lower tap contact 32, while the circuit through the tap contact 84 and the winding 80 is interrupted. As the load switch contact 93 continues to move in a clockwise direction, it temporarily engages the contact members 98 and 99 to include the winding portions 102 and 102 in the local circuit between tap contacts 31 and 32 until the switch contact member 93 has moved sufficiently to interrupt the circuit through the selector contact 83, the winding portion 81 and the contacts 94 and 99. While this circuit is interrupted, the selector contact 83 is moved downwardly into engagement with the next tap contact member, such as 32, and the load switch contact member 93 is brought to its central position, bridging contacts 95 and 94 to complete the tap change.

Successive tap changes, during each step of which the selector contacts 83 and 84 are moved downwardly one tap contact position, are effected in the same manner, the load switch contact 93 making a complete revolution during each complete tap change.

When the tap changing mechanism is operated in a reverse direction to decrease the voltage supplied to the secondary or load circuit conductors 3'—5, the load switch contact 93 is revolved in a counter-clockwise direction as viewed in the drawings, one complete revolution during each complete tap changing step, and the selector contact members 83 and 84 are moved upwardly in the reverse order above described, each selector contact being moved from engagement with one tap contact to the next tap contact while the circuit through the load switch is interrupted. A resistor 104 is provided connected between intermediate points 105 and 106 on the winding portions 80 and 81 to prevent the voltages applied to either winding to float to undesirable values while the circuits therethrough are interrupted during tap changing operations.

Obviously, the upper portions of the regulated windings 2 between the tap contact 31 and the conductor 3 shown in Figs. 5 to 12 inclusive, may be omitted, depending upon the voltages of the secondary circuit required. Suitable mechanisms for effecting the sequential operation of the various switch elements in the order described are provided employing any convenient arrangement of cams, shafts, changeover cables, according to known mechanisms for effecting desired sequential operation of switch contact elements.

Many modifications in the arrangement of apparatus and circuits illustrated may be employed within the spirit of my invention, and I do not wish to be limited otherwise than by the scope of the appended claims.

I claim as my invention:

1. In a regulating transformer, in combination, a regulated winding portion provided with a plurality of tap connections at spaced intervals therealong and an unregulated winding portion, a tap changing switch mechanism including tap contacts connected to the several tap connections, two movable selector contacts cooperating with the tap contacts, each selector contact being movable over a range corresponding to the number of tap contacts without movement of the other selector contact, and a changeover switch having two operative positions for connecting a selected one of said selector contacts to said load circuit conductor, said unregulated winding portion being included in circuit between one of said selector contacts and said changeover switch.

2. In a regulating transformer, in combination, a regulated winding portion provided with a plurality of tap connections at spaced intervals therealong and an unregulated winding portion, a tap changing switch mechanism including tap contacts connected to the several tap connections, two pairs of selector contacts, cooperating with the tap contacts, a pair of intermediate circuit conductors and a pair of load circuit conductors, a load switch associated with each pair of selector contacts for selectively connecting the one or the other of each selector contact of a pair to an intermediate circuit conductor, and a changeover switch having two operative positions for connecting a selected one of said intermediate circuit conductors to one load circuit conductor, said unregulated winding portion being included in circuit with one of said intermediate circuit conductors between a selector switch of one pair and said changeover switch to serve as a part of the useful output voltage source.

3. In a regulating transformer, in combination, a regulated winding portion provided with a plurality of tap connections at spaced intervals therealong and an unregulated winding portion, a pair of intermediate circuit conductors and a pair of load circuit conductors, a tap changing switch mechanism including tap contacts connected to the several taps, two pairs of selector contacts, cooperating with the tap contacts, a load switch associated with each pair of selector contacts for selectively connecting the one or the other of each selector contact of a pair to one of said intermediate circuit conductors, and a changeover switch having two operative positions for connecting a selected one of said intermediate circuit conductors to one of said load circuit conductors, said unregulated winding portion being included in circuit between one of said intermediate circuit conductors and said changeover switch to serve as a part of the useful output voltage source, each of said pairs of selector contacts being movable over the whole regulating range of said tap contacts without movement of the other pair.

4. In a regulating transformer, in combination, a regulated winding portion provided with a plu-

rality of tap connections at spaced intervals therealong and an unregulated winding portion, a pair of intermediate circuit conductors and a pair of load circuit conductors, a tap changing switch mechanism including tap contacts connected to the several tap connections, two pairs of selector contacts cooperating with the tap contacts, a load switch associated with each pair of selector contacts for selectively connecting the one or the other of each selector contact of a pair to an intermediate circuit conductor, each pair of selector contacts being movable over a range corresponding to the number of tap contacts without movement of the other pair of selector contacts, and a changeover switch having two operative positions for connecting a selected one of said intermediate circuit conductors to one of said load circuit conductors, said unregulated winding portion being included in circuit between one of said intermediate circuit conductors and said changeover switch, means for coordinating the operation of said selector contacts and of said load switches so that a selector contact is moved from engagement with one tap contact to the next tap contact only when the circuit therethrough is interrupted by the associated load switch.

5. In a regulating transformer, in combination, a pair of load circuit conductors, a regulated winding portion having a tapped part provided with a plurality of tap connections at spaced intervals therealong and an unregulated winding portion, and a tap changing switch mechanism including tap contacts connected to the several tap connections, two movable selector contacts arranged for successive operative engagement with each of said tap contacts, each selector contact being movable independently of the movement of the other, and a changeover switch connected to one of said load circuit conductors and having two operative positions for connecting a selected one of said selector contacts to said load circuit conductor, said unregulated winding portion being connected in circuit between one of said selector contacts and said changeover switch, and said changeover switch being arranged to transfer the connection of said load circuit conductor from the one to the other of said selector contacts while said selector contacts are in engagement with tap selector contacts at opposite ends of said tapped winding part.

6. In a regulating transformer, in combination, a pair of load circuit conductors, a regulated winding portion having a tapped part provided with a plurality of tap connections at spaced intervals therealong and an unregulated winding portion having a number of turns corresponding to the number of turns of the tapped part of the regulated winding portion, and a tap changing switch mechanism including tap contacts connected to the several tap connections, two movable selector contacts arranged for successive operative engagement with each of said tap contacts, each selector contact being movable independently of the movement of the other, and a changeover switch connected to one of said load circuit conductors and having two operative positions for connecting a selected one of said selector contacts to said load circuit conductor, said unregulated winding portion being connected in circuit between one of said selector contacts and said changeover switch, and said changeover switch being arranged to transfer the connection of said load circuit conductor from the one to the other of said selector contacts while said selector contacts are in engagement with tap selector contacts at opposite ends of said tapped winding part.

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