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Sept. 7, 1926. 1,598,694

S. P. SHACKLETON

ELECTRICAL REGULATOR

Filed August 19, 1922

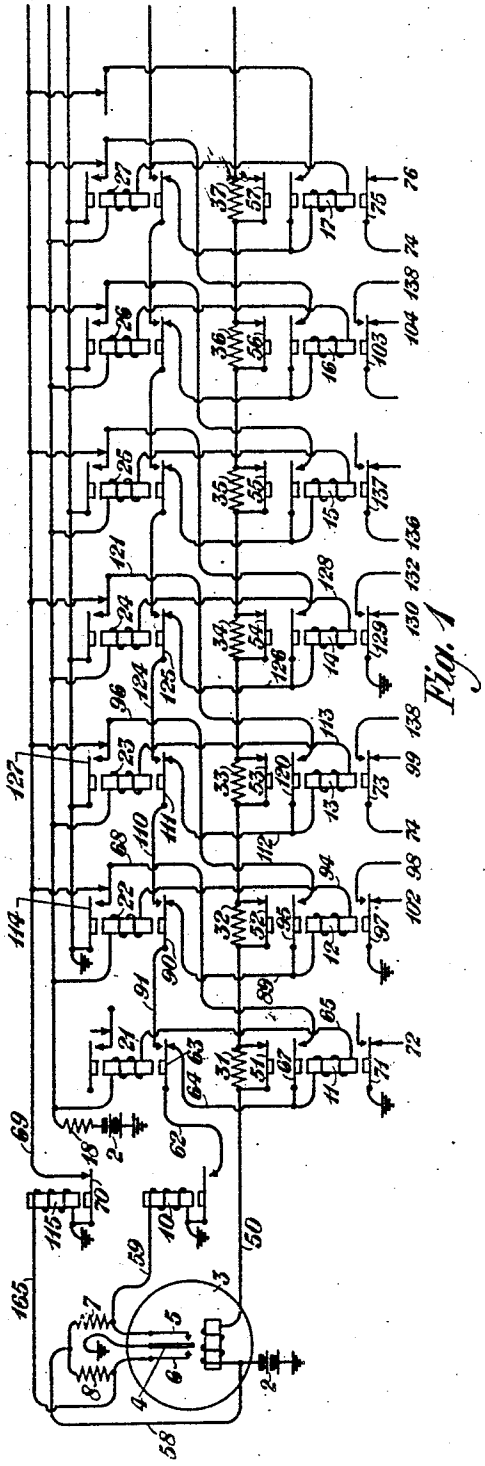


Fig. 1

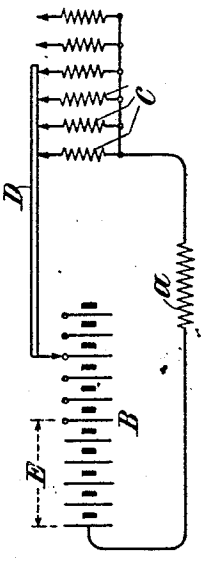


Fig. 2

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Patented Sept. 7, 1926. BEST AVAILABLE COPY 1,598,694

UNITED STATES PATENT OFFICE.

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ELECTRICAL REGULATOR.

Application filed August 19, 1922. Serial No. 582,981.

This invention relates to arrangements for regulating an electrical characteristic of a circuit, such as the intensity of current flowing therethrough. The object of the invention is to provide means for insuring a constant flow of current through each of several channels as the number of channels changes. More specifically, the object is to provide means whereby, in a circuit with variable E. M. F. and in which a plurality of relays are introduced in accordance with the variations in the E. M. F., the current flowing through each relay shall remain substantially constant and independent of the variations in the E. M. F.

The invention has found particular application in connection with means described in the patent to R. D. Conway, No. 1,438,944, granted December 19, 1922, for regulating the flow of current in a work circuit, regulation being obtained by the step-by-step operation of relays which are adapted to control resistances in the circuit to be regulated and the regulatnon being one to overcome the deleterious effects of variations in the source of E. M. F. supplying the load circuit. In this circuit, however, the relays which are introduced step by step are themselves supplied from the variable source of E. M. F., and in view of the fact that it is necessary to use relays which are nicely adjusted as to current value on which they operate, it is desirable to provide additional means by which the relays themselves shall be made independent of the fluctuations in the voltage of the source, and I accomplish this by the introduction of a resistance element of a certain value associated with the relay circuits.

The invention will be better understood by reference to the accompanying drawings in which Figure 1 shows in part the regulating circuit of the Conway patent mentioned above and including in addition certain changes comprising my invention. Fig. 2 is a schematic circuit to illustrate the principle underlying my invention. Reference may now be made to Fig. 1, the description to be given being only such as is necessary to make more fully clear that portion relating to my invention. Connected to a battery 2 is a voltmeter relay 3 which has a needle 4 between two stationary contacts 5 and 6. Since these contacts are extremely delicate and easily burned out, the needle 4 is connected to ground, while the contact 5 is connected to battery through a resistance 7 and the contact 6 to the same point of the battery through resistance 8. Connected to the contact 5 is also the relay winding 10, and connected to the contact 6 is the relay 115. The relay 10 is normally operated from the battery 2 through the following circuits: battery 2, conductor 58, resistance 7, relay winding 10 and ground. The relay 115 is also normally operated through a similar path, including the contact 6 and the resistance 8. In case of deflection of the needle 4 in such a direction as to close with contact 5, the relay 10 will be short-circuited, and its armature will accordingly fall away. On the other hand, if the needle 4 closes in contact 6, the relay 115 is short-circuited and its armature falls away. The advantage of this circuit arrangement is that more positive operation of the relays 10 and 115 is obtained than would be the case were they controlled by a series connection through the contacts 5 or 6, and at the same time these contacts are protected inasmuch as current is not interrupted but shunted through another path. The relay 10 controls the successive operation of the relays in the two series 11 to 17 inclusive and 21 to 27 inclusive. Each of the relays in series 21 to 27 inclusive is a slow-acting relay designed so that it will not operate or close its contacts until after its corresponding relay in the series 11 to 17 inclusive has been operated.

The successive operation of the relays 11 to 17 inclusive serves to add to the winding of the voltmeter relay, the resistances 31 to 37 respectively by the breaking of shunt paths around said resistances. These resistances have a value predetermined with respect to the adjustment of the contacts of the voltmeter relay.

The operation of the circuit is as follows: The circuit normally closed through the winding of the voltmeter relay 3 is from ground, battery 2, winding of voltmeter 3, conductor 50 and movable contacts 51 to 57 inclusive to ground. An increase in the voltage of the source 2 will be indicated by a deflection to the right of the needle of the voltmeter relay thereby short-circuiting the relay winding 10 and permitting its armature to fall away and thus closing the fol-

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lowing circuit: From ground, movable contact of relay 10, conductor 62, movable contact 63, conductor 64, winding of relay 11, conductor 65, winding of relay 21 to battery and ground. This energizes relay 11 which pulls up its movable contact 67 and is locked up over the following circuit: From ground and battery winding of relay 21, conductor 65, winding of relay 11, movable contact 67, conductors 68, 69 and movable contact 70 of relay 115 to ground. The energization of relay 11 also serves to pull over its movable contact 51 thereby breaking the short-circuit around resistance 31 so that the closed circuit for the winding of the voltmeter relay may be traced from ground, battery 2, winding of voltmeter relay 3, conductor 50, resistance 31 and movable contacts 52 to 57 inclusive to ground. If the addition of resistance 31 is sufficient to counter-balance the increase in the voltage of source 2, the needle of the voltmeter relay will return to neutral position and thus open the circuit formerly closed by the operation of relay 10. After the relay 11 has pulled up its movable contacts and has been locked through the circuit described above, the slow-acting relay 21 attracts its movable contact 63 so as to disconnect the windings of relays 11 and 21 from the armature of relay 10 and to connect instead the windings of relays 12 and 22 thereto through conductors 94 and 89, movable contact 90, conductor 91, movable contact 63 to the movable contact of relay 10. This change therefore makes relays 12 and 22 responsive to the energization of relay 10.

If by the addition of the resistance 31, the circuit including the voltmeter relay 3 is not sufficient to counterbalance the increase in the voltage of the battery 2, the needle of the voltmeter relay will not return to neutral position but will remain deflected to the right and the relay 10 will remain deenergized and after the slow-acting relay 21 has changed the relay under the control of relay 10 from relay 11 to relay 12, the following circuit will be closed: From ground, movable contact of relay 10, conductor 62, movable contact 63, conductor 91, movable contact 90, conductor 89, winding of relay 12, conductor 94, winding of relay 22 to battery and ground. The closing of this circuit will energize relay 12 which will pull up its armatures and become locked up over the following circuit: From ground and battery, winding of relay 22, conductor 94, winding of relay 12, movable contact 95, conductors 96 and 69 to movable contact 70 of relay 115 to ground. The actuation of relay 12 by pulling up its armature 52 opens the short-circuit around resistance 32 so that the circuit of the voltmeter relay winding may now be traced from ground, battery 2, winding of voltmeter relay 3, conductor 50, resistances 31, 32 and movable contacts 53 to 57 inclusive, to ground. Thus the circuit of the voltmeter relay winding now includes resistance 32 as well as resistance 31. If the addition of these two resistances is sufficient to counter-balance the rise in voltage of battery 2, the needle of the voltmeter relay will return to neutral position and thus open the circuit formerly closed by the operation of relay 10.

Subsequent to the actuation of relay 12, the slow-acting relay 22 pulls up its lower armature 90 so as to remove the control of relay 10 from relay 12 to relay 13 by including the winding of relay 13 by the following circuit: From movable contact of relay 10, conductor 62, 91, movable contact 90, conductor 110, movable contact 111, conductor 112, winding of relay 13, conductor 113, winding of relay 23 to battery and ground. Winding of relay 22 by pulling up its movable contact 114 removes the locking circuit for relay 11 from under the control of movable contact 70 of relay 115 by causing relay 11 to be locked up instead directly through contact 114 to ground.

If the increase in the voltage of source 2 has not been counter-balanced by including in the voltmeter circuit the resistance elements 31 and 32, the voltmeter relay needle will not return to neutral position, but will remain deflected to the right. Accordingly, relay 10 remains deenergized, and after slow-acting relay 22 has operated will energize relays 13 and 23 over the following circuit: From ground, movable contact of relay 10, conductors 63, 91, 110, movable contact 111, conductor 112, winding of relay 13, conductor 113, winding of relay 23 to battery and ground. The closing of this circuit will energize relay 13 which will pull up its movable contacts and become locked up over the closing of the following circuit: From ground and battery, winding of relay 23, conductor 113, winding of relay 13, movable contact 120, conductors 121 and 69 to movable contact 70 of relay 115 to ground. The actuation of relay 13 also serves to open the short-circuit around the resistance 33 thereby increasing the amount of resistance in the circuit of the winding of the voltmeter relay. If the addition of resistance 33 is sufficient to counter-balance the change in the voltage of source 2, the voltmeter relay needle will return to neutral position.

Subsequent to the operation of relay 13, relay 23 operates to pull over its movable contact 111 to change the control of relay 10 from relay 13 to relay 14 by making the following circuit: Movable contact of relay 10, conductors 62, 91, 110, 124, movable contact 125, conductor 126, winding of relay 14, conductor 128, winding of relay 24 to battery and ground. The operation of relay 23, by pulling up its movable contact 127,

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removes the control of the locking circuit of relays 12 and 22 from under the control of the movable contact 70 by locking these relays instead over the following circuit: Ground and battery, winding of relay 22, conductor 94, relay winding 12, movable contact 95, conductor 96, movable contact 127 to ground. Relay 12 therefore ceases to be under the control of movable contact 70 when relays 13 and 23 have been energized.

It is thus seen that by a step-by-step procedure adjustment is made of the resistance in series with the voltmeter winding to maintain a constant current as the voltage of the battery increases. Additional steps may be supplied, but since the operations are merely a continuation of those already described, it is not necessary to describe them further. The drawing shows seven such steps, but any number may be used, and in every case the stepping operations will cease when proper current value has been reached, as indicated by the falling away of the needle 4 from contact 5.

The above description describes the operation of the system for increases in voltage. A reversal of the process will occur if the voltage should fall in value. If, after the resistances 31 to 37 have been included in the voltmeter relay circuit, the voltage of the source 2 should fall, the system operates to successively cut out of circuit, resistances 37, 36, 35, etc., until the decrease in voltage has been counter-balanced.

The manner in which the system operates for decrease in voltage may be explained as follows: Suppose, for example, that the voltage of source 2 has increased to such a value that relays 11, 12, and 13 have been energized to include resistances 31, 32 and 33 in the circuit of the voltmeter relay winding in order to bring back voltmeter needle 4 to neutral position. Under this assumption, relays 21 to 23 inclusive would also have been energized so that the movable contact of relay 10 is now connected to the winding of relay 14 which is the next in series and disconnected from the winding of relay 13. As has been traced before, relay 13 under these conditions is locked up over the following circuit: from ground, and battery, winding of relay 23, conductor 113, winding of relay 13, movable contact 120, conductor 121 and 69 to movable contact 70 of relay 115 and ground. If now the voltage of source 2 should decrease, the voltmeter needle would be deflected to the left and make contact with contact 6 thereby short-circuiting relay 115. The armature of this relay now falls away thereby opening the locking circuit for relays 13 and 23 and deenergizing these relays. The deenergization of relay 13 causes movable contacts 53 to short-circuit resistance 33 thereby decreasing the amount of resistance in circuit with the voltmeter relay winding.

If this reduction in resistance in the circuit of the voltmeter relay winding is sufficient to counter-balance the decrease of voltage of source 2, the needle of the voltmeter relay will return to neutral position and no further operation of the series of relays will take place.

The deenergization of relay 23 allows its armature 111 to fall back so as to put the winding of relay 13 under the control of the movable contact of relay 10 so that relay 13 may again be energized in case the voltage of source 2 should increase. The falling back of armature 127 of relay 23 breaks the locking circuit for relays 12 and 22 which consisted of ground, battery, winding of relay 22, conductor 94, winding of relay 12, movable contact 95, conductor 96, movable contact 127 to ground, thereby causing the locking circuit for these relays to be traced instead from conductor 96 to conductor 69 and movable contact 70 to ground. This change of the locking circuit places relays 12 and 22 under the control of the movable contact 70 of relay 115.

If the decrease in voltage of source 2 has not been counter-balanced by the unlocking of relay 13 and the subtraction from the voltmeter relay circuit of the resistance 33, the needle of the voltmeter relay will remain deflected to the left, and the movable contact 70 of relay 115 will then break the locking circuit just described for relays 12 and 22 thereby deenergizing these two relays. The deenergization of relay 12 will allow movable contact 52 to fall back so as to short-circuit resistance 32 thereby decreasing the resistance in the voltmeter relay circuit.

The effect of further decrease in the voltage of source 2 in releasing further relays in the train is obvious, this release continuing until balance of the voltmeter has been attained, and at any stage the operation of the relays may proceed in either direction, depending on whether there is an increase or decrease in voltage of source 2.

In addition to maintaining constant the current flowing through the voltmeter relay 3, other circuits may be regulated. For example, there are shown movable armatures 71, 97, 73, 129, 137, 103 and 75 associated respectively with the relays 11 to 17, and it is apparent that these contacts may be used to control resistances in other circuits in a manner similar to the control exercised over the resistances 31 to 37, or in other manners as may be desired.

In the description thus far, no mention has been made of the resistance 18 inserted in series with the battery 2 and in such a position as to carry the current supplied to the relays 11 to 17 and 21 to 27. In view of the fact that the former group of these relays

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act comparatively quickly and the latter group are slow-acting relays, it is apparent that the current which is supplied to these relays must lie within certain limits, otherwise the time relations in the matter of operation will be affected. On the other hand, as the voltage of the battery 2 rises or falls, there would, in general, be a corresponding change in the current supplied to these relays. I propose, therefore, to insert the resistance 18, adjusting this resistance to such a value that it will absorb the increase in voltage of the battery 2, leaving a constant voltage impressed across or a constant current flowing through the relays. In order to do this, I take advantage of the fact that, as the voltage of the battery 2 rises, the resistance of the relay circuit which it supplies becomes less because of the addition of relays in parallel to those already in operation. The variation in voltage may be combined with the variation in the resistance of the relays to maintain a constant current. This may be better explained by reference to Fig. 2 in which there is shown a battery B in series with a resistance A and a plurality of circuits C. The voltage from the battery B, which is impressed on the circuit, is made variable, and after each certain increment in this voltage a change is produced in the resistance of the circuit by the introduction of one of the elements, C. In this case I have shown the voltage as being made variable by a movable bar D, so related to the other elements of the circuit that as it slides to the right it increases the voltage of the battery B by certain increments E and increases the number of the elements C, which are arranged in parallel, each increase of voltage E resulting in an addition of one element C. If this bar for the moment be considered as moved to the left to such a position that but one element C of resistance R is inserted, there will be a certain current flow, and the problem is to find a value of a resistance A, which, included in series in the circuit will maintain the current constant as the bar D slides. If but one element C is included in the circuit and the voltage then effective is indicated by E, the current will be

$$i=\frac{E}{a+R}.$$

After n increments of voltage, there will have been added n elements C, the total number of these elements in the circuit being $n+l$. The current now flowing will be

$$i'=\frac{E+ne}{a+\frac{R}{n+l}};$$

and the condition is that the current flowing through each element C shall be equal to the current i. This condition reveals the following equation:

$$\frac{E}{a+R}=\frac{l}{n+l}\cdot\frac{E+ne}{a+\frac{R}{n+l}}.$$

Solving for A, this yields

$$A=\frac{eR}{E-e},$$

and it is seen that this value of A is independent of n and contains quantities which are constant. While Fig. 2 has shown the elements C as being simple resistances, it is obvious that they may be relays of the form described in connection with Fig. 1.

What is claimed is:—

1. In a circuit containing a variable source of E. M. F., means for introducing in said circuit a plurality of elements in accordance with the variations of the E. M. F. and means for maintaining the current through each element independent of the variation in the E. M. F.

2. In a circuit containing a variable source of E. M. F., means for introducing a plurality of elements into the circuit in parallel with each other in accordance with the variation of the E. M. F. and means for maintaining the current through each element independent of the variation in the E. M. F.

3. In a circuit containing a variable source of E. M. F., means for introducing a plurality of elements in parallel with each other and in accordance with the variations of the E. M. F. and a resistance in series with this source for maintaining the current through each element independent of the variations in the E. M. F.

4. In a circuit containing a variable source of E. M. F., means for introducing in said circuit a plurality of elements in accordance with the variations of the E. M. F. and means for maintaining the current through each element independent of the variations in the E. M. F.

5. In a circuit containing a variable source of E. M. F., means for introducing a plurality of elements into the circuit in parallel with each other and in accordance with the variation of the E. M. F. and means for maintaining the current through each element independent of the variation in the E. M. F.

6. In a circuit containing a variable source of E. M. F., means for introducing a plurality of elements into the circuit in parallel with each other and in accordance with the variation of the E. M. F. and means for maintaining the current through each element independent of the variation in the E. M. F.

7. In a circuit containing a variable source of E. M. F. of normal value E, means for introducing in said circuit a plurality of

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elements of resistance R, one element being introduced with each increment of E. M. F. e and a resistance in series with the source and having a value of

$$\frac{eR}{E-e}.$$

8. In combination, a circuit comprising a source of electromotive force and a plurality of steps of resistance in series, and means to cut said resistance steps in or out in correspondence with variations of said source of electromotive force, said means comprising relays, each controlling a step of said resistance and adapted to be connected successively in multiple with said source according to the variations thereof and a single resistance also in series with said source and with said relays in multiple thereto, said last mentioned resistance having such value as to keep the voltage drop constant through the said relays according as any or all of them are energized.

9. In combination, a circuit comprising a plurality of steps of resistance in series, a source of electromotive force also in series and means to cut said steps of resistance in or out to correspond with variation of said source, said means comprising a plurality of relays in multiple on said source of electromotive force controlling respective resistance steps, and means to keep the voltage constant through the relays according as any or all of them are energized.

10. In combination, a source of electromotive force of variable magnitude, a plurality of translating devices, means to connect any or all of them in multiple to said source according to the magnitude thereof and a resistance in series with said source to which said translating devices are also connected in multiple, said resistance having such value as to keep the voltage drop constant through the translating devices according as any or all of them are operatively connected in circuit with said source.

In testimony whereof, I have signed my name to this specification this 18th day of August 1922.

SAMUEL P. SHACKLETON.