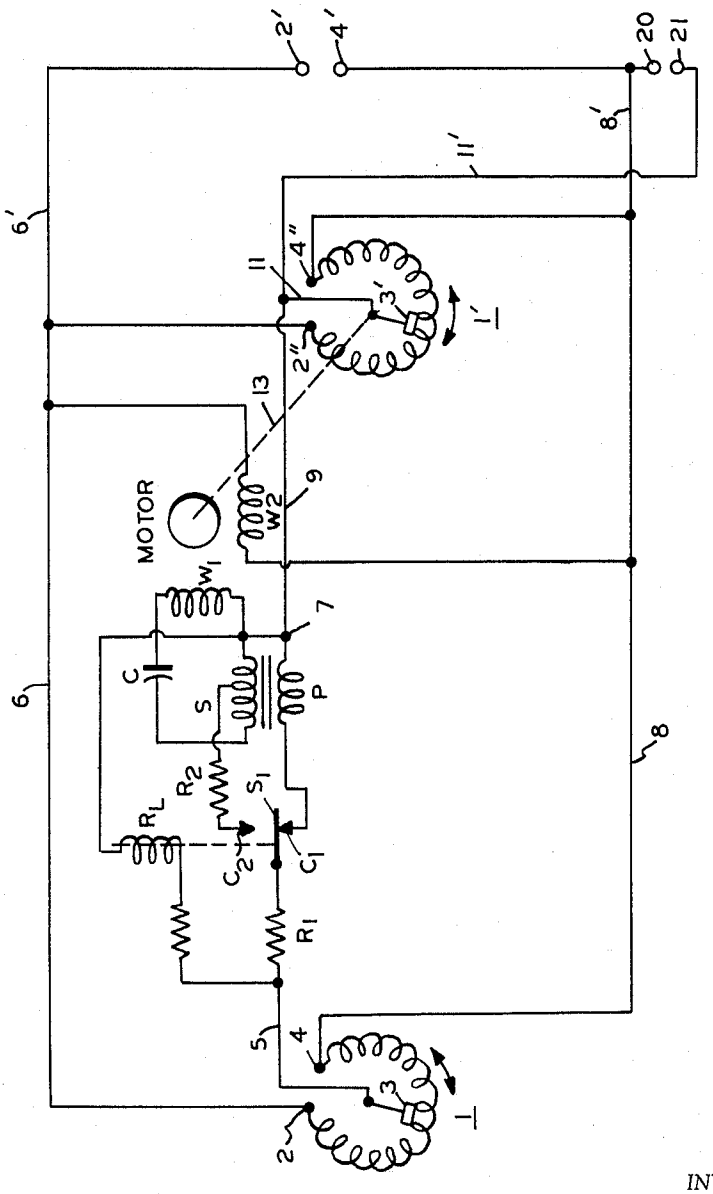
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REMOTE CONTROL VARIABLE AUTOTRANSFORMER SYSTEM

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REMOTE CONTROL VARIABLE AUTOTRANSFORMER SYSTEM

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The present invention relates to remote control variable autotransformer systems and, more particularly, to systems embodying variable autotransformers of the type employing resistive brushes for tapping off variable voltages from the autotransformer winding.

The brushes of autotransformers of the above-described character have often been positioned by motor drives and the like, as with the aid of push-button controls. Such controls operate a circuit for causing a motor to change the setting of the brush upon the autotransformer winding. A voltmeter is employed to indicate the output voltage, thereby to make possible precise voltage settings by operating the controls at a remote point, while viewing the meter. While such systems provide great simplicity and reliability, the meter ballistics and reaction time of the operator in making the remote adjustment, require that the motor drive be relatively slow, as otherwise, considerable difficulty is experienced in adjusting to the desired output voltage as indicated on the meter.

In accordance with the present invention, a novel remote control variable autotransformer system is provided that is not subject to the above-described disadvantage but that, to the contrary, eliminates the requirement for slow-speed operation.

A further object is to provide a novel variable autotransformer system in which there is automatic compensation for load regulation; and, if a low-power regulated line is available to operate the remote control, line-voltage fluctuations may also, in accordance with the present invention, be corrected.

Still an additional object is to provide a new and improved system of the character described that maintains the basic simplicity and reliability of the prior-art push-button control system, while offering the possibility of higher speed operation and greater flexibility.

In summary, from one of its broadest aspects, the invention relates to a remote control variable autotransformer system having, in combination, command and driven variable autotransformers each provided with a winding along successive portions between opposite terminals of which a brush may be positioned to tap off various voltages. Means is provided for supplying alternating-current voltage at predetermined frequency and phase between opposite terminals of the command autotransformer winding, as is means for supplying alternating-current voltage of substantially the same frequency and phase between opposite terminals of the driven autotransformer winding. In many cases, the connections may be effected from a common line and source of voltage. An electric circuit is connected between the brushes of the command and driven autotransformers that preferably introduces no power gain and that develops a difference voltage representative of any difference in voltage between the voltages tapped off upon the autotransformers by their respective brushes. Means, preferably a two-phased motor or the like, is then provided that is controlled by any such developed difference voltage for moving the brush of the driven autotransformer to a position that effects reduction of the said difference voltage to substantially zero.

Other and further objects will be explained hereinafter and will be more particularly pointed out in connection with the appended claims.

The invention will now be described in connection with the accompanying drawing the single figure of which is the schematic circuit diagram illustrating the invention in preferred form.

Referring to the drawing, a command variable autotransformer is illustrated at **1**, as of the type described, for example, in U.S. Letters Patent No. 2,949,592 issued August 16, 1960, to Gilbert Smiley. Such transformers may be in the form of annular copper or similar windings providing a conductive track that is substantially circular in contour and upon which may ride a carbon, graphitic or other resistive or similar brush **3** which, as explained in the said Letters Patent, preferably bridges at least two turns of the winding along the circular track thereof in order to insure contact with a next successive turn before breaking circuit with the preceding turn. Transformers of this or similar character in other forms than the illustrated circular contour may also, of course, be employed, as is well known.

Opposite terminals of the command autotransformer winding **1** are shown at **2** and **4**, respectively connected by the conductors **6–6′** and **8–8′** to the terminals **2′** and **4′** of, for example, an alternating-current main voltage source. The same terminals **2′**, **4′** may also be respectively connected, by conductors **6′** and **8′** to the corresponding opposite terminals **2″** and **4″** of the driven variable autotransformer **1′**, shown for illustrative purposes as of the same type and configuration as the transformer **1**, though such is not always necessary.

The command and driven variable autotransformers are thus supplied with alternating-current voltage of the same frequency and phase between their opposite terminals. Separate voltage sources maintained at the same frequency and phase could also be used for each transformer. Connected between the brushes **3** and **3′** of the respective command and driven autotransformers **1** and **1′** is an electric circuit that, as later more fully explained, is preferably a substantially power-gainless circuit in which there will be developed a difference voltage representative of any difference in voltage between the voltages tapped off the autotransformers **1** and **1′** by their respective brushes **3** and **3′**. This electric circuit is traceable from the brush **3**, by way of a conductor **5** and a surge-current limiting resistor R_1, to the primary winding P of a step-up transformer, preferably of the autotransformer type, having a terminal **7** in common with its secondary winding S. The electric circuit continues from terminal **7**, by way of conductor **9** and conductor **11**, to the brush **3′** of the driven variable autotransformer **1′**.

Any developed difference voltage of the type above-described will be stepped up in the step-up transformer P-S, and will be applied from the secondary winding S through a phase-shifting capacitor C, to one of the windings W_1 (shown as the control winding) of a motor, so labeled. The shaft of the motor is schematically shown, by the dotted gang connection **13**, coupled to the shaft that permits rotation of the brush **3′** of the driven variable autotransformer **1′** along its circular winding. A second and differently phased field winding W_2 is also associated with the motor and receives its field energization from the terminals **2′** and **4′**, by way of the conductors **6′** and **8′**. The motor will thus rotate in response to the stepped-up difference voltage at S to adjust the position of the brush **3′** along its winding until there is no longer any difference voltage applied to the winding W_1. In this event, there is no difference voltage present in the electric circuit **5–R1–P–9–11** connected between the brushes **3** and **3′**, a condition for which the voltage tapped off by the command autotransformer brush **3** is the same as that tapped off by the driven autotransformer brush **3′**.

The step-up transformer P-S may, of course, be replaced by other well-known step-up mechanisms that provide the advantages of this type of operation; but the circuit connecting the brushes 3 and 3' is preferably a power-gainless circuit. The advantages of the stepping up with or without power gain are, indeed, important. Assuming, for example, that the motor requires ten volts or more to start, the setting of the brush 3' of the remote or driven autotransformer 1' might differ by as much as plus or minus 10 volts from that of the command or control autotransformer setting, were the difference voltage to be used directly to drive the motor. To decrease the possible magnitude of this error, the step-up transformer P-S, or similar device, is employed with, for example, a 10-to-1 step-up ratio. A one-volt error can thus cause the motor to operate.

Though the use of a 10-to-1 step-up transformer P-S decreases the required voltage difference between the command and driven transformers 1 and 1' by the ratio of 10-to-1, this also creates the possibility of applying ten times the line or other voltage at terminals 2', 4', across the motor winding, in the event that the command and driven autotransformers 1 and 1' are momentarily adjusted so that their brushes 3 and 3' are at the opposite ends of their respective windings. Such a high voltage could occur, for example, if the brushes 3 and 3' are set at opposite terminals before the power is applied to the terminals 2', 4'; or if a command or control unit 1 were to be set very rapidly from zero to full output.

In order to obviate the effects of such a temporary high voltage, the transformer P-S is preferably designed to saturate for a relatively low voltage applied to its primary-winding P. In the case of 120-volt line voltage, as an illustration, it will be desirable to cause the autotransformer P-S to saturate when, say, 13 volts is applied to the primary P, thus limiting the motor voltage to about 130 volts. The magnetizing current in the step-up transformer P-S will increase rapidly as its core approaches saturation, requiring the provision of means for limiting this current. It is not satisfactory to employ a mere series resistor for such a purpose since a resistor large enough to protect the autotransformer will also contribute a significant voltage drop and phase shift in the voltage applied to the motor. This will result in decreasing the motor torque and increasing the minimum error or difference voltage to several volts. While the use of a non-linear resistor can provide adequate protection from momentary large error or difference voltages and still contribute negligible voltage drop and phase shift as balance is approached, it is generally preferred not to employ such a device, though it may be utilized for certain applications of the invention.

In the drawing, accordingly, in order to provide the unit with a general-purpose function suitable for both slow and high-speed applications, a current-limiting protective relay R_L is employed to limit the current whenever the error or difference voltage is large enough to result in a current in the transformer P-S greater than, say, 2 amperes. The armature-controlled switch S_1 associated with the relay R_L will then become actuated to switch the connection of the brush 3 and its conductor 5 out of engagement with the lower contact member C_1, that connects with the primary winding P of the step-up transformer P-S, and into engagement with an upper contact member C_2. A connection is then effected through a further current-limiting resistor R_2 to an intermediate point of the secondary winding S that introduces in circuit with the brush 3 a greater number of winding turns that the number of turns of the widning P. This will thus serve to maintain the voltage applied to the motor M at a safe value and it will limit the transformer current without dissipating too much power.

The resistor R_1 is series with the switch S_1 limits surge current before the relay R_L has time to operate. As an example, resistor R_1 combined with the transformer winding impedance at saturation may limit the surge current to 20 amperes under the worst possible condition. This surge current will flow for half a cycle only.

The voltage fluctuations that may arise from changes in a load connected to the output or load terminals 20 and 21, that in turn connect by way of conductors 8' and conductor 11' between the brush 3' of the remote or driven autotransformer 1' and the terminal 4' thereof, are automatically compensated in this circuit. This result occurs because, at balance, there can be no appreciable difference of voltage between the command and driven autotransformers. If a regulated line voltage is available to supply the small amount of power needed to operate the command autotransformer 1, corrections may also be automatically obtained for fluctuations in line voltage at the remote or driven autotransformer 1'. The regulated line voltage must have a low impedance at the power frequency, say 60 cycles per second, and must have the same phase angle as the unregulated line to the remote or driven autotransformer 1', as before explained. Such a combination can be used to provide large amounts of power at a regulated voltage which is adjustable from zero to say 140 volts. The addition of a buck-boost transformer, not shown, to limit the correction range to plus or minus ten percent about the normal line voltage, would then result in an increase of 5-to-1 in power rating.

Further modifications will occur to those skilled in the art, and all such are considered to fall within the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A remote control variable autotransformer system having, in combination, command and driven variable autotransformers each having a winding along successive positions between opposite terminals of which a brush may be positioned to tap off various voltages, means for supplying alternating-current voltage of predetermined frequency and phase between opposite terminals of the command autotransformer winding, means for supplying alternating-current voltage of substantially the same frequency and phase between opposite terminals of the driven autotransformer winding, an electric circuit including voltage step-up means connected between the brushes of the command and driven autotransformers for developing and stepping up a difference voltage representative of any difference in voltage between the voltages tapped off upon the autotransformers by their respective brushes, and means comprising an electric motor having at least two phases and controlled by the stepped-up difference voltage for moving the brush of the driven autotransformer to a position that effects reduction of the said difference voltage to substantially zero, the electric circuit being provided with means for limiting the current therein in order to safeguard the said motor against too great a controlling voltage.

2. Apparatus as claimed in claim 1 and in which the voltage step-up means comprises a step-up transformer the primary winding of which introduces a predetermined number of winding turns into the said electric circuit.

3. A remote control variable autotransformer system having, in combination, command and driven variable autotransformers each having a winding along successive positions between opposite terminals of which a brush may be positioned to tap off various voltages, means for supplying alternating-current voltage of predetermined frequency and phase between opposite terminals of the command autotransformer winding, means for supplying alternating-current voltage of substantially the same frequency and phase between opposite terminals of the driven autotransformer winding, a power-gainless electric circuit including voltage step-up means connected between the brushes of the command and driven autotransformers for developing and stepping up a difference voltage representative of any difference in voltage between the voltages tapped off upon the autotransformers by their respective

brushes, and means comprising an electric motor having at least two phases and controlled by the stepped-up difference voltage for moving the brush of the driven autotransformer to a position that effects reduction of the said difference voltage to substantially zero, the electric circuit being provided with means for limiting the current therein in order to safeguard the said motor against too great a controlling voltage.

4. Apparatus as claimed in claim 3 and in which the voltage step-up means comprises a step-up transformer the primary winding of which introduces a predetermined number of winding turns into the said electric circuit.

5. A remote control variable autotransformer system having, in combination, command and driven variable autotransformers each having a winding along successive positions between opposite terminals of which a brush may be positioned to tap off various voltages, means for supplying alternating-current voltage between opposite terminals of the command and driven autotransformer windings, an electric circuit connected between the brushes of the command and driven autotransformers containing the primary winding of a step-up transformer for developing and stepping-up in the secondary winding thereof a difference voltage representative of any difference in voltage between the voltages tapped off upon the autotransformers by their respective brushes, an electric motor having two phase-displaced windings one of which is connected to the said secondary winding of the step-up transformer, means for connecting the brush of the driven autotransformer to be moved in accordance with the movement of the electric motor, and means provided in the said electric circuit for limiting the current therein in order to safeguard the said motor against too great a controlling voltage.

6. A remote control variable autotransformer system having, in combination, command and driven variable autotransformers each having a winding along successive positions between opposite terminals of which a brush may be positioned to tap off various voltages, means for supplying alternating-current voltage of predetermined frequency and phase between opposite terminals of the command autotransformer winding, means for supplying alternating-current voltage of substantially the same frequency and phase between opposite terminals of the driven autotransformer winding, an electric circuit including voltage step-up means connected between the brushes of the command and driven autotransformers for developing and stepping up a difference voltage representative of any difference in voltage between the voltages tapped off upon the autotransformers by their respective brushes, and means comprising an electric motor having at least two phases and controlled by the stepped-up difference voltage for moving the brush of the driven autotransformer to a position that effects reduction of the said difference voltage to substantially zero, the electric circuit being provided with means for limiting the current therein in order to safeguard the said motor against too great a controlling voltage, the voltage step-up means comprising a step-up transformer the primary of which introduces a predetermined number of turns into said electric circuit and the current-limiting means comprising a relay for switching the electric circuit to introduce therein a larger number of winding turns than the said predetermined number.

7. A remote control variable autotransformer system having, in combination, command and driven variable autotransformers each having a winding along successive positions between opposite terminals of which a brush may be positioned to tap off various voltages, means for supplying alternating-current voltage of predetermined frequency and phase between opposite terminals of the command autotransformer winding, means for supplying alternating-current voltage of the same frequency and phase between opposite terminals of the driven autotransformer winding, a power-gainless electric circuit including voltage step-up means connected between the brushes of the command and driven autotransformers for developing and stepping up a difference voltage representative of any difference in voltage between the voltages tapped off upon the autotransformers by their respective brushes, and means comprising an electric motor having at least two phases and controlled by the stepped-up difference voltage for moving the brush of the driven autotransformer to a position that effects reduction of the said difference voltage to substantially zero, the electric circuit being provided with means for limiting the current therein in order to safeguard the said motor against too great a controlling voltage, the voltage step-up means comprising a step-up transformer the primary of which introduces a predetermined number of turns into said electric circuit and the current-limiting means comprising a relay for switching the electric circuit to introduce therein a larger number of winding turns than the said predetermined number.

8. A remote control variable autotransformer system having, in combination, command and driven variable autotransformers each having a winding along successive positions between opposite terminals of which a brush may be positioned to tap off various voltages, means for supplying alternating-current voltage between opposite terminals of the command and driven autotransformer windings, an electric circuit connected between the brushes of the command and driven autotransformers containing the primary winding of a step-up transformer for developing and stepping-up in the secondary winding thereof a difference voltage representative of any difference in voltage between the voltages tapped off upon the autotransformers by their respective brushes, an electric motor having two phase-displaced windings one of which is connected to the said secondary winding of the step-up transformer, and means for connecting the brush of the driven autotransformer to be moved in accordance with the movement of the electric motor, means being provided in the electric circuit for limiting the current therein in order to safeguard the said motor against too great a controlling voltage, the current-limiting means comprising a relay responsive to a predetermined current for switching into the electric circuit a larger number of winding turns than that of the said primary winding of the step-up transformer, thereby to maintain the motor-controlling voltage at a safe value and to limit the step-up transformer current without dissipating a significant amount of power.

9. Apparatus as claimed in claim 8 and in which the said step-up transformer is an autotransformer having a common primary- and secondary-winding terminal, and the said relay switches the connection of the said electric circuit between the brush of the command autotransformer and the step-up transformer primary winding to a point of the secondary winding of the step-up transformer.

10. Apparatus as claimed in claim 9 and in which the said brushes are resistive, the command and variable autotransformers are wound to provide substantially circular brush tracks, and the motor is provided with a shaft coupled to the driven autotransformer brush for moving the same, in accordance with the rotational position of the motor shaft, along the said substantially circular brush track of the driven autotransformer.

11. Apparatus as claimed in claim 10 and in which a load circuit is connected between the brush of the said driven autotransformer and one of the said terminals thereof.

References Cited by the Examiner

UNITED STATES PATENTS

2,323,716	7/1943	Lennox	307—51 X
2,648,045	8/1953	Weathers	323—47
2,913,591	11/1959	Smith et al.	307—51

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