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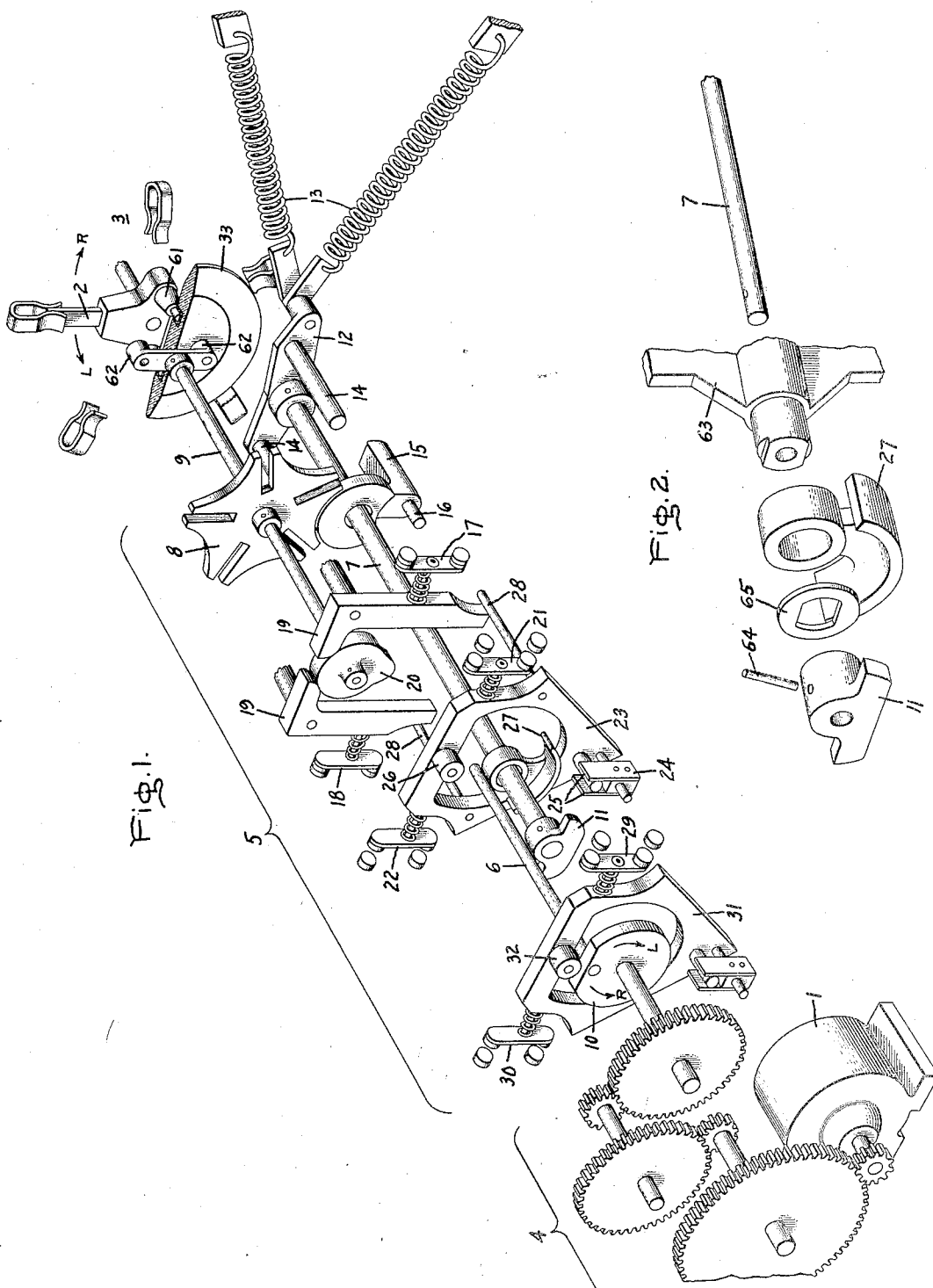
T. C. LENNOX ET AL

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ELECTRIC REGULATOR

Filed Jan. 5, 1938

2 Sheets-Sheet 1



Inventors:
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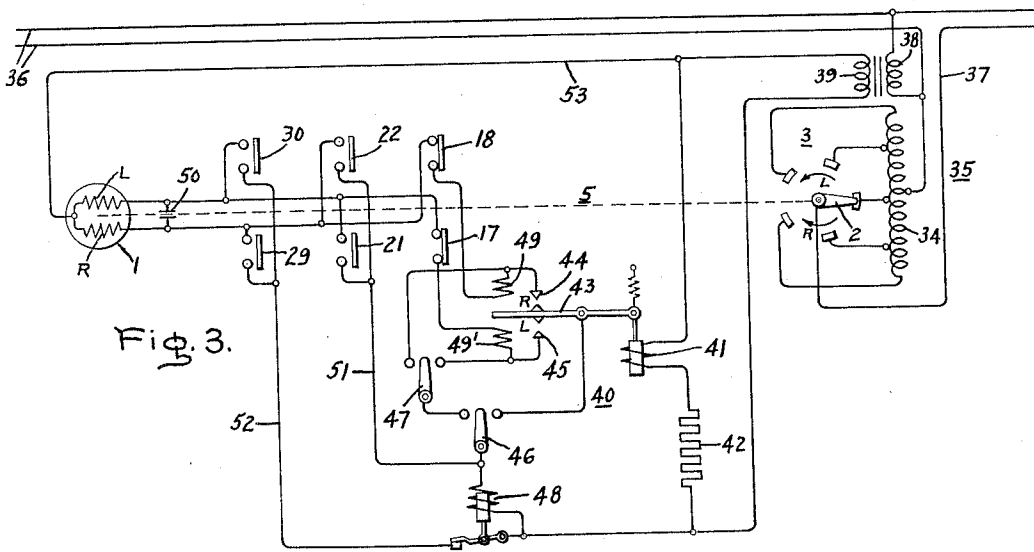
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UNITED STATES PATENT OFFICE

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ELECTRIC REGULATOR

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Application January 5, 1938, Serial No. 183,494

8 Claims. (Cl. 200—92)

This invention relates to electric regulators and more particularly to improvements in the mechanical construction of the operating mechanism and control of automatic step-type feeder-voltage regulators.

Typical regulators of this type consist essentially of a transformer provided with tap-changing means for changing the transformer ratio under load. Primary voltage responsive means is included for automatically controlling the direction of operation of reversible operating means for the tap-changing switch. A typical primary control device of this character is a conventional contact-making voltmeter. In many such regulators the operating mechanism includes a spring drive whereby a relatively low-powered motor stresses the spring relatively slowly until a dead center point is passed, whereupon the spring rapidly snaps the switch through a tap-changing operation.

It is an object of this invention to provide a new and improved operating mechanism of the spring drive type.

It is another object of the invention to provide an interlock between seal-in switches operated by the mechanism and opposite direction of operation limit switches so as to prevent stalling of the mechanism by a reversal of the primary device after the seal-in switches have closed.

Further objects of the invention will occur to those skilled in the art from the following description taken in connection with the accompanying drawings and the scope of the invention will be pointed out in the appended claims.

In the drawings, in which like reference characters designate the same elements throughout the several views, Fig. 1 is an expanded perspective view of the regulator operating mechanism, Fig. 2 is an enlarged detail view of part of the mechanism illustrated in Fig. 1, and Fig. 3 is a diagram of the control circuit used with the mechanism of Fig. 1.

Referring now to the drawings and more particularly to Fig. 1, there is shown therein an operating motor 1 for driving a movable contact 2 of a tap changing switch 3 through reduction gearing 4 and a spring drive 5. Both the motor 1 and the switch 3 are reversible. The main elements of the driving mechanism are a winding pin 6 for turning a crank shaft 7 which operates a Geneva-gear 8 fastened to the movable contact 2 by means of a secondary shaft 9. Because of the Geneva-gear the rotation of the winding pin in one direction will cause the rotation of the movable contact in the opposite direction and to

facilitate the description it will be assumed that a clockwise rotation of the movable contact 2 and a counterclockwise rotation of the winding pin 6 will correspond to a voltage raising operation of the regulator, whereas, a counterclockwise rotation of the movable contact 2 and a clockwise rotation of the winding pin 6 will correspond to a voltage lowering operation of the regulator. These directions of operation are labeled adjacent the movable contact 2 and on a cam 10 which carries the winding pin 6.

As the motor 1 turns in either direction, the winding pin 6 will be turned with it and after the pin has made approximately a quarter of a revolution from the position illustrated in the drawings, it will engage a transverse member or segment 11 rigidly fastened to the crank shaft 7. On the opposite end of the crank shaft 7 is a crank 12 to which are fastened a pair of power springs 13 which normally hold the crank in the illustrated position. Carried by the crank on opposite sides of the shaft 7 are a pair of driving lugs 14 which are arranged to engage a Geneva-gear driver 15 loosely mounted with respect to the crank shaft and carrying a driving pin 16 which engages the slots in the Geneva-gear. When the crank shaft has been rotated through half a revolution from the illustrated position, the springs 13 will be fully stressed and the mechanism will be on dead center. If now the crank shaft is rotated past dead center, the springs will rapidly return the crank and crank shaft to the illustrated position, thus, rotating these parts through the remaining half revolution to the position illustrated in the drawings and in so doing the Geneva-gear will be rapidly turned through a part revolution and the movable contact 2 will be rapidly snapped from the illustrated contact-making position to an adjacent contact-making position.

It will be noted that the connection between the winding pin 6 and the segment 11 permits the crank shaft 7 to turn ahead of the cam 10 and motor 1 so that these latter parts do not act to retard the tap-changing operation.

The mechanism is illustrated in its so-called neutral position and it typically requires approximately 25 seconds for a tap change to be completed after the parts start from this position.

By reason of the number of fixed contacts on the switch 3, the regulator is a 4-step regulator. Thus, as shown, there are two fixed contacts to the right of the center fixed contact corresponding to two steps of voltage raise and there are

two fixed contacts to the left of the center contact corresponding to two steps of voltage lower.

A continued operation of the regulator beyond the maximum raise position or the maximum lower position would cause a sudden change from maximum raise to maximum lower in one step or from maximum lower to maximum raise in one step. This, of course, is very undesirable and to prevent it limit switches 17 and 18 are provided. The movable contacts of these switches are carried by pivoted members 19 which are engaged by a cam 20 operated by the shaft 9. The cam is so arranged that when the tap switch reaches its maximum raise position, the limit switch 18 is opened and when the tap switch reaches its maximum lower position, the limit switch 17 is opened.

In order to prevent the primary control device from stopping the operating motor when the dead center position is reached, a pair of seal-in or seal-through switches 21 and 22 are provided. The movable members of these switches are carried by a frame 23 pivotally carried by a support 24 and normally held in the illustrated vertical mid-position by spring members 25. Carried by frame 23 is a cam roller 26 which is engaged by a cam 27 mounted loosely with respect to the crank shaft 7 and arranged to be driven by the winding pin 6. Thus, as the winding pin 6 rotates in either direction from the illustrated mid-position, it will pick up the cam 27 and upon a predetermined further rotation the cam 27 will engage the roller 26 and will move the frame 23 about its pivot, thereby closing the switch 21 if the winding pin is turning in a lowering direction and closing the switch 22 if the winding pin is turning in the raising direction.

It is to be noted that because the cam 27 is loosely mounted it does not turn ahead rapidly with the crank shaft after the dead center position of the springs has been passed but, on the contrary, it stays against the winding pin 6 and thus holds the seal-in switch closed. As will be explained more clearly in connection with the control diagram of Fig. 3, this causes the motor to continue operation after the springs 13 have discharged their power and insures that if the springs have not completed the tap change, the motor will complete it.

The reason that it is undesirable to permit the primary control device to stop the motor near the dead center position is that a reversal of the motor may "unlatch" the mechanism and leave the tap changing switch in an "off" position.

In order to prevent stalling of the motor and mechanism if the primary control device should attempt to reverse the motor after a seal-in switch has closed, interlocks are provided between the seal-in switches and the opposite limit switches by means of pins 28 carried by frame 23 and engaging members 19. Thus, when seal-in 21 starts to close, the pins 28 move to the right or in a clockwise direction about the pivot 24 thereby causing limit switch 18 to open, while if seal-in switch 22 starts to close, the pins 28 move in the opposite direction thereby causing limit switch 17 to open. These interlocks are preferably so arranged that the limit switches open before the seal-in switches close so as to prevent the momentary occurrence of the overlapping condition in which both the seal-in switches and the limit switches are closed. If such an overlapping were permitted to occur and the primary relay should call for a reversal of the operating motor during this overlap, the motor

would simultaneously be energized for operation in both directions and would stall.

In order to insure a positive return of the mechanism to its neutral position in case a tap change has begun but is not completed, or after a tap change has been completed, or if the primary relay should open between the time that a limit switch opens and the opposite seal-in switch closes, there are provided a pair of neutral return switches 29 and 30. The movable members of these switches are carried by a frame 31 which is similar to frame 23 and which is mounted in the same manner. A cam roller 32 carried by this frame is engaged by the cam 10, the arrangement being such that as soon as the cam 10 starts to turn in either direction, the frame 31 will be turned about its pivot and will close the switch 29 if rotation is in the lowering direction and will close switch 30 if rotation is in the raising direction and whichever switch has been closed will remain closed until the neutral position is again reached. By means of control circuits which will be described hereinafter in connection with Fig. 3, switch 29 controls a circuit for the motor 1 which tends to return the motor in a backward or raising direction to the neutral position, while switch 30 controls a circuit which tends to operate the motor in a backward or lowering direction. By reason of these switches the system has a uniform time delay in its operation because normally it will always start from the same point.

So as to insulate the operating mechanism from the high voltage power circuit, a disk of insulating material 33 is interposed between the movable contact 2 and the shaft 9. By means of a novel construction, this insulating member 33 also acts as a universal joint which will permit operation even though the shaft carrying the movable contact 2 and the Geneva-gear shaft 9 are not in alignment. As shown, the movable contact 2 carries a pair of projections 61, and the Geneva-gear shaft 9 carries a pair of projections 62 and these projections enter staggered openings in opposite faces of the disk 33. These openings do not pass all the way through the disk so that it is impossible to make an electrical connection through the disk itself. This construction results in the insulator having a substantial vertical creepage distance which is desirable in apparatus of this kind, as horizontal creepage distance is unreliable because dust, dirt, and other foreign material settling on a horizontal surface will impair its insulating ability, but no such material will remain on the vertical creepage surfaces of the insulator 33. The insulator is preferably made of porcelain. In order to secure long life and reduce the cutting action of the porcelain to a minimum, the inner surfaces of the openings into which the projections 61 and 62 fit, are glazed and fiber bushings are interposed between the projections and the walls of the openings.

While the parts of Fig. 1 have been separated in a lengthwise direction so as to facilitate their illustration, it should be understood that in practice these parts can be and are very compactly arranged so that actually they do not take up any more lengthwise space than does the motor 1 itself.

This compact arrangement means that the adjacent surfaces of the crank 12 and the Geneva-gear driver 15 on the one hand, and the segment 11 and the seal-in cam 27 on the other hand, will be very close to each other. With an ordinary construction in which these parts can

touch each other, it has been found that false operation of the mechanism will sometimes be produced. This is because the voltage of a feeder circuit is never absolutely constant, with the result that the normal small fluctuations in voltage will cause the motor repeatedly to start and stop in one direction or the other, and sometimes it will stop and start repeatedly in the same direction. This causes the winding pin 6 to be in almost continuous motion and whenever the winding pin turns far enough to move the segment 11, any friction between the segment and the cam 27 on the one hand, and the crank 12 and the Geneva-gear driver 15 on the other hand, will tend to rotate devices 15 and 27, so that in time these devices will be inched along far enough to cause improper operation of the tap-changing switch and improper operation of the seal-in switches respectively.

In order to prevent such undesired operation, the novel anti-friction construction, shown in Fig. 2, is employed. As shown in this figure, the crank shaft 7 is supported in a bushing or journal member 63 and the segment 11 is fastened to the crank shaft 7 rigidly by means of a pin 64 passing through both elements. The seal-in cam 27, however, is loosely mounted on the outside of the bushing or support for the crank shaft 7. Opposite portions of this outside surface are flattened and a washer 65, having correspondingly flattened portions on its inner surface, is mounted on the end of the bearing between the adjacent surfaces of the segment 11 and the cam 27. From this construction, it will be seen that washer 65 cannot rotate and, consequently, any motion of the segment 11 cannot be transmitted by friction to the cam 27. A similar anti-friction construction is provided between the crank shaft 12 and the Geneva-gear driver 15.

While various motor control systems and circuits using the present invention form the subject matter of a divisional application, Serial No. 240,820, filed November 16, 1938, a description of one of said circuits is included herein to facilitate a more complete understanding of this invention. This circuit is shown in Fig. 3 in which, the fixed contacts of the switch 3 are connected to taps in a series winding 34 of a regulating transformer 35. As shown, the electrical mid-point of this winding is connected both to the center fixed contact of the switch 3 and to one side of a single phase alternating current power line or feeder circuit 36. The movable contact 2 is connected to the same side of the line 36 by means of a conductor 37 so that with the movable contact 2 on the center fixed contact, as shown, none of the series winding is connected in the power circuit and the regulator is in its neutral position corresponding to the position of the movable contact 2 in Fig. 1. If now movable contact 2 is moved in either direction, varying amounts of the series winding are connected in the power circuit for either boosting the circuit voltage or bucking the circuit voltage. Transformer 35 is also provided with a shunt or primary winding 38 and an auxiliary winding 39 for supplying low voltage current to motor 1 and for producing a voltage which is proportional to the voltage of the feeder circuit 36. Connected to respond to this voltage is a primary relay in the form of a contact-making voltmeter 40 having an operating winding 41 connected in series with a resistor 42. Contact-making voltmeter 40 is provided with a movable contact 43

for cooperation respectively with a raise contact 44 and a lower contact 45. A control switch 46 is provided for securing selective automatic and manual operation. The manual operation is controlled by means of a manually operated raise and lower switch 47.

When control switch 46 is moved to the right it connects the movable contact 43 of the contact making voltmeter to one side of the auxiliary winding 39 through the operating winding 10 of an auxiliary relay 48 which cooperates with the neutral return contacts 29 and 30, while when it is moved to the left it makes a similar connection between the manually-operated raise and lower switch and the same side of the auxiliary winding 39. The raise and lower contacts of the manually-operated switch 27 connect respectively to the raise and lower contacts of the contact-making voltmeter. The raise and lower contacts are connected respectively to the limit switches 18 and 17 through conventional holding coils 49 and 49' on the contact-making voltmeter. These holding coils are provided for preventing chattering of the voltmeter contacts. The motor 1 is provided with a phase-splitting 25 capacitor 50 in a conventional and well-known manner.

The seal-in switches 21 and 22 are connected respectively to the terminals of the motor for causing it to operate in a lowering and raising 30 direction and they are connected by means of a common conductor 51 to the lowermost side of the auxiliary winding 39 through the operating winding of the auxiliary relay 48.

The neutral return switches 29 and 30 are 35 connected respectively to the motor terminals for causing operation in the raising and lowering directions and they are supplied by a common conductor 52 through the contacts of the auxiliary relay 48. A common return conductor 53 40 connects the common terminal of the motor to the upper side of the auxiliary winding 39.

The operation is as follows: With the parts in the positions shown, the regulator is in its neutral position and the voltage of the circuit 36 is normal causing the contact-making voltmeter 40 to be in its mid-position. If automatic operation of the regulator is desired, the control switch 46 is moved to the right into its automatic operation position. If now the voltage of circuit 36 should 50 decrease, the contact-making voltmeter would close its raise contacts, thereby completing a circuit for the motor through the holding coil 49 and the raise limit switch 18. This will start the motor in a raising direction. The motor 55 current in flowing through the operating winding of the auxiliary relay 48 will cause this relay to open its contacts. Very soon after the motor starts the neutral return switch 30 will close, but as the contacts of the auxiliary relay 48 are 60 opened no circuit is completed by the closure of the neutral return switch. Continued operation of the motor will cause the power springs 13 (Fig. 1) to be stretched until, shortly before the dead center position is reached, the lower limit switch 65 17 will open and almost immediately thereafter the seal-in switch 22 will close. Opening of the lower limit switch 17 and closing of the seal-in switch 22 removes control of the operating motor from the contact-making voltmeter. The motor, 70 therefore, will continue to operate in a raise direction regardless of what the contact-making voltmeter does and as soon as dead center is passed, the springs 13 will snap the movable contact 2 in a clockwise direction to the next adja- 75

cent fixed contact, thereby inserting in the circuit 36 a portion of the series winding 35 and raising the circuit voltage one step.

If this brings the voltage within the normal voltage range, the contact-making voltmeter will go to its non-contact-making position and will not call for any further regulation. However, as previously explained in connection with Fig. 1, the seal-in switch 22 remains closed until the motor 1 has been run long enough to return all of the parts of the driving mechanism to their neutral positions as shown in Fig. 1, whereupon the seal-in switch 22 opens and the motor is de-energized.

If the fall in voltage has been only momentary and the contact-making voltmeter opens its raise contacts before the seal-in switch 22 closes, the auxiliary relay 48 will be deenergized, thus closing its contacts and completing a circuit through the neutral return switch 30. This circuit reverses the motor and causes it to turn in the lowering direction until the operating mechanism is returned to its neutral position. The springs 13, of course, tend automatically to return the mechanism toward the neutral position at such times but because of friction, the retarding action of thickened oil during cold weather and the large mechanical advantage of the reduction gearing 4, the springs cannot be relied upon to provide the return movement. In any event, they would never return the part of the mechanism including the motor and driving pin exactly to its neutral position and thus could not provide inherently the equal time delay feature provided by the present invention through the action of the neutral return switches in causing positive neutral return by reverse energization of the motor.

If the voltage should rise high enough to cause the contact-making voltmeter to close its lower contacts 45 before the lower limit switch 17 opens, the motor will be reversed through the lower contacts 45, the holding coil 49' and the lower limit switch 17 and if the high voltage condition persists the motor will continue on through the neutral position to cause a lowering operation of the regulator in a manner corresponding to the above-described raising operation. During this lowering operation, the lower seal-in switch 21 and the neutral return switch 29 and the raise limit switch 18 will operate to provide the same protection of the mechanism as has just been described for a raising operation. That is to say, the neutral return switch 29 will close as soon as the neutral position has been passed in the lowering direction and just before dead center is reached the raise limit switch 18 will open and immediately thereafter the lower seal-in switch 21 will close.

For manual operation, the control switch 46 is moved to the left and then raising and lowering operations can be selectively secured by moving the manual switch 47 to the left or to the right respectively, the resulting operation being just the same as though control were by means of the contact-making voltmeter.

While there has been shown and described a particular embodiment of this invention, it will be obvious to those skilled in the art that changes and modifications can be made therein without departing from the invention and, therefore, it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What we claim as new and desire to secure by Letters Patent of the United States, is:

1. In an automatic transformer tap changing step regulator, in combination, a tap changing switch having a contact adapted to be moved in forward and reverse directions into successive engagement with a plurality of fixed tap contacts, a Geneva-gear for operating said movable contact, a crankshaft, a power spring attached to a crank on said shaft and adapted normally to hold said shaft in a given angular position, a Geneva-gear driver, driving lugs for said Geneva-gear driver fastened to said crankshaft on opposite sides thereof, a transverse member rigidly fastened to said crankshaft, a winding pin for engaging said member, reduction gears for driving said winding pin, and a reversible motor for operating said reduction gears.

2. In an automatic transformer tap changing step regulator, in combination, a tap changing switch having limit positions and provided with a contact adapted to be moved in forward and reverse directions into successive engagement with a plurality of fixed tap contacts, a Geneva-gear for operating said movable contact, a pair of limit switches, means operated when said tap changing switch reaches its limit positions for respectively opening said limit switches, a crankshaft, a power spring attached to a crank on said shaft and adapted normally to hold said shaft in a given angular position, a Geneva-gear driver, driving lugs for said Geneva-gear driver fastened to said crankshaft on opposite sides thereof, a transverse member rigidly fastened to said crankshaft, a winding pin for engaging said member, reduction gears for driving said winding pin, and a reversible motor for operating said reduction gears.

3. In an automatic transformer tap changing step regulator, in combination, a tap changing switch having a contact adapted to be moved in forward and reverse directions into successive engagement with a plurality of fixed tap contacts, a Geneva-gear for operating said movable contact, a crankshaft, a power spring attached to a crank on said shaft and adapted normally to hold said shaft in a given angular position, a Geneva-gear driver, driving lugs for said Geneva-gear driver fastened to said crankshaft on opposite sides thereof, a transverse member rigidly fastened to said crankshaft, a winding pin for engaging said member, a pair of seal-in switches, a cam for operating said seal-in switches loosely mounted on said crankshaft and adapted to be engaged by said winding pin, reduction gears for driving said winding pin, and a reversible motor for operating said reduction gears.

4. In an automatic transformer tap changing step regulator, in combination, a tap changing switch having limit positions and provided with a contact adapted to be moved in forward and reverse directions into successive engagement with a plurality of fixed tap contacts, a Geneva-gear for operating said movable contact, a pair of limit switches, means operated when said tap changing switch reaches its limit positions for respectively opening said limit switches, a crankshaft, a power spring attached to a crank on said shaft and adapted normally to hold said shaft in a given angular position, a Geneva-gear driver, driving lugs for said Geneva-gear driver fastened to said crankshaft on opposite sides thereof, a transverse member rigidly fastened to said crankshaft, a winding pin for engaging said member, a pair of seal-in switches, a cam for

operating said seal-in switches loosely mounted on said crankshaft and adapted to be engaged by said winding pin, interlocks between each limit switch and the seal-in switch which is closed during opposite direction rotation of the mechanism for opening the limit switch before the seal-in switch closes, reduction gears for driving said winding pin, and a reversible motor for operating said reduction gears.

5. In an automatic transformer tap changing step regulator, in combination, a tap changing switch having a contact adapted to be moved in forward and reverse directions into successive engagement with a plurality of fixed tap contacts, a Geneva-gear for operating said movable contact, a crankshaft, a power spring attached to a crank on said shaft and adapted normally to hold said shaft in a given angular position, a Geneva-gear driver, driving lugs for said Geneva-gear driver fastened to said crankshaft on opposite sides thereof, a transverse member rigidly fastened to said crankshaft, a winding pin for engaging said member, said winding pin having a neutral position, a pair of neutral return switches, means responsive to the direction of rotation of said winding pin for closing a neutral return switch whenever said pin is out of its neutral position, reduction gears for driving said winding pin, and a reversible motor for operating said reduction gears.

6. In an automatic transformer tap changing step regulator, in combination, a tap changing switch having limit positions and provided with a contact adapted to be moved in forward and reverse directions into successive engagement with a plurality of fixed tap contacts, a Geneva-gear for operating said movable contact, a pair of limit switches, means operated when said tap changing switch reaches its limit positions for respectively opening said limit switches, a crankshaft, a power spring attached to a crank on said shaft and adapted normally to hold said shaft in a given angular position, a Geneva-gear driver, driving lugs for said Geneva-gear driver fastened to said crankshaft on opposite sides thereof, a transverse member rigidly fastened to said crankshaft, a winding pin for engaging said member, a pair of seal-in switches, a cam for operating said seal-in switches loosely mounted on said crankshaft and adapted to be engaged by said winding pin, interlocks between each limit switch and the seal-in switch which

is closed during opposite direction rotation of the mechanism for opening the limit switch before the seal-in switch closes, a pair of neutral return switches, means responsive to the direction of rotation of said winding pin for closing a neutral return switch whenever said pin is out of its neutral position, reduction gears for driving said winding pin, and a reversible motor for operating said reduction gears.

7. In a step regulator, a switch adapted to change taps on a winding of a relatively high voltage transformer, relatively low voltage control and operating means having a member for driving said switch, said switch having a movable contact, said movable contact and said operating member being adapted to turn about respective axes which are in substantial alignment, said movable contact carrying a plurality of projections which face toward said operating member, said operating member carrying a plurality of projections which face toward said movable contact, a disk of porcelain having staggered imperforate openings in opposite faces thereof which are entered by said projections, the inner surfaces of said openings being glazed, and fiber bushings interposed between said glazed surfaces and said projections.

8. In an automatic transformer tap changing step regulator, in combination, a tap changing switch having a contact adapted to be moved in forward and reverse directions into successive engagement with a plurality of fixed tap contacts, a Geneva-gear for operating said movable contact, a crankshaft, a power spring attached to a crank on said shaft and adapted normally to hold said shaft in a given angular position, a Geneva-gear driver, driving lugs for said Geneva-gear driver fastened to said crankshaft on opposite sides thereof, a transverse member rigidly fastened to said crankshaft, a winding pin for engaging said member, a pair of seal-in switches, a cam for operating said seal-in switches loosely mounted on said crankshaft adjacent said transverse member and adapted to be engaged by said winding pin, a non-rotatably mounted washer interposed between said transverse member and said loosely mounted cam, reduction gears for driving said winding pin, and a reversible motor for operating said reduction gears.

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