Feb. 5, 1946. A. POTTINGER 2,394,102

ELECTRICAL APPARATUS

Filed Sept. 19, 1944

Fig. 1.

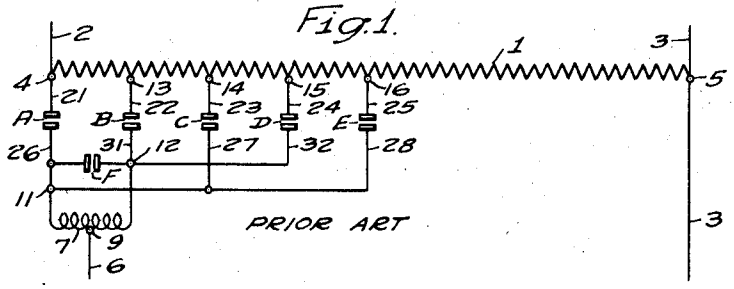


Fig. 2.

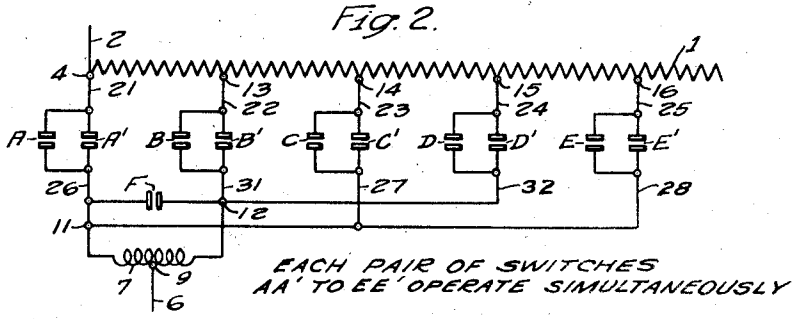


Fig. 3.

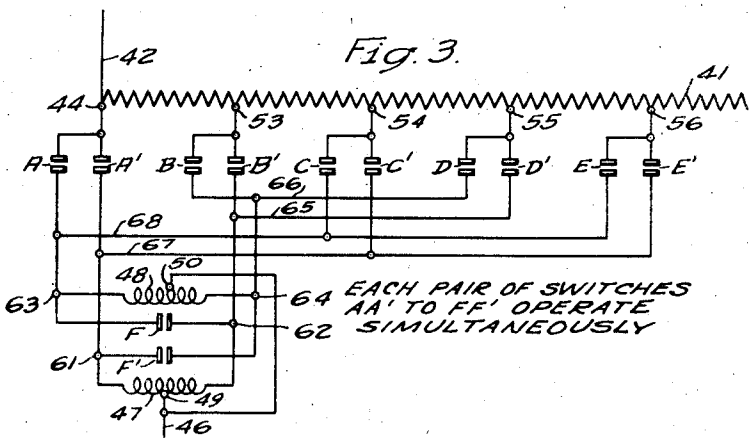


Fig. 4.

	1		2		3		4		5		6		7		8		9
AA'	○	○	○														
BB'			○	○	○	○	○										
CC'							○	○	○	○	○						
DD'											○	○	○	○	○		
EE'															○	○	○
FF'	○				○				○				○				○

INVENTOR
Alexander Pottinger.
BY
Franklin E. Hardy
ATTORNEY

Patented Feb. 5, 1946

2,394,102

UNITED STATES PATENT OFFICE

2,394,102

ELECTRICAL APPARATUS

Alexander Pottinger, Hamilton, Ontario, Canada, assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Application September 19, 1944, Serial No. 554,843

8 Claims. (Cl. 171—119)

My invention relates to apparatus for adjusting the voltage of alternating-current electric circuits such as regulating transformers of the tap-changing type in which tap-changing equipment is operated while the transformer is under load. More particularly, my invention is related to improvements in the tap-changing circuit connections for such transformers.

In maintaining the voltage supplied to load centers constant through distribution or feeder circuits, regulating apparatus is required to compensate for variations in the voltage of the power source and for changes in the circuit impedance drop which result from load demand fluctuations. My invention is directed to step-type voltage regulators or tap-changing transformers which, because of their low cost and other desirable characteristics, are particularly well suited for application to feeder circuits of the relatively high-voltage low-current ratings which are prevalent in certain distribution systems.

In regulating transformers of the tap-changing type, a preventive reactor is commonly used to effect the transition from one tap position to another tap position of the equipment. In certain situations, it is desirable to employ two pairs of switches in parallel, connecting the tap point on the transformer winding to a feeder circuit conductor, in order to increase the current carrying capacity of the equipment. Normally, when switches are connected in parallel, unless their resistances are the same, one will carry more than its share of the total current so that the combined current carrying capacity of the two switches will be appreciably less than double that of one switch. In accordance with the invention, means is provided for forcing substantially equal division of current between the two switches so as to allow the rating of each pair of switches to be twice that of a single switch.

It is an object of the invention to provide, in a tap-changing system of the above-indicated character, two tap switches associated with each transformer tap point for connecting the tap connection from that tap point to a main circuit conductor and to provide means for effecting a substantially equal division of current flow between them.

Other objects and advantages of the invention will be apparent from the following description of a preferred embodiment thereof, reference being had to the accompanying drawing, in which:

Figure 1 is a diagrammatic view of apparatus and circuits comprising a prior-art tap-changing system;

Fig. 2 is a diagrammatic view of apparatus and circuits illustrating a modification of the system shown in Fig. 1;

Fig. 3 is a diagrammatic view of apparatus and circuits arranged in accordance with my invention; and

Fig. 4 is a chart showing the sequence of operation of the several switches utilized by the tap-changing system illustrated in Figs. 1, 2 and 3.

Referring to the drawing, and particularly to Fig. 1, an autotransformer winding 1 is illustrated and is connected to be supplied with energy from a suitable source through circuit conductors 2 and 3 that are connected to the winding terminals 4 and 5 and to deliver energy to a secondary or feeder circuit represented by conductors 6 and 3. A preventive reactor 7 is shown having a midpoint 9 connected to the secondary circuit conductor 6, and terminals 11 and 12 that are adapted to be connected to selected tap points on the transformer winding 1 represented by the winding terminal 4 and the intermediate tap points 13, 14, 15 and 16. Tap conductors 21, 22, 23, 24 and 25 extend from the above-indicated tap points and connect to one terminal respectively of tap switches A, B, C, D and E. The remaining terminals of the tap switches are connected to one of the terminals 11 or 12 of the preventive reactor 7. The lower terminals of tap switches A, C and E, for example, are shown as connected through circuit conductors 26, 27 and 28, respectively, to the reactor end terminal 11 and the lower terminals of switches B and D are shown as connected through circuit conductors 31 and 32 to the opposite end terminal 12 of the reactor 7. A short circuiting switch F is shown for connecting the terminals 11 and 12 of the preventive reactor 7 together under certain steps in the sequence of operation of the apparatus, as indicated in the chart shown in Fig. 4.

In the chart of Fig. 4, the switches A, B, C, D, E and F are indicated in the vertical column at the left of the chart and the tap positions 1 to 9 are indicated along the top of the chart, there being a space between each one of the numbered columns representing an intermediate step in the tap-changing operation from one tap position to the next tap position in the sequence of operation of the equipment. The presence of a circle opposite any one of the indicated switches indicates that the switch is closed in that position of the voltage adjusting equipment, and the absence of a circle indicates that the switch is in its circuit-interrupting position. Thus, in the first position of the voltage-adjusting mechanism, under the column indicated by the

numeral 1, the tap-changing switch A and the short-circuiting switch F are closed and all other tap-changing switches are open. The secondary circuit conductor 6 is, therefore, connected to the primary circuit conductor 2 through the two halves of the preventive reactor 7 in parallel from the terminals 11 and 12 to the midpoint 9. The preventive reactor is so arranged that when current flows in this manner through it, the reactance is substantially nil, while when current flows in either direction through the entire winding between the terminals 11 and 12 an appreciable reactance exists. As the tap-changing system operates, the several switches are operated in a sequence shown in the chart in Fig. 4 by mechanism not shown in the drawing. When the voltage adjusting mechanism is operated from position 1 to position 2, the short-circuiting switch F is first opened, thus connecting the conductor 2 to the conductor 6 through one-half only of the reactor winding 7, placing temporarily a certain reactance drop in the circuit. Then the tap switch B is next closed connecting the preventive reactor 7 in shunt between tap points 4 and 13, thus applying a voltage to the conductor 6 that corresponds to the voltage on the transformer winding 1 at a point mid-way between the two tap points 4 and 13. This sequence of operation is continued as shown by the chart in Fig. 4 so that, for every alternate tap position 3, 5, 7 and 9, both ends of the reactor 7 will be connected through the short-circuiting switch F to one of the tap points 13, 14, 15 and 16 while at the intermediate positions in the operation of the tap equipment 4, 6, and 8, the reactor winding 7 will be connected between adjacent tap points in the series along the winding 1 in a manner similar to that corresponding to position 2 of the tap-changing equipment.

In order to increase the value of current that can be conducted from a tapped point to the conductor 6, two tap switches may be connected in parallel as shown in Fig. 2, such as A, A'; B, B'; C, C'; etc. The system shown in Fig. 2 is similar to that shown in Fig. 1 except for the use of two switches A, A' in place of the single switch A, etc., for the various switches associated with the several tap points of the winding. When a circuit arrangement, such as that shown in Fig. 2, is employed, the current is very likely not to divide evenly between the two switches in parallel because of the difference in the contact resistances of the switch so that the rating of the two switches as a unit can not be double that of a single switch of the same size.

In order to force an equal division of current between the two parallel switches, there is provided an arrangement of the tap-changing circuit connections, as shown in Fig. 3.

A portion of a transformer winding 41 is shown, the terminal 44 being supplied by a current conductor 42 and the opposite terminal and conductor being connected similarly to Fig. 1 but not shown, for the purpose of enlarging the diagram covering that portion of the winding including the tap points thereof. A secondary circuit conductor 46 is shown connected to the mid-points 49 and 50 of two preventive reactors 47 and 48, respectively, which are used in place of the single preventive reactor 47 in Figs. 1 and 2. The terminal or tap point 44 is shown connected to the upper contact member of the pair of tap switches A and A' and successive tap points 53, 54, 55 and 56 are shown equally spaced along the winding 41 and connected respectively to the upper contacts of cooperating pairs of tap switches B and B', C and C', D and D', E and E'. The preventive reactor 47 is provided with a pair of terminals 61 and 62 connected to opposite ends thereof and the preventive reactor 48 is provided with terminals 63 and 64 at the opposite ends thereof. A pair of first and second conductors 65 and 66 are provided connected to the like ends 62 and 64, respectively, of the pair of reactor windings 47 and 48. Another pair of first and second conductors 67 and 68 are connected to the opposite like ends 61 and 63, respectively, of the pair of reactor windings 47 and 48. The conductor 65 connects to switch B' and D' and the conductor 66 to switches B and D so that whenever either pair of tap switches B and B' or D and D' close, the tap points 53 and 55 will be connected to the like terminals 62 and 64 of the reactors 47 and 48. Likewise, the conductor 67 is connected to switch terminals A', C' and E' and the conductor 68 is connected to switch terminal A, C and E, so that whenever the pair of tap switches A and A', C and C', or E and E' are closed, the tap points 44, 54 or 56 on the transformer winding will be connected to both terminals 61 and 63 comprising like ends of the pair of reactor windings 47 and 48. A pair of short-circuiting switches F and F' are provided which operate together to a circuit-closing or circuit-opening position and which connect the opposite ends of the pair of preventive reactors 47 and 48 together. For example, the switch F connects the terminal 62 of the preventive winding 47 to the opposite terminal 63 of the winding 48 and the switch F' connects the terminal 64 of the reactor winding 48 to the opposite terminal 61 of the reactor winding 47. The chart in Fig. 4 applies equally to the circuit arrangement shown in Fig. 3, it being understood that with the operation of each one of the switches shown in the chart of Fig. 4, the correspondingly lettered and primed switch is in a similar position. Each pair of switches A and A', B and B', etc., open together and close together.

With the circuit arrangement shown in Fig. 3, when the equipment is in position 1 to which the switches A and A', F and F' are in their circuit closing positions, all four end terminals 61, 62, 63 and 64 of the two reactor windings 47 and 48 ar connected through the switches A and A' to the tap point 44 so that current will flow from the tap point 44 to the end terminals of both preventive reactors 47 and 48 and to the mid-position of each and from these mid-positions 49 and 50 to the circuit conductor 46. In the second tap position, indicated by the numeral 2 in Fig. 4, the switches A and A', B and B' are closed and all other switches of the system are in their open position. Current will flow from the tap point 44 through switch A to the end terminal 63 of preventive reactor winding 48 and also from tap point 44 through switch A' to the like end terminal 61 of the preventive reactor winding 47, and from these two end points to the conductor 46 through mid-points 49 and 50 of the two reactor windings. Likewise, current will flow from the tap position 53 through switch B to the end terminal 64 of the reactor winding 48 and from tap point 53 through switch B' to the like end terminal 62 of the preventive reactor winding 47 and from these two end terminals 64 and 62 toward the midpoints 49 and 50 of their respective reactor windings to the circuit conductor 46. Because the current to the circuit conductor 46 is required to flow through switches A and B to the

opposite ends of the preventive reactor winding 48 and from the midpoint 50 thereof and likewise through switches A' and B' to the opposite terminals 61 and 62 of a preventive reactor winding 47 that is similar in character to the preventive winding 48 and from the mid-point 49 thereof, there are four equal reactor winding portions between each one of the four switches A, A', B, B' and the conductor 46 arranged to permit a ready flow of current toward the mid-tap points 49 and 50 but to prevent the flow of current between the end terminals of the reactor windings. It follows that the current flowing through the several tap switches A, A', B, B' remain substantially equal. This is equally true in each of the positions 4, 6 and 8 of the tap-changing equipment in which the reactor windings 47 and 48 are connected between adjacent tap positions 53 and 54, 54 and 55, or 55 and 56, as will be seen by reference to the chart in Fig. 4.

Modifications in the apparatus and circuits illustrated and described will occur to those skilled in the art and I do not wish to be otherwise limited than by the scope of the appended claims.

I claim as my invention:

1. In a tap-changing system for transformers, a primary power circuit comprising a pair of conductors, a transformer energized from said power circuit and provided with a plurality of tap connections, a pair of tap bridging reactor windings, a secondary circuit conductor connected to the midpoint of each of said reactor windings, a pair of tap switches associated with each tap connection, the pairs of tap switches connected with alternate tap connections in the series being connected and arranged to simultaneously connect a corresponding end of each of said reactor windings to a tap connection, and the remaining pairs of switches being connected with the remaining alternate tap connections in the series and arranged to simultaneously connect the opposite ends of each of said reactor windings to a tap connection, and means for operating said several pairs of tap switches in sequence to connect one end of the two reactor windings to one tap connection, then the other end of the two reactor windings to the next adjacent tap connection in the series to connect the pair of reactor windings in parallel with a portion of the transformer winding between two adjacent tap connections, then to disconnect the first-named ends of the two reactor windings from the first-named tap connection, and in continuing the sequence of tap switch operations to alternately connect one end of the pair of reactor windings to successive tap connections and then between adjacent ones of the plurality of tap connections so as to maintain at all times an equal division of current between the parallel connected tap switches associated with any tap connection.

2. In a tap-changing system for transformers, a primary power circuit comprising a pair of conductors, a transformer energized from said power circuit and provided with a plurality of tap connections, a pair of tap bridging reactor windings, a secondary circuit conductor connected to the midpoint of each of said reactor windings, a pair of tap switches associated with each tap connection, the pairs of tap switches connected with alternate tap connections in the series being connected and arranged to simultaneously connect a corresponding end of each of said reactor windings to a tap connection, and the remaining pairs of switches being connected with the remaining alternate tap connections in the series and arranged to simultaneously connect the opposite ends of each of said reactor windings to a tap connection, and means for operating said several pairs of tap switches in sequence to connect one end of the two reactor windings to one tap connection, then the other end of the two reactor windings to the next adjacent tap connection in the series to connect the pair of reactor windings in parallel with a portion of the transformer winding between two adjacent tap connections, then to disconnect the first-named ends of the two reactor windings from the first-named tap connection, and in continuing the sequence of tap switch operations to alternately connect one end of the pair of reactor windings to successive tap connections and then between adjacent ones of the plurality of tap connections and provided with a pair of tap switches adapted to connect one end of one of the pair of reactor windings to the opposite end of the other one of the pair of reactor windings, and arranged to be operated to a circuit-closing position when the pair of reactor windings are connected to one tap connection only.

3. In a tap-changing system for transformers, a primary power circuit comprising a pair of conductors, a transformer energized from said power circuit and provided with a plurality of tap connections, a pair of tap bridging reactor windings, a secondary circuit conductor connected to the midpoint of each of said reactor windings, a pair of tap switches associated with each tap connection, the pairs of tap switches connected with alternate tap connections in the series being connected and arranged to simultaneously connect a corresponding end of each of said reactor windings to a tap connection, and the remaining pairs of switches being connected with the remaining alternate tap connections in the series and arranged to simultaneously connect the opposite ends of each of said reactor windings to a tap connection, and means for operating said several pairs of tap switches in sequence to connect one end of the two reactor windings to one tap connection, then the other end of the two reactor windings to the next adjacent tap connection in the series to connect the pair of reactor windings in parallel with a portion of the transformer winding between two adjacent tap connections, then to disconnect the first-named ends of the two reactor windings from the first-named tap connection, and in continuing the sequence of tap switch operations to alternately connect one end of the pair of reactor windings to successive tap connections and then between adjacent ones of the plurality of tap connections so as to maintain at all times an equal division of current between the parallel connected tap switches associated with any tap connection, and a pair of short-circuiting switches simultaneously operated for connecting the opposite ends of the two reactor windings to a tap connection when one pair only of the tap switches are in their circuit closing positions.

4. In a tap-changing system for transformers, a primary power circuit comprising a pair of conductors, a transformer energized from said power circuit and provided with a plurality of tap connections, a pair of tap bridging reactor windings, a secondary circuit conductor connected to the midpoint of each of said reactor windings, a pair of tap switches associated with each tap connection, the pairs of tap switches connected

with alternate tap connections in the series being connected and arranged to simultaneously connect a corresponding end of each of said reactor windings to a tap connection, and the remaining pairs of switches being connected with the remaining alternate tap connections in the series and arranged to simultaneously connect the opposite ends of each of said reactor windings to a tap connection, and a pair of short-circuiting switches simultaneously operated for connecting the opposite ends of the two reactor windings together through a pair of tap switches and the associated tap connection, the several pairs of tap switches being arranged to operate in sequence to close the tap switches associated with the first tap connection together with the pair of short circuiting switches, to then close the tap switches associated with the next tap connection in the series of tap connections, to then open the tap switches associated with the first tap connection, then to close the pair of short-circuiting switches, and to continue this sequence of operation to connect corresponding ends of the two reactor windings to one tap connection, then the other end of the two reactor windings to the next adjacent tap connection in the series, so as to connect the pair of reactor windings in parallel with a position of the transformer winding between two adjacent tap connections, then to disconnect the first-named ends of the two reactor windings from the first-named tap connection, and to continue the sequence of tap switch operations to alternately connect one end of the pair of reactor windings, to a tap connection, and then to connect opposite ends of the pair of reactor windings to adjacent tap connections continuing the operation to include, in sequence, the several of the plurality of tap connections.

5. In a transformer tap-changing-under-load system of the type in which the opposite terminals of a mid-tapped reactor are connected in alternate steps to successive tap points along a transformer winding, the combination with a pair of reactors having their midpoints connected to the same circuit conductor, a pair of switches associated with each tap point of the transformer winding for simultaneously connecting corresponding terminals of the pair of reactors to the same tap point and simultaneously disconnecting the corresponding ends of the pair of reactors from the same tap point, and a pair of simultaneously operated short-circuiting switches for short circuiting the one or the other of the two reactors through one of two adjacent tap points of the transformer winding, said pair of short-circuiting switches being simultaneously operative to circuit closing positions when a pair of switches connected to one end only of the reactor windings are in circuit closing position.

6. In combination, a transformer winding provided with a plurality of tap points, a circuit conductor, means for connecting said circuit conductor to selected tap points of the transformer winding including a pair of mid-tapped reactor windings having their mid-points connected to said circuit conductor and pairs of ratio adjusting tap-changer switches simultaneously connecting corresponding ends of both reactor windings to a selected tap point and arranged to connect alternate tap points of the transformer winding to opposite ends of the reactor windings, and a pair of simultaneously operated short-circuiting switches for short circuiting said reactor windings, said short-circuiting switches being operated to a closed circuit position only when one end of said reactor windings are connected to a tap point of the transformer winding to short circuit one of said reactor windings through the pair of ratio-adjusting tap-changing switches associated with that tap point.

7. In combination, a transformer winding provided with a plurality of tap points, a circuit conductor, means for connecting said circuit conductor to selected tap points of the transformer winding including a pair of mid-tapped reactor windings having their mid-points connected to said circuit conductor and pairs of ratio-adjusting tap-changer switches simultaneously connecting corresponding ends of both reactor windings to a selected tap point and arranged to connect alternate tap points of the transformer winding to opposite ends of the reactor windings, and a pair of simultaneously operated short circuiting switches for short circuiting said reactor windings, said pair of short-circuiting switches being arranged to connect like ends of each of the pair of reactor windings to the opposite end of the other one of the pair of reactor windings, the short-circuiting switches being arranged to operate to closed circuit positions when one end only of said reactor windings are connected to a tap point on the transformer winding to short circuit one of said reactor windings through the pair of ratio adjusting tap-changing switches associated with that tap point.

8. In combination, a transformer winding provided with a plurality of tap points, a main circuit conductor, means for connecting said circuit conductor to selected tap points including a pair of reactors each having a winding having a mid-tap connected to said main circuit conductor and each having a pair of end terminals, a pair of first and second conductors connected to like ends of the pair of reactor windings, another pair of first and second conductors connected to the opposite like ends of the pair of reactor windings, a pair of ratio-adjusting tap changer switches associated with each tap point on the transformer winding for simultaneously connecting the tap point to one of the pairs of first and second conductors, the pair of ratio-adjusting tap-changer switches associated with any tap point being adapted to connect with the other one of the two pairs of first and second conductors then the pair of ratio-adjusting tap-changer switches associated with adjacent tap points on the transformer winding, and a pair of simultaneously operated short-circuiting switches for short circuiting said reactor windings, said pair of short-circuiting switches being arranged to connect like ends of each of the pair of reactor windings to the opposite end of the other one of the pair of reactor windings, the short-circuiting switches being arranged to operate to a closed circuit position when one end only of said reactor windings are connected to a tap point on the transformer winding to short circuit one of said reactor windings through the pair of ratio-adjusting tap changing switches associated with that tap point.

ALEXANDER POTTINGER.