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R. D. CONWAY.

ELECTRIC REGULATOR.

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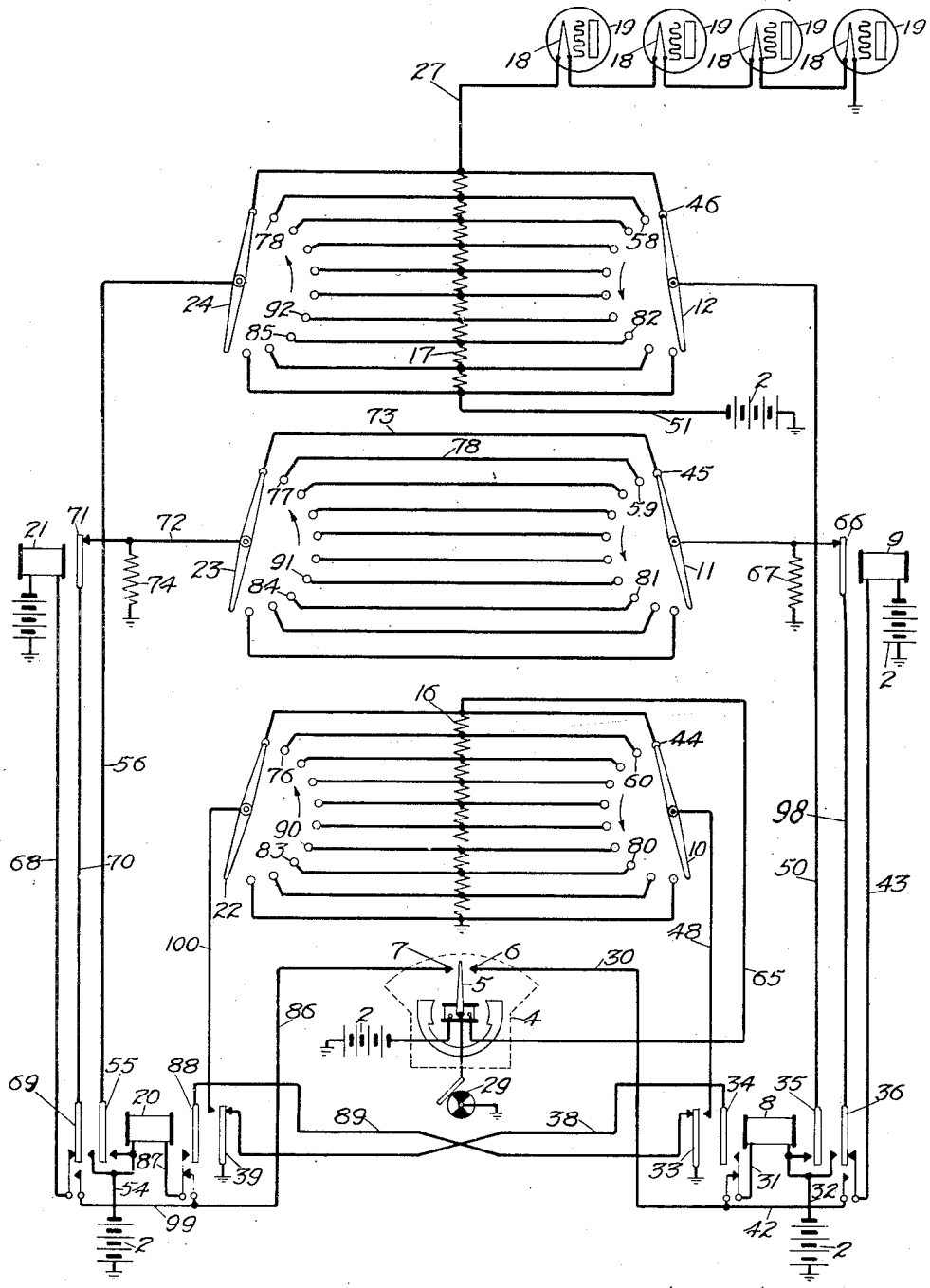

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UNITED STATES PATENT OFFICE.

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ELECTRIC REGULATOR.

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To all whom it may concern:

Be it known that I, ROY D. CONWAY, a citizen of the United States, residing at Chatham, in the county of Morris, State of New Jersey, have invented certain new and useful Improvements in Electric Regulators, of which the following is a full, clear, concise, and exact description.

This invention relates to arrangements for regulating an electrical characteristic of a circuit such as the intensity of current flowing therethrough. One of the objects of the invention is to provide a method and means for insuring a constant flow of current through a circuit. Another object consists in providing means for automatically increasing the resistance in a circuit whenever the current flow therethrough has a tendency to increase, and also means for automatically reducing the resistance in said circuit as the current flow tends to decrease. Other objects of this invention will appear in the detailed description to be given later.

It has often been found desirable to associate with a work circuit including translating devices, such, for example, as a circuit including the filaments of vacuum tube repeaters, an arrangement for regulating the current flow therethrough. This is because the voltage of the source supplying the electrical current may have a tendency to vary beyond the limits within which satisfactory operation of the apparatus will result. As it has been found that a vacuum tube repeater will give better service if the current flow in its filament heating circuit remains constant, the regulating apparatus comprising this invention has been provided.

The preferred form of this invention comprises a voltmeter relay sensitive to slight variations in voltage, the winding of which is connected to a source which supplies current for the work circuit. An increase in the voltage of this source will cause a circuit to be closed over the needle and one of the contacts of the voltmeter, thereby operating a resistance varying mechanism to add a certain amount of resistance in series with the winding of the voltmeter and in the work circuit. If the resistance thus added to the voltmeter circuit and the work circuit is insufficient to counterbalance the increase in current due to the change in voltage, the voltmeter needle will not fall back to neutral position, but will serve to hold closed the circuit over the contact of the voltmeter. Accordingly the resistance varying mechanism will continue to operate and will add further resistance units to the circuit including the voltmeter winding and the work circuit until the increase in current flow has been counterbalanced and the needle returned to neutral position. If the current flow from the source decreases, a circuit is closed over the needle and another contact of the voltmeter which serves to operate the resistance varying mechanism to reduce the resistance in the voltmeter circuit and the work circuit in proportion to the decrease in voltage.

In the preferred form of this invention, this resistance varying mechanism comprises two single motion step-by-step switches responsive to the voltmeter and controlling through a plurality of contact arms the amount of resistance in the voltmeter circuit and the work circuit. One of these switches is adapted to rotate its contact arms so as to increase the amount of resistance while the other switch is adapted to rotate its contact arms in such a direction as to decrease the amount of resistance. Means are also provided for insuring that the corresponding contact arms of the two switches will always be connected to the same points of the resistance so that there will be no break in the operation of the regulator for either increases or decreases in the voltage or current of the work circuit.

This invention may now be more fully understood from the following detailed description taken in connection with the accompanying drawing which illustrates the preferred form of the circuit arrangements in this invention.

Connected to a battery 2 is the winding of a voltmeter relay 4 which has a needle 5 located between two stationary contacts 6 and 7. Under the control of needle 5 and contact 6 is a relay 8 which has under its control a magnet 9 for operating the step-

ping mechanism for contact arms 10, 11 and 12. These three contact arms if desired may be mounted on a common shaft. The step-by-step mechanism for contact arms 10, 11 and 12 is not shown in the drawing, but may be of any suitable type, and may comprise for example a ratchet wheel mounted on the shaft and controlled by a stepping pawl adjacent magnet 9. These contact arms should be controlled by their stepping mechanism in such a manner as to cause them to rotate in a counter clockwise direction. The position of contact arm 10 determines the effective amount of resistance 16 which is connected in circuit with the winding of voltmeter relay 4 for increasing values of the resistance. Contact arm 12 serves to determine the effective amount of resistance 17 which is included in the heating circuit for filaments 18 of the vacuum tube repeaters 19, for increasing values of the resistance. The function of contact arm 11 will be described later.

Under the control of needle 5 and stationary contact 7 is a relay 20 which has under its control a magnet 21 for operating the stepping mechanism (not shown) for the contact arms 22, 23 and 24. These three arms may, if desired, be mounted on a common shaft and may have a stepping mechanism similar to that for arms 10, 11, and 12. Contact arms 22, 23 and 24 should be controlled by their stepping mechanism in such a manner as to cause them to rotate in a counter-clockwise direction. Contact arm 22 serves to control the amount of resistance 16 in circuit with the voltmeter relay winding for decreasing values of the resistance. Similarly contact arm 24 serves to control the amount of resistance 17 in the work circuit for decreasing values of the resistance.

The method of operation of the circuit arrangement of this invention may now be explained as follows: Assume, with contact arms 10, 11 and 12 and 22, 23 and 24 in the positions shown, that battery 2 is supplying normal value of heating current for the filaments 18. The needle 5 of voltmeter 4 will, therefore, be in neutral position. With contact arm 12 on contact 46 a heating circuit for cathodes 18 may be traced as follows: from ground, battery, conductor 51, resistance 17, conductor 27, cathodes 18 to ground. Since in the operation of the circuit arrangement, either relay 8 or 20 is always energized, another heating circuit for the filaments 18 is provided as follows: from ground, battery 2, conductor 32, movable contact 35, conductor 50, contact arm 12 to contact 46 or from ground and battery, conductor 54, movable contact 55, conductor 56, contact arm 24 to conductor 27 and cathodes 18 to ground. The heating current supplied to the cathodes 18, therefore, consists of two components, one fed to the cathodes through conductor 51 and all of resistance 17, the other component being fed through either conductor 50 or 56 to the cathodes.

Suppose for example that the amount of heating current supplied to the cathode should tend to increase beyond its normal value due to a change in the voltage of source 2. This increase of the voltage of source 2 will cause needle 5 to be deflected to the right and close the following circuit: from ground, through the motor-driven interrupter 29, needle 5, contact 6, conductors 30, 31, winding relay 8, conductor 32 to battery and ground. The closing of this circuit will cause relay 8 to become energized, thereby pulling up its movable contacts 33, 34, 35 and 36. The pulling up of movable contact 34 will cause relay 8 to be locked up over the following circuit: from ground and battery, conductor 32, winding relay 8, conductor 31, movable contact 34, conductor 38, and movable contact 39 to ground. The pulling up of movable contact 36 closes the following circuit, from ground, interrupter 29, needle 5, contact 6, conductors 30, 42, and 43, winding relay 9 to battery and ground. The closing of this circuit will cause interrupter 29 to send out impulses over this circuit. The first impulse produced by interrupter 29 will cause relay 9 to operate the stepping mechanism of contact arms 10, 11 and 12 so as to move them one step in a counter-clockwise direction. Contact arms 10, 11 and 12 will, therefore, be moved from contacts 44, 45 and 46 to contacts 58, 59 and 60. The moving of contact arm 12 from contact 46 to contact 58 will increase the resistance in circuit with cathodes 18 and conductor 50 by an amount equal to that part of resistance 17 which is located between the two contacts. The amount of heating current supplied to cathodes 18 through conductor 50 will, therefore, be decreased. Due to the moving of contact arm 10 from contact 44 to contact 60 the supply circuit for voltmeter 4 may now be traced as follows: from ground and battery 2, winding of voltmeter 4, conductor 65, that part of resistance 16 which is included between contact 44 and contact 60, contact arm 10, conductor 48, movable contact 33 to ground. The moving of contact arm 10 from contact 44 to contact 60 has, therefore, increased the amount of resistance in the voltmeter circuit. If the amount of resistance added to the filament circuit and to the voltmeter circuit is sufficient to compensate for the increase in voltage of source 2, needle 5 will return to neutral position. Relay 8, however, will remain energized on account of its being locked up over movable contact 39 of relay 20 so that the filament heating circuit and the voltmeter circuit are

still traced over the closed contacts of relay 8, as described above. If, as just assumed, the addition of the two elements of resistance to the filament circuit and the voltmeter circuit are sufficient to compensate, needle 5 will return to neutral position before sufficient time has elapsed for interrupter 29 to send a second impulse to relay 9 for stepping the mechanism a second time. Contact arms 10, 11 and 12 will, therefore, remain on contacts 58, 59 and 60.

As noted above, either relay 8 or 20 is always energized in the operation of this circuit arrangement. Prior to the energization of relay 8 described above and while relay 20 was therefore energized, the following circuit was completed over the contacts of relay 9: from ground, battery, winding of relay 9, conductor 43, movable contact 36, conductor 98, movable contact 66 and resistance 67 to ground. Although this circuit was closed, battery 2 was prevented from energizing relay 9 because relay 9 was short-circuited at the same time by the following connection: battery 2, conductor 54, contact 69 of energized relay 20, conductor 70, contact 71, conductors 72, 73, contact 66, conductors 98 and 43 to winding of relay 9. Since the battery 2 shown adjacent relay 9 is the same battery as that shown adjacent relay 20, (the battery being shown at various places in the drawing as a matter of convenience only), it follows that the connection just traced through conductors 43, 98, 72 and 70, acts as a direct short-circuit across relay 9 and thereby prevents its operation. With relay 20 energized, relay 21 will also not be energized because its only connection to ground is through conductors 68 and 99, through the contacts of voltmeter relay 4. A similar condition exists when, in the operation of the circuit arrangement, relay 20 is deenergized and relay 8 is energized. In this last condition, the only energizing circuit for relay 9 is through conductors 43, 42 and 30 to the contacts of the voltmeter relay 4 so that relay 9 will operate only upon the deflection of the needle 5 to the right. Although with relay 20 deenergized, the path from ground, battery, winding of relay 20, conductors 68, 70, contact 71, resistance 74 to ground is closed, the closing of this circuit will not operate relay 21 since the relay is short-circuited with respect to battery 2 by conductors 68, 70, 72, 73, 98, 32 to battery 2.

Keeping in mind, the fact that relay 21 is temporarily short-circuited when relay 20 is deenergized and relay 8 is energized, it will be seen that as soon as interrupter 29 has sent out an impulse over the previously traced circuit to step the contact arm 11 from contact 45 to contact 59, the short-circuiting connection for relay 21 through the energized contacts of relay 8 will be broken since conductor 73 is no longer connected to conductor 98 leading to the connection to battery adjacent relay 8.

Relay 21, by the breaking of this connection with relay 9, will at once begin to operate as a self-interrupter to rotate arms 22, 23 and 24 in a counter-clockwise direction due to the opening and closing of the following circuit: ground, battery, winding relay 21, conductors 68 and 70, movable contact 71, through resistance 74 to ground. Due to the opening and closing of this circuit, relay 21 will continue to operate the stepping mechanism for contact arms 22, 23 and 24 until these contact arms are connected to contacts 76, 77 and 78. As soon as contact arm 23 reaches contact 77, the relay 21 will cease operating since it will be connected through conductors 78, 98 and 32 to battery 2, thereby reestablishing the short-circuiting above described.

If, however, the amount of resistance that has been added to the voltmeter circuit and the filament circuit is not sufficient to compensate for the increase in voltage of source 2, needle 5 will remain deflected to the right and the interrupter 29 will send a second impulse to relay 9, thereby causing this relay to rotate, contact arms 10, 11 and 12 one step farther in a counter-clockwise direction. The moving of contact arms 10 and 12 will add a second element of resistance to both the voltmeter circuit and the filament circuit by circuits previously traced. The moving of contact arm 11 from contact 59 on to the next contact in order will remove the neutralizing connection for relay 21, and allow it to step around contact arms 22, 23 and 24, until contact arm 23 is on such a contact as to reestablish the neutralizing action. If the addition of this second element of resistance to the voltmeter circuit and the work circuit is sufficient to counterbalance the increase in voltage of source 2, the needle 5 will return to neutral position before interrupter 29 has had sufficient time to send out a third impulse to relay 9.

If, however, the second element of resistance is not sufficient to compensate for the increase in voltage, it follows that needle 5 will remain deflected to the right, and interrupter 29 will continue to send out energizing impulses to relay 9, until relay 9 has stepped around contact arms 10, 11 and 12 far enough to add to the work circuit and the voltmeter circuit a sufficient number of the elements of resistances 16 and 17 to compensate for the increase in voltage. Every change in the position of contact arms 10, 11 and 12 will cause contact arms 22, 23 and 24 to change their positions so that when the compensation for the increase of voltage for source 2 has been obtained, contact arms 10, 11 and 12 and 22, 23 and 24 will be resting on corresponding contacts. Suppose, for ex-

ample, that in order to compensate for the increase in voltage, contact arms 10, 11 and 12 were moved to contacts 80, 81 and 82, respectively. With contact arms 10, 11 and 12 in this position, contact arms 22, 23 and 24 will be located on contacts 83, 84 and 85, respectively. With the six contact arms on these last-mentioned contacts, suppose that the heating current for cathodes 18 is decreased in value due to the decrease in voltage of battery 2. Needle 5, which before the decrease in voltage was in neutral condition, will now be deflected on the left and close the following circuit: ground, interrupter 29, needle 5, contact 7, conductors 86 and 87, winding relay 20, conductor 54 to battery and ground. The closing of this circuit will energize relay 20 to pull up its movable contacts. The pulling up of contact 39 will break the locking circuit for relay 8, which was previously traced as follows: from ground, battery 2, conductor 32, winding relay 8, conductor 31, movable contact 34, conductor 38, movable contact 39 to ground. The deenergization of relay 8 will cause movable contact 33 to fall back and close the following locking circuit for relay 20: from ground, battery 2, conductor 54, winding relay 20, conductor 87, movable contact 88, conductor 89, movable contact 33 to ground. Due to the pulling up of movable contact 69, interrupter 29 will now send an energizing impulse over the following circuit to relay 21: from ground, interrupter 29, needle 5, contact 7, conductors 86, 99, and 68, winding relay 21 to battery and ground. The closing of this circuit will cause relay 21 to operate the stepping mechanism of contact arms 22, 23 and 24 one step in a counter-clockwise direction, so that they now rest on contacts 90, 91 and 92, respectively. When the contact arm 24 was on contact 85, the variable heating current component for cathodes 18 may be traced through the following circuit: from ground, battery 2, conductor 54, movable contact 55, conductor 56, contact arm 24, contact 85, that part of resistance 17 located between contact 85 and conductor 27, cathodes 18 to ground. As soon, however, as contact arm 24 has been moved to contact 92, it is evident that the resistance in the circuit just traced has been decreased by an amount equal to that part of resistance 17 located between contacts 85 and 92. Similarly when contact arm 22 was on contact 83, the supply circuit for voltmeter 4 was as follows: from ground, battery 2, winding of voltmeter 4, conductor 65, contact 83, contact arms 22, conductor 100, movable contact 39 to ground. With the moving, however, of contact arm 22 from contact 83 to contact 90, the amount of resistance in the voltmeter circuit has been decreased by the amount of resistance located between these two contacts. With the moving of contact arms 22, 23 and 24 one step in a counter-clockwise direction, relay 9 will be operated to move contact arms 10, 11 and 12 until they rest on corresponding contacts. If the decrease in amount of resistance in the work circuit and the voltmeter circuit is sufficient to counterbalance the decrease in the voltage of source 2, needle 5 will return to neutral position before interrupter 29 has had sufficient time to send out a second energizing impulse for relay 21. Relay 20, however, will remain locked up over the circuit previously traced.

If, however, the decrease in the amount of resistance in the voltmeter circuit and the work circuit is not sufficient to counterbalance the decrease in voltage of source 2, needle 5 will remain deflected to the left, so that interrupter 29 will send a second impulse to energize relay 21 for stepping around contact arms 22, 23 and 24 and additional step in the counter-clockwise direction, thereby producing a second decrease in the amount of resistance in the work circuit and the voltmeter circuit. If this second decrease in the value of the resistance is not sufficient to counterbalance the decrease in the voltage of source 2, it follows that interrupter 29 will continue to send out energizing impulses for relay 21 until contact arms 22, 23 and 24 have been stepped around a sufficient number of steps to cause the proper decrease in the value of the resistances. Every change in the position of contact arms 22, 23 and 24 will cause relay 9 to step contact arms 10, 11 and 12 to corresponding positions so that contact arms 10, 11 and 12 will be ready at any time to increase the value of the resistances beginning at the value of the resistances last determined by contact arms 22, 23 and 24. Contact arms 22, 23 and 24 will, therefore, take care of decreases in voltage of battery 2, while contact arms 10, 11 and 12 will take care of increases in the value of voltage of source 2, and each set of contact arms will start operating with that amount of resistance 16 and 17 which has been determined by the last movement of either set of contact arms.

It will generally be found preferably to adjust the circuits so that with normal voltage from source 2, the contact arms will be connected approximately to the middle of the resistances, thereby allowing the regulator to compensate for a large increase as well as decrease in voltage.

Although magnets 9 and 21 are shown controlling contact arms for only one filament heating circuit, it is evident that these magnets may control a plurality of sets of such arms in a similar manner for controlling a plurality of heating circuits.

In the drawing only ten contacts have been illustrated for each contact arm. It is evident, however, that any desired num-

ber of contacts may be employed for each contact arm so as to give any desired graduation in the step-by-step variation of the value of resistances 16 and 17. It is also evident that other modifications may be made in the circuit arrangement above described without departing in anywise from the spirit of this invention as defined in the appended claims.

What is claimed is:

1. In an electric system, a work circuit, a solenoid responsive to a condition of said work circuit, a variable impedance in said work circuit, means responsive to said solenoid for increasing the value of said impedance, means responsive to said solenoid for decreasing the value of said impedance, contacts connected to a plurality of points on said impedance individual to said first means and contacts connected to a plurality of points on said resistance individual to said second means.

2. In an electric system, a work circuit, a source of voltage in said circuit, and means responsive to the voltage of said source for holding substantially constant the current in said circuit, said means comprising a solenoid responsive to the voltage of said source, a variable impedance in said work circuit, magnetic means responsive to said solenoid for increasing the value of said impedance, magnetic means responsive to said solenoid for decreasing the value of said impedance, contacts connected to a plurality of points on said impedance individual to said first magnetic means, and contacts connected to a plurality of points on said impedance individual to said second magnetic means.

3. In an electric system a work circuit, a solenoid responsive to a condition of said work circuit, a variable impedance, means responsive to said solenoid for increasing the value of said impedance, and means responsive to said solenoid for decreasing the value of said impedance, each of said means at times being responsive to the other of said means.

4. In an electric system a work circuit, a solenoid responsive to a condition of said work circuit, a variable impedance in said work circuit, means responsive to said solenoid for increasing the value of said impedance, means responsive to said solenoid for decreasing the value of said impedance, each of said means comprising a movable contact arm adapted to be connected to a plurality of points on said impedance.

5. In an electric system, a work circuit, a solenoid responsive to a condition of said work circuit, a variable impedance in said work circuit, magnetic means responsive to said solenoid for increasing the value of said impedance, magnetic means responsive to said solenoid for decreasing the value of said impedance, each of said magnetic means comprising circuit-closing means adapted to be connected to a plurality of points on said impedance, one of said magnetic means being responsive at times to the other of said means.

6. In an electric system, a source of voltage, a work circuit comprising said source, a solenoid responsive to a condition of said work circuit, a variable impedance in said work circuit, a set of contacts connected to a plurality of points on said impedance, a second set of contacts connected to a plurality of points on said impedance, circuit-closing means cooperating with one set of said contacts, a second circuit-closing means cooperating with the second set of said contacts, magnetic means responsive to said solenoid for operating one of said circuit-closing means for a change in voltage of said source, and magnetic means responsive to said first magnetic means for operating said second circuit-closing means.

7. In an electric system a source of voltage, a work circuit comprising said source, a solenoid responsive to a condition of said work circuit, a variable impedance in said work circuit, a set of contacts connected to a plurality of points on said impedance, a second set of contacts connected to a plurality of points on said impedance, circuit-closing means cooperating with one set of said contacts, a second circuit-closing means cooperating with the second set of said contacts, magnetic means operating one of said circuit-closing means for an increase in voltage, magnetic means operating the other of said circuit-closing means for a decrease in voltage, only one of said magnetic means at one time being responsive to said solenoid, the other of said magnetic means at such a time being responsive to said other magnetic means.

8. In an electric system, a source of voltage, a work circuit comprising said source, a solenoid responsive to a condition of said work circuit, a variable impedance in said work circuit, a set of contacts connected to a plurality of points on said impedance, a second set of contacts connected to a plurality of points on said impedance, circuit-closing means cooperating with one set of said contacts, a second circuit-closing means cooperating with the second set of said contacts, magnetic means responsive to said solenoid when an increase in voltage in said circuit occurs for operating one of said circuit-closing means, magnetic means responsive to said solenoid when a decrease in voltage in said circuit occurs for operating the other of said circuit-closing means, and connections whereby both of said magnetic means operate when an increase or decrease in voltage occurs.

9. In an electric system a work circuit, a

source of voltage in said circuit, a voltmeter responsive to a condition of said work circuit, means for changing the calibration of said voltmeter when changes in said source occur, a variable impedance in said work circuit, means responsive to said voltmeter for increasing the value of said impedance, means responsive to said voltmeter for decreasing the value of said impedance, each of said means at times being responsive to the other of said means.

10. In an electric system, a work circuit, a source of voltage in said circuit, a voltmeter responsive to a condition of said circuit, a variable impedance in circuit with said voltmeter, a variable impedance in said work circuit, two sets of contacts connected to a plurality of points on each of said impedances, circuit-closing means cooperating with two sets of said contacts, a second circuit-closing means cooperating with the other two sets of said contacts, magnetic means responsive to said voltmeter for operating said first circuit-closing means, and magnetic means responsive to said voltmeter for operating the other of said circuit-closing means.

11. In an electric system, a work circuit, a source of voltage in said circuit, a voltmeter responsive to a condition of said circuit, a variable impedance in said work circuit, a set of contacts connected to a plurality of points on said impedance, a second set of contacts connected to a plurality of points on said impedance, circuit-closing means cooperating with one set of said contacts, a second circuit-closing means cooperating with said second set of contacts, and magnetic means responsive to a condition of said work circuit for operating both of said circuit-closing means when a change in the condition of said work circuit occurs.

12. In an electric system a work circuit, a source of voltage, a solenoid responsive to a condition of said work circuit for regulating said work circuit, a variable impedance in said work circuit, a rotary switch for varying the effective value of said impedance for an increase in voltage in said source, a second rotary switch for varying the effective value of said impedance for a decrease in voltage of said source, and magnetic means responsive to said solenoid for operating said switches when a change in voltage occurs.

13. In an electric system a work circuit, a source of voltage in said circuit, a solenoid responsive to a condition of said work circuit, a variable impedance in said work circuit, a rotary switch for varying the effective amount of said impedance when an increase in voltage occurs, a second rotary switch for varying the effective amount of said impedance when a decrease in voltage occurs, magnetic means responsive to said solenoid for operating one of said switches, and magnetic means responsive to said solenoid for operating the other of said switches, only one of said magnetic means at one time being responsive to said solenoid, the other of said magnetic means at such a time being responsive to said first magnetic means.

14. In an electric system, a work circuit, a source of voltage in said circuit, means responsive to the voltage in said circuit for regulating the current in said circuit, said means comprising a voltmeter responsive to the voltage of said circuit, a variable resistance in said work circuit, a second variable resistance in circuit with said voltmeter, a rotary switch for varying the effective amounts of said impedances when an increase in voltage occurs, a second rotary switch for varying the amount of said impedances when a decrease in voltage occurs, magnetic means under the control of said voltmeter for operating said switches, each of said switches having a contact arm individual to each of said resistances, a set of contacts connected to a plurality of points on each of said impedances cooperating with each of said contact arms, a third contact arm on each of said switches, contacts cooperating with each of said third arms, corresponding contacts for said third arms being electrically connected, and connections whereby the operation of one of said switches operates said other switch to move its contact arms until its third contact arm is on that cooperating contact which is electrically connected to the contact on which the third arm of said other switch rests.

15. In an electric system, a work circuit, a variable impedance and a source of voltage in said work circuit, a control element responsive to a condition of said work circuit, a variable impedance in circuit with said control element, and a rotary switch responsive to said control element for varying the value of said impedance.

16. In an electric system, a work circuit, a variable impedance and current supplying means in said work circuit, a voltmeter responsive to the current in said work circuit, a second variable impedance in circuit with the winding of said voltmeter, and a rotary switch responsive to said voltmeter for simultaneously varying the effective values of said impedances.

17. In an electric system, a work circuit, current supplying means and a regulating element in said work circuit, a plurality of switches each adapted to vary the effective value of said regulating element, a control element responsive to a condition of said work circuit for controlling the motion of one of said switches and for subsequently moving another thereof.

18. In an electric system, a work circuit, current supplying means and a variable impedance for said work circuit, a plurality of switches each adapted to vary the effective value of said impedance, a solenoid responsive to the current of said work circuit for controlling the motion of one of said switches and for subsequently controlling the motion of another thereof for a single change in the current of said work circuit.

19. In an electric system, a work circuit, a regulating element and current supplying means for said work circuit, a control element responsive to a condition of said work circuit, a set of switches responsive to said control element for controlling said regulating element for increases in a condition of said work circuit and a second set of switches responsive to said control element for controlling said regulating element for decreases in a condition of said work circuit.

20. In an electric system, a work circuit, a plurality of switching mechanisms, each having an active contact and a plurality of passive contacts, connections between corresponding passive contacts of said mechanisms, means responsive to a condition of said work circuit for causing the active contact of any one of said mechanisms to distinguish one of its associated passive contacts, and means responsive thereto for causing the active contact of another of said mechanisms to hunt and rest on that one of its associated passive contacts which is connected to the passive contact on which said first mentioned active contact rests.

21. In combination a work circuit, a regulating element in said work circuit, a one-way rotary switch for increasing the value of said regulating element and means for decreasing the value of said regulating element.

22. In combination a work circuit, a regulating element in said work circuit, a one-way rotary switch adapted to produce a change in the effective value of said regulating element, means responsive to a variation in said work circuit for causing said rotary switch to produce a change in the effective value in said regulating element and means responsive to said first means for producing an opposite change in the effective value of said regulating element.

23. In combination a work circuit, a regulating element for said work circuit and a one-way rotary switch operating in one direction only for varying the effective value of said regulating element in said work circuit.

24. In combination a work circuit, a regulating element in said work circuit, a one-way rotary switch adapted to increase the effective value of said regulating element, a second one-way rotary switch adapted to decrease the effective value of said regulating element and means responsive to a condition of said work circuit for controlling said switches.

25. In combination a work circuit, a regulating element in said work circuit, a row of stationary contacts arranged in the form of a portion of a circle, a movable switch member adapted to cooperate with said contacts, means responsive to a condition of said work circuit for controlling a position of said movable member, a second row of contacts corresponding to the first row, a second movable member cooperating with said second row of contacts and means operating on the motion of said first movable member for causing said second movable member to find a contact corresponding to the contact cooperating at any particular instant with said first movable member.

26. In combination a work circuit, a regulating element adapted to be placed to a varying degree in said circuit and a plurality of controlling means for said element, one of said means being arranged for progressive operation in an opposite sense to another of said means.

27. In combination a work circuit, a regulating element in said work circuit, a solenoid having a stationary contact and a movable contact and responsive to a condition of said work circuit, a relay having a movable contact and responsive to said solenoid for controlling the effective value of said regulating element for a change in the condition of said work circuit, a second relay having a movable contact and responsive to said solenoid for controlling the effective value of said element for an opposite change in said work circuit, and an interrupter operating over the contacts of said solenoid for controlling the energization of said relays.

28. In combination a work circuit, a regulating element in said work circuit, a one-way rotary switch adapted to increase the value of said element, a second one-way rotary switch adapted to decrease the effective value of said element, electro-magnetic means for controlling the position of said switches and an interrupter for periodically energizing one of said means.

In witness whereof, I hereunto subscribe my name this 4th day of December, A. D., 1919.

ROY D. CONWAY.