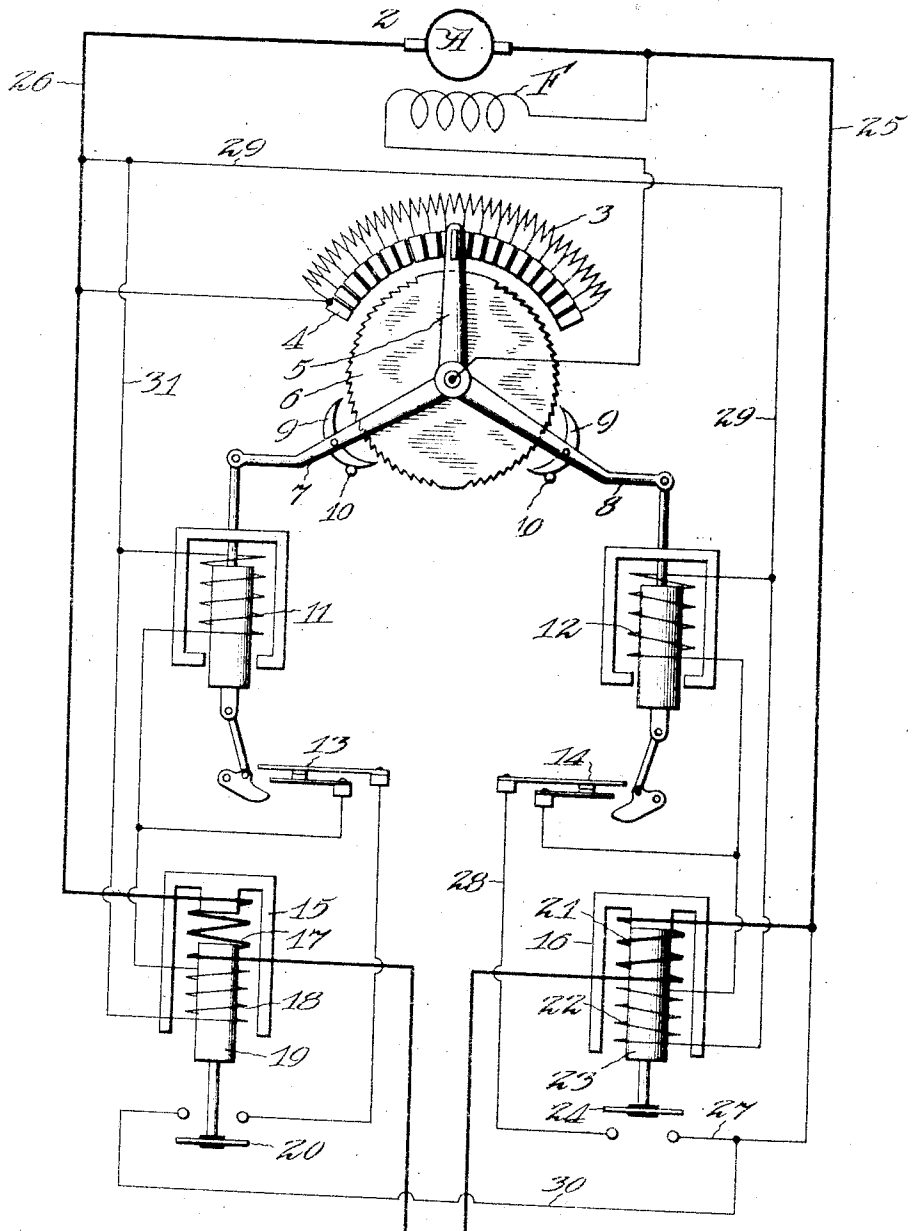
L. L. TATUM.

ELECTRORESPONSIVE REGULATOR.

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UNITED STATES PATENT OFFICE.

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ELECTRORESPONSIVE REGULATOR.

1,142,858. Specification of Letters Patent. Patented June 15, 1915.

Application filed November 6, 1911. Serial No. 658,873.

To all whom it may concern:

Be it known that I, LEWIS L. TATUM, a citizen of the United States, residing at Milwaukee, in the county of Milwaukee and State of Wisconsin, have invented new and useful Improvements in Electroresponsive Regulators, of which the following is a full, clear, concise, and exact description, reference being had to the accompanying drawing, forming a part of this specification.

My invention relates to improvements in electro responsive regulators.

It is one of the objects of my invention to provide a positive and durable regulator by means of which a very fine degree of regulation may be obtained.

Various other objects and advantages of my invention will be hereinafter clearly and fully set forth.

My invention may be used in various different relations for various different purposes.

For the purpose of illustration I have shown in the accompanying drawing one embodiment of my invention used for current regulation. It should be understood however, that my invention is not limited to this particular application thereof or to the specific form illustrated.

In the system selected for the purpose of illustration, the regulator controls the flow of current through an electrolytic bath contained in the schematically illustrated tank 1. Current is supplied to this tank from a generator 2 having an armature A and a shunt field winding F. It may be assumed that the current taken by the bath is subjected to variation from any cause, as for example the sudden immersion in the bath of material which increases or decreases the resistance of the circuit giving either a positive or negative current variation.

Such current variations may be rectified in any preferred manner. In the system illustrated this is accomplished by a resistance 3 adapted to be cut in or out of the field circuit of the generator in accordance with the nature of the current variation. This resistance is connected to a series of contacts 4 over which is adapted to move a contact arm 5. In practice I prefer to have this arm actuated in a step by step manner. Any suitable operating mechanism may be employed in practice. The mechanism illustrated is of a conventional form including a ratchet wheel 6 and two levers 7 and 8 each carrying a pawl 9 adapted to engage with said ratchet wheel. Pins 10 are provided to throw the pawls out of engagement with the ratchet wheel upon descent of the levers. The lever 7 moves the arm 5 in a clockwise direction and the lever 8 moves said arm in a counter-clockwise direction. The levers 7 and 8 are provided with operating solenoids 11 and 12 respectively, which solenoids are provided with circuit making and breaking devices 13 and 14 respectively. The devices 13 and 14 are preferably of the type disclosed in my co-pending application Serial No. 658,872, filed Nov. 6, 1911. The devices 13 and 14 automatically make and break the circuits of their respective solenoids to cause the same to reciprocate their plungers and thus impart a step by step movement to the rheostat arm 5. Furthermore each of the devices 13 and 14 breaks the circuit of its corresponding solenoid with a snap action as clearly set forth in my co-pending application aforesaid. The importance of this feature will be hereinafter set forth. The solenoids 11 and 12 are normally deënergized and are separately controlled by relays 15 and 16 respectively.

The relay 15 is adapted to respond upon a rise of current to cause the solenoid 11 to respond to operate the arm 5 to insert resistance in the field circuit of the generator. The relay 16 is adapted to operate upon a decrease in current through the tank to cause the solenoid 12 to respond to move the arm 5 to cut out resistance from the field circuit of the generator. The relay 15 comprises a solenoid having windings 17 and 18 provided with a common plunger 19 to which is secured a switch 20 having coöperating contacts which it engages and bridges upon lifting of the plunger 19. The winding 17 is connected in series with the tank 1 and is so designed as to respond to a predetermined rise in the current flowing through the tank. The winding 17 is the actuating winding for the switch 20 and under normal current conditions has not sufficient strength to attract its plunger 19.

The relay 16 is provided with windings 21 and 22 having a common plunger 23 to which is connected a switch 24. The winding 21 which is the operating winding for the plunger 23 is so designed as to hold up its plunger under normal conditions, there-

by holding the switch 24 out of engagement with its coöperating contacts and to drop its plunger upon a predetermined decrease in the flow of current through the tank.

The windings 18 and 22 of the relays have a double function. Under certain conditions the windings 18 and 22 function to increase the pressure of the relay switches against their coöperating contacts to insure a good electrical contact. Under other conditions they have just the opposite effect, namely they tend to withdraw the relay switches from their stationary contacts, or in other words restore the switch members to normal position. This latter function as will be hereinafter more clearly brought out greatly augments the sensitiveness of the relays and in consequence provides for a very fine degree of regulation.

The reversal in function of the windings 18 and 22 is obtained by connecting said windings in parallel with the windings of solenoids 11 and 12 respectively. The solenoids 11 and 12 which are provided with relatively larger magnetic frames than the relay solenoids produce, upon interruption of their circuits by the devices 13 and 14, a back discharge commonly known as an inductive kick which sends a reverse current through the relay windings 18 and 22. This reverses the polarity of the windings 18 and 22 resulting in the reversal of function aforesaid.

I shall now describe the operation of the regulator as a whole, at the same time more specifically bringing out the advantages thereof. Current flows from one terminal of the generator armature by line 25 through the winding 21 of relay 16 thence through the tank 1 and winding 17 of relay 15 to line 26 and thence to the opposite terminal of the generator. Assume now that the current flowing through the tank falls below normal. The winding 21 of relay 16 thereupon releases its plunger. The plunger 23 upon descending causes the relay switch 24 to bridge its contacts. This completes a circuit from line 25 by conductor 27 through the relay switch 24 by conductor 28 and switch 14, through the solenoid winding 12 and winding 22 of relay 16 in parallel by conductor 29 to line 26. Thus the solenoid 12 and winding 22 of relay 16 are energized. The winding 22 under these conditions opposes the winding 21 of relay 16 thus tending to increase the pressure of the relay switch 24 against its coöperating contacts. This insures firm engagement of the relay contacts and eliminates the danger of arcing. The solenoid 12 operates to move the rheostat arm 5 in a direction to cut out the resistance 3 from the field circuit of the generator, thereby tending to restore the current delivered to the tank to normal value. The solenoid 12 will of course continue to operate intermittently so long as the relay switch 24 remains closed. When however, the solenoid 12 has once responded its control switch 14 will open its circuit and also the circuit of the winding 22 of relay 16. The inductive kick of the solenoid 12 will then momentarily reverse the polarity of the winding 22 of relay 16, whereupon said winding will act cumulatively with the winding 21 and tend to withdraw the relay switch from its contacts. It is a well known fact that a solenoid will release its plunger upon a lower current than will suffice to cause it to lift its plunger. Thus if the relay 16 was provided with only the winding 21 and said winding was adjusted to release its plunger upon a small negative variation in current, it would not be sufficiently energized to attract its plunger until the current had been restored to a value above normal. Thus with the relay equipped only with the winding 21 it would be impossible to obtain regulation of current within close limits. The winding 22 however, counteracts the aforesaid condition. By proper design and proportion of the solenoid 12 and the relay solenoid the effect of the inductive kick of the former upon the winding 22 may be so calculated as to more than counterbalance the additional pull required to open the relay switch 16. Under such conditions the relay could be made to resume normal position upon each stroke of the solenoid 12 or at least within a predetermined limit of current variation. Hence the relay may be adjusted to drop upon a very small negative variation in current and yet be insured restoration to normal position without an unduly large increase in current. Of course under some conditions the current variation might be so wide that the cumulative effect of the windings 21 and 22 would not be sufficient to restore the relay to normal position, but under such circumstances with the steps of resistance regulation properly calculated this would be advantageous rather than disadvantageous. The result would be that so long as the current varfation exceeded a predetermined limit the relay would remain closed during a number of strokes of the solenoid 12 with the result that the solenoid 12 would so operate the regulator as to quickly bring the current within the limit at which the cumulative effect of the windings 21 and 22 would raise the relay plunger and open the switch 24. Thereafter until current had been restored to approximately normal value the relay 16 would vibrate, thereby necessitating a complete cycle of operation of the relay and solenoid 12 as a prerequisite to each step of resistance regulation. This would slow down the operation of the regulator as a whole as normal current conditions were approached, and in consequence permit resto-

ration of normal current conditions with a fine degree of accuracy.

To recapitulate, the winding 22 upon operation of the relay responds to oppose the winding 21 and thus insure a good electrical contact of the relay switch and upon interruption of circuit by switch 14 receives the inductive kick of the solenoid 12 causing its polarity to change and causing it to act cumulatively with the winding 21 to restore the relay switch to normal position. This change in polarity of the winding 22 is merely momentary, said winding becoming inert with cessation of the back discharge of solenoid 12 which is of very short duration. This temporary period of reverse polarity of the winding 22 is however amply sufficient to enable said winding to perform its desired function and yet is of such short duration as to in no wise effect or delay subsequent operation of the relay. The purpose of providing for a snap action of the switch 14 is for the purpose of securing the full effect of the back discharge of the solenoid 12 upon the relay winding 22. Should the operation of switch 14 be slow the back discharge of solenoid 12 might take the path including said switch instead of that including relay winding 22. Assume now that there is a positive variation of current or in other words an abnormal rise of current. The relay 15 responds, closing the circuit of ratcheting solenoid 11. This circuit extends from line 25 by conductor 30, relay switch 20 and switch 13 through solenoid winding 11 and relay winding 18 in parallel by conductors 31 and 29 to line 26. This causes operation of the rheostat to insert resistance in the field circuit of the generator and in consequence a reduction in the current supplied to tank 1. The winding 18 of relay 15 performs the same functions as the winding 22 of relay 15. This winding however, instead of normally opposing the main relay winding normally acts cumulatively therewith and opposes the main winding when energized by the inductive kick of solenoid 11. This difference in relation of the windings of the relay 15 is necessary in view of the character of said relay. Unlike relay 16 its plunger is normally down and it responds to raise its plunger only upon an increased flow of current through the winding 17. With a small increase of current it is obvious that the pull on the plunger by the winding 17 would be weak. However, with the assistance of the winding 18 the relay 15 will raise its plunger with the requisite amount of force to insure good electrical contact of its switch upon a small rise in current. Likewise the relay 15 if only provided with the coil 17 would tend to hold the switch 20 in closed position until the current had been reduced to a degree considerably below that at which the winding 15 was adjusted to respond. However with the provision of the coil 18 which upon opening of the switch 13 opposes or bucks the coil 17 the release of the relay may be insured under any desired current conditions or at least within certain limits as previously explained. The operation of the relay 15 upon an abnormal rise in current is substantially the same as that of the relay 16 upon an abnormal decrease in current, and accordingly it will be unnecessary to explain the operation of the relay 15 in detail. Upon an abnormal rise in current within a prescribed limit it would vibrate until the rheostat had been operated to restore the current to approximately normal value. If on the other hand the variation in current was wide it would respond and remain closed until the rheostat had been operated to reduce the current within a certain limit and would thereafter vibrate until the value of current had been restored to the desired degree. The relay 16 providing means whereby the flow of current may be restored with a fine degree of accuracy from negative variations and the realy 15 providing means whereby the current may be restored with a fine degree of accuracy from positive varia tions it naturally follows that the two relays would confine the variations in current between very narrow limits thereby providing a most satisfactory regulation.

What I claim as new and desire to secure by Letters Patent is as follows:—

1. In a regulator, in combination, an electro-responsive device operating automatically under certain electrical conditions, and means associated with said device and acting upon the aforesaid operation thereof to first tend to effect continued movement of the same and then tend to effect return movement thereof.

2. In a regulator, in combination, an electro-responsive device operating automatically under certain electrical conditions, and normally inert electro-responsive means associated therewith and acting upon the aforesaid operation thereof to first tend to effect continued operation in the same direction and then tend to effect return movement thereof.

3. In a regulator, in combination, an electro-responsive relay, and means associated with said relay to assist in effecting movement thereof away from and toward normal position progressively, said means being effective for only a temporary period whereby the sensitiveness of said relay is rendered independent thereof.

4. In a regulator, in combination, an electro-responsive relay, and normally inert electro-responsive means associated therewith to assist and oppose its winding in a predetermined cycle of operation of said relay.

5. In a regulator, in combination, an elec-

tro-responsive relay, and normally inert electro-responsive means associated therewith to assist and oppose its winding in a predetermined cycle of operation of said relay, and acting only for a temporary period within such cycle.

6. In a regulator, in combination, an electro-responsive device, and electro-responsive means associated therewith to be energized to assist and oppose the operating winding thereof, and means automatically governing said former means to render the same effective only after movement of said relay from normal position and only for a limited period thereafter.

7. In a regulator, in combination, an electro-responsive relay, and means associated therewith to act upon operation thereof from normal position to progressively assist in continued and return movement thereof, said means being inert in the intervals of rest of said relay.

8. In a regulator, in combination, a relay having a plurality of windings, one of the same being responsive to predetermined electrical conditions to operate said relay, and means for automatically energizing the other of said windings subsequent to response of said relay to assist in restoring said relay to normal position, said means energizing said second winding only for a temporary period and said second winding when deënergized remaining inert until subsequent operation of said relay.

9. In a regulator in combination, an electro responsive relay having a main winding for causing its response under predetermined electrical conditions and an auxiliary winding adapted upon response of said relay to augment the force of its operation and means for momentarily reversing the polarity of said auxiliary winding after response of said relay to restore said relay to normal position.

10. In a regulator, in combination, a relay having a main winding and a normally inert auxiliary winding to act cumulatively and differentially with said main winding, said auxiliary winding being energized upon movement of said relay from normal position, and means associated with said auxiliary winding to reverse the polarity thereof temporarily upon full operation of said relay.

11. In a regulator in combination, an electro responsive relay having a main winding for causing its operation under predetermined conditions and an auxiliary winding, said windings normally having certain relative polarities and means for momentarily reversing the polarity of said auxiliary winding automatically after response of said relay.

12. In a regulator in combination, an electro responsive relay switch having a main winding and an auxiliary winding, said auxiliary winding upon response of said relay switch tending to augment the pressure thereof at its contact points and means for momentarily reversing the polarity of said auxiliary winding after closure of said relay switch to restore the same to open position.

13. In a regulator in combination, a relay switch having a main controlling winding for causing the same to close under predetermined electrical conditions and an auxiliary winding energized upon closure thereof to augment the pressure at its contact points and means operating automatically after closure of said relay switch to cause a momentary reversal of the polarity of said auxiliary winding to open said relay switch.

14. In a regulator in combination, an electro responsive relay responsive to predetermined electrical conditions and an electro responsive device temporarily energized upon response of said relay, the windings of said relay and said device having connections whereby the back discharge of the winding of said device tends to restore said relay to normal position irrespective of said electrical conditions.

15. In a regulator in combination, an electro responsive relay responsive to predetermined electrical conditions, said relay having an auxiliary winding, an electro responsive device temporarily energized upon response of said relay, and electrical connections between the operating winding of said device and said auxiliary relay winding for causing the back discharge of the former to energize the latter to restore said relay to normal position.

16. In a regulator in combination, an electro responsive relay responsive to predetermined electrical conditions, an electro responsive device temporarily energized upon response of said relay, and an auxiliary winding for said relay responsive to the back discharge of the winding of said device to restore said relay to normal position.

17. In a regulator in combination, an electro responsive relay responsive to predetermined electrical conditions, an electro responsive device temporarily energized upon response of said relay and an auxiliary winding for said relay energized upon energization of said device to augment the force of operation of said relay and responsive to the back discharge of the operating winding of said device to cause restoration of said relay to normal position.

18. In a regulator in combination, an electro responsive relay having a main winding and an auxiliary winding, an electro responsive device having its operating winding permanently connected in parallel with said auxiliary relay winding, said parallel

windings being energized upon response of said relay and said auxiliary winding upon responding tending to augment the force of operation of said relay, and automatic means for disconnecting said parallel windings from circuit, the back discharge of the winding of said device momentarily reversing the polarity of said auxiliary winding.

10. In a regulator in combination, a regulating rheostat, an automatically intermittently energized operating solenoid therefor and an electro responsive relay controlling said solenoid, said relay having a main winding governing the response thereof and an auxiliary winding connected in parallel with said solenoid and intermittently energized simultaneously therewith, said auxiliary winding normally tending to augment the force of operation of said relay and being responsive to the back discharge of said solenoid winding to return said relay to normal position.

In witness whereof, I have hereunto subscribed my name in the presence of two witnesses.

LEWIS L. TATUM.

Witnesses:
FRANK H. HUBBARD,
G. W. HAYNES.