June 17, 1930. K. KURDA ET AL 1,764,320

REGULATING TRANSFORMERS

Filed June 27, 1929

Fig. 1.

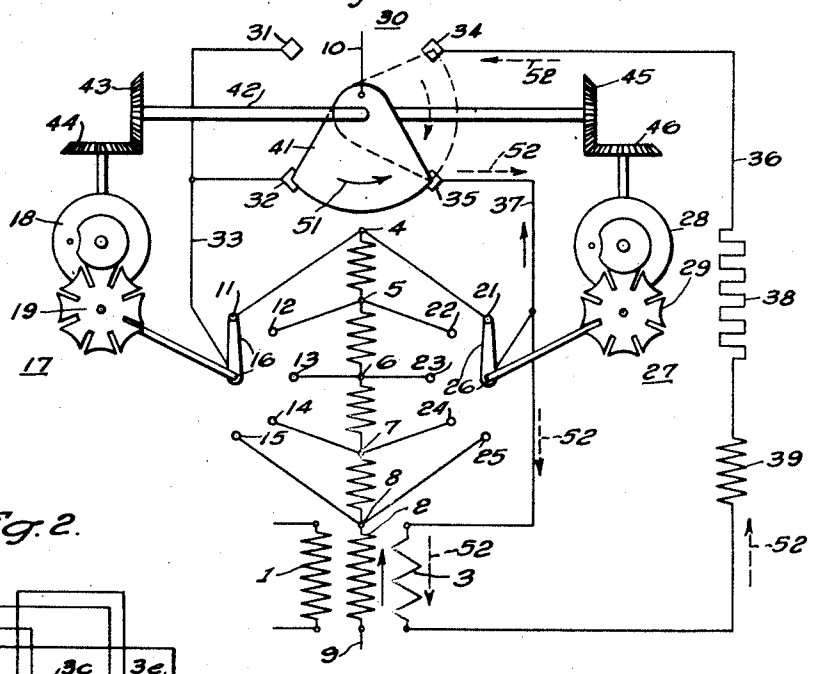


Fig. 2.

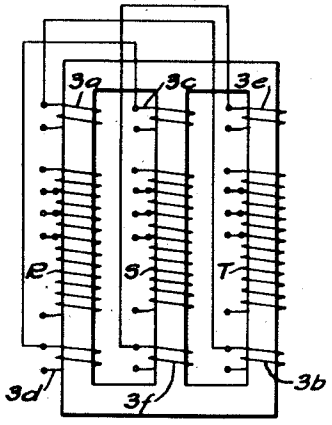


Fig. 3.

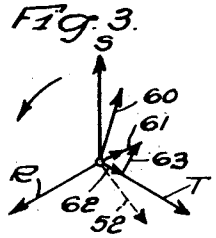
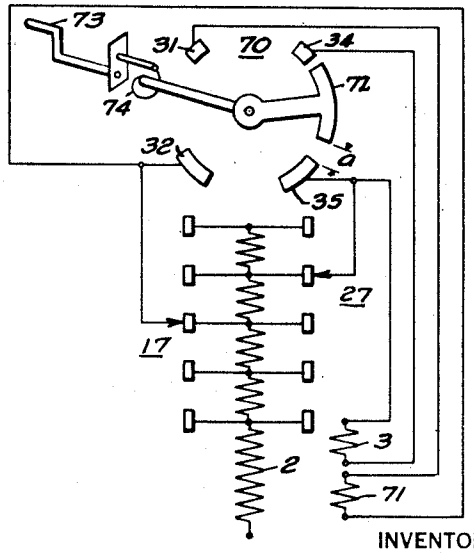


Fig. 4.



INVENTORS
Karl Kurda and
Paul Schade.
BY
Wesley J. Barr
ATTORNEY

Patented June 17, 1930 1,764,320

UNITED STATES PATENT OFFICE

KARL KURDA AND PAUL SCHADE, OF NUREMBERG, GERMANY, ASSIGNORS TO WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA

REGULATING TRANSFORMERS

Application filed June 27, 1929, Serial No. 373,989, and in Germany June 14, 1928.

Our invention relates to a system for regulating transformers and more particularly to a system for changing tap connections to a transformer winding without removing the load from the transformer.

In many transformer installations, it is desirable to change the tap connections to a transformer winding in order to change the voltage ratio of transmission, or the phase-angle relation, between the primary and the secondary windings of the transformer. In order to avoid interruption of the service of the system, it is necessary to make the changes in tap connections without removing the load from the transformer.

To accomplish the desired result, one of the line conductors may be connected, through one of two or more tap selecting switches, to a selected point on the transformer winding. In such a system, where, to provide continuity of service, one line conductor is connected to one tap connection of the transformer winding before it is disconnected from another tap connection of such winding, it is necessary to provide means for limiting the current flow through that portion of the transformer winding that is temporarily connected to the power-circuit conductor in a loop circuit through two tap selecting switches. In order to prevent excessive current flow through a section of the transformer winding during this period, resistors or choke coils may be provided in the local loop circuit. In transformers in which the current values are high, these resistors or choke coils become very large.

In accordance with our invention, the use of a resistor or choke coil of the character described above is avoided, and a transformer winding having a large stray flux is provided and connected between one of the tap-selecting switches and a load-interrupting switch of the tap-changing system. This auxiliary transformer winding may be disposed on a separate core connected to the primary winding of the main transformer or on the iron core of the main transformer itself.

An object of our invention is the provision of means for introducing a countervoltage in a circuit connected between a power-circuit conductor and a selected tap of the transformer winding during the period of transition from one tap connection to another, thus avoiding or reducing heavy arcing upon operation of a current-interrupting switch of the tap-changing system.

Other objects of our invention will be apparent from the following description of apparatus corresponding to a preferred embodiment of the invention.

Our invention will be better understood by reference to the accompanying drawing, in which

Figure 1 is a schematic view of apparatus and circuits arranged in accordance with one preferred embodiment of our invention.

Fig. 2 is a diagrammatic view showing the arrangement of the auxiliary transformer windings of a three-phase transformer system.

Fig. 3 is a vector diagram showing the relation of the several voltage values in the windings shown in Fig. 2; and

Fig. 4 is a diagram of apparatus and circuits embodying a second form of the invention.

Referring to the drawing and especially to Fig. 1 thereof, numerals 1 and 2, indicate the primary and secondary windings of a transformer, and the numeral 3 indicates an auxiliary winding inductively related thereto. The winding 2 is provided with tap-connecting points 4, 5, 6, 7 and 8 that are connected, respectively, to the contact members 11, 12, 13, 14 and 15 of a tap-selecting switch 17, which is shown as provided with a movable contact arm 16 for engaging a selected one of the contact members 11 to 15. The tap points 4, 5, 6, 7 and 8 are also connected, respectively, to contact members 21, 22, 23, 24 and 25 of a tap-selecting switch 27 that is provided with a contact arm 26 for engaging a selected one of the above-mentioned contact members.

A current-interrupting switch 30 is provided to cooperate with the tap-selecting switches 17 and 27, to complete the tap connection between the line conductor 10 and the selected tap of the transformer winding

2. The current-interrupting switch 30 comprises fixed contact members 31 and 32 that are connected by the conductor 33, to the arm 16 of the tap-selecting switch 17, and fixed contact members 34 and 35 that are connected to the auxiliary transformer winding 3 and to the arm 26 of the tap-selecting switch 27 by the conductors 36 and 37, respectively. A reactor 39 and a resistor 38 are provided in the circuit of the auxiliary winding 3 between this winding and the contact member 34.

The current-interrupting switch 30 is illustrated as having a rotary contact member 41 for engaging any two of the adjacent contact members 31, 32, 34 and 35. The rotary contact member 41 is coupled, by means of the shaft 42, gear wheels 43 and 44 and the Maltese-cross gears 18 and 19, to the tap-selecting switch 17, and, by means of similar gears 45 and 46 and the Maltese-cross gears 28 and 29, to the tap-selecting switch 27, so that the tap-selecting switches 17 and 27 are operated in predetermined sequence with respect to each other and with respect to current-interrupting switch 30.

The operation of the form of the invention illustrated in Fig. 1 of the drawing is as follows:

The position of the switches illustrated in Fig. 1 corresponds to that wherein the entire winding 2 is connected between the circuit conductors 9 and 10. In order to so operate the tap-changing mechanism as to eliminate a portion of the winding from the circuit, the switch 30 is operated in a direction indicated by the arrow 51. As soon as the contact member 41 becomes disengaged from the contact member 32, the arm 16 of the tap-selecting switch 17 is advanced from engagement with the contact member 11 to engagement with the contact member 12. As the switch contact member 41 is moving from the full-line position, in which it engages the contact members 32 and 35, to the dotted-line position, in which it engages the contact members 34 and 35, the current through the winding 2 of the transformer flows from the conductor 9, through the entire winding 2, contact members 21 and 26 of the tap-selecting switch 27, conductor 37 and contact members 35 and 41 of the current-interrupting switch 30, to conductor 10.

When the contact member 41 reaches the dotted-line position, bridging the contact members 34 and 35, the winding 3 is connected in a loop circuit including the reactor 39 and the resistor 38. When the contact member 41 is disengaged from the contact member 35 in its further movement in a counterclockwise direction, the loop circuit previously described is interrupted and the voltage of the auxiliary winding 3 combines with that of the winding 2. The value and the phase relation of the voltage of the auxiliary winding 3 are such that, in this position of the current-interrupting switch 30, the voltage of the contact member 34 is substantially that of the contact member 35. The system may be so designed that the voltage of the contact member 34 will be between those of the contact members 35 and 31, in this position of the contact member 41. Preferably, the voltage of the auxiliary winding 3 is made equal to one half of the voltage between adjacent tap points 4, 5, 6, 7 and 8, and the windings are so connected that the voltage vectors are substantially in opposite directions.

Upon disengagement of the contact member 41 from the contact member 35, the voltage between the conductors 9 and 10 is decreased by an amount corresponding to one half the voltage between the tap points 4 and 5, and, on disengagement of the contact member 41 from the contact member 34, the voltage drops an equal amount. After the contact member 41, in its counter clockwise movement, is disengaged from the contact member 34 and before it again engages the contact member 35, thus completing one rotation, the tap-selecting switch 27 is so operated that the contact arm 26 moves from engagement with the contact member 21 into engagement with the contact member 22. With further rotations of the contact member 41, in a counterclockwise direction, a similar sequence of steps is effected, and the conductor 10 is successively connected to the tap points 6, 7 and 8. When the contact member 41, during the counterclockwise movement just described, engages the contact members 34 and 31, the tap points 4 and 5 are temporarily connected together through the auxiliary winding 3 and the resistor 38 and the reactor 39. For the purpose of operating the tap changing-mechanism in a direction to increase the number of sections of the winding 2 connected between the conductors 9 and 10, the contact member 41 is actuated in a clockwise direction, and the several switch operating steps take place in the reverse order from that described above.

In order to increase the stray field of the auxiliary winding 3, such winding may be disposed on different legs of a three-phase transformer core, as indicated in Fig. 2. The winding 3 is shown sub-divided into two portions 3^a and 3^b. Assuming that the corresponding main winding 2 is that of the phase S, the winding sections 3^a and 3^b are disposed on the legs of the core corresponding to the phases of the transformer R and T and positioned as closely as possible to the end yokes of the core, thereby producing a large stray-field flux.

With the windings disposed as illustrated in Fig. 2, the winding sections 3^a and 3^b are so dimensioned and arranged that the

resulting voltage vector 61, which is composed of the components 62 and 63 corresponding to the windings 3^a and 3^b, respectively, will lag about 90° behind the voltage vector S of the main winding 2. The current in the loop circuit, indicated by the voltage vector 52 and denoted by dotted lines in Fig. 1, is about 90° out of phase with the voltage vector 61 and about 180° out of phase with the voltage vector 60, corresponding to the load current in the transformer winding 2. The two currents represented by the vectors 60 and 52, therefore, substantially compensate each other so that, when the contact member 41 of switch 30 is disengaged from the contact member 35, there is very little difference in voltage between the contact members 34 and 35. The voltage vectors of the windings 3^c and 3^d combine with the vector of the winding T, and the vectors of the windings 3^e and 3^f combine with the vector of the winding R, for the second and third phases of the transformer bank, in a manner similar to the vectors of the windings 3^a, 3^b and S.

Fig. 4 illustrates a modification of the system in which a so-called snap switch 70 is used to interrupt the current. The transformer winding 3 is shown connected between the contact members 34 and 35, and a transformer winding 71 is shown connected between the contact members 31 and 32. The voltages of the windings 3 and 71 are so dimensioned that the voltage between the contact member 34 and the contact member 35 is one third of the voltage between adjacent tap connections, and the voltage between the contact members 31 and 32 is also one third of the voltage between adjacent tap connections.

The movable contact member 72 of the load switch 70 and the fixed contacts 31 and 34 are so dimensioned and arranged that between the contact members 35 and 34, 34 and 31, and 31 and 32, no bridging takes place, the length of the movable contact member 72 being less, by a quantity *a*, than the distance between these contacts. The distance *a* is such that it cannot be bridged by an arc fed by the voltage of a step, or even the third portion of a step, but, however, can be easily bridged by the arc of the load current fed with the total voltage. On passage of the switch 70, for example, from the contact member 35 to the contact member 34 an arc thus plays only so long as the movable contact member 72 touches the contact member 34, that is, only so long as the load current has no other way of reaching the movable contact member. At the instant when the latter reaches the contact member 34, the arc goes out at the contact member 35 because the voltage of the winding 3 is not sufficient to maintain it. By the resistance of the arc, the balancing current is substantially diminished. The stray field of the windings 3 and 71 in Fig. 4 may thus be kept much smaller than that of the winding 3 in Fig. 1.

In order that the arc may cause no damage, it is allowed to play only for a very brief period, for example, only during about 1/1000 of a second. Such action is readily obtained by the above-mentioned jump switches, since these switches operate in such a manner that the movable switch member is, at first, prevented from following the movement of the handle 73, to which it is connected by a spring by means of a locking device. The spring 74 is then tensioned, and, as soon as the handle 73 has assumed a certain position, the locking device is released, and the movable switch member is impelled into the new switch position at high speed, in which it is also held by the latching device. The general structure and operation of snap-action switches of this general type are well known in the art.

It may be stated in conclusion that, while the illustrated examples constitute practical embodiments of our invention, we do not wish to limit ourselves strictly to the exact details herein illustrated, since other modifications of the same may be made without departing from the spirit of the invention, as defined in the appended claims.

We claim as our invention:

1. In combination, a transformer winding having a plurality of tap points, a plurality of selector switches each adapted to be connected to a selected one of said tap points, a circuit-interrupting switch connected between a power-circuit conductor and said selector switches and having a plurality of contact members connected, respectively, to each selector switch, means for actuating said several switches in a predetermined sequence for changing the connection between said power-circuit conductor and said winding without interrupting the flow of power therethrough, and an auxiliary transformer winding connected between one selector switch and said power circuit conductor during a certain portion of a cycle of operation of the circuit interrupting switch.

2. In combination, a transformer winding having a plurality of tap points, power-circuit conductors connected to said winding, a circuit-interrupting switch, a pair of selector switches for establishing parallel circuits between selected tap points of said winding and said circuit-interrupting switch, an auxiliary winding inductively related to said first named winding, and means for effecting such a sequence of operation of said switches that, in advancing from one tap position to the next tap position, the circuit through one tap switch is first interrupted and the selector switch is ad-

vanced to its next position, and the auxiliary winding is introduced into the circuit to modify the voltage prior to reestablishing the parallel circuits through the selector switches.

3. In combination, a transformer winding having a plurality of tap points, power-circuit conductors connected to said winding, a pair of selector switches and a current-interrupting switch for connecting one of said conductors to selected tap points of the winding, an auxiliary winding inductively related to said first named winding and connected between certain contact members of said circuit-interrupting switch and to one of said selector switches, and means for so controlling the sequence of operation of said current-interrupting switch and said selector switches that said selector switches are alternately advanced from one tap position to the next tap position, and each switch is advanced only when the circuit therethrough is interrupted by the current-interrupting switch, said means also operating to connect said auxiliary winding between a tap point on the main winding and said conductor during the transition from one tap point to the next tap point.

In testimony whereof, we have hereunto subscribed our names this 28th day of May, 1929, at Nuremberg, Germany.

KARL KURDA.
PAUL SCHADE.