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W. C. SEALEY

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TAP-CHANGING UNDERLOAD SYSTEM WITH TIME DELAY DEVICE
SELECTIVELY RESPONSIVE TO DIFFERENT CONDITIONS

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2 Sheets-Sheet 1

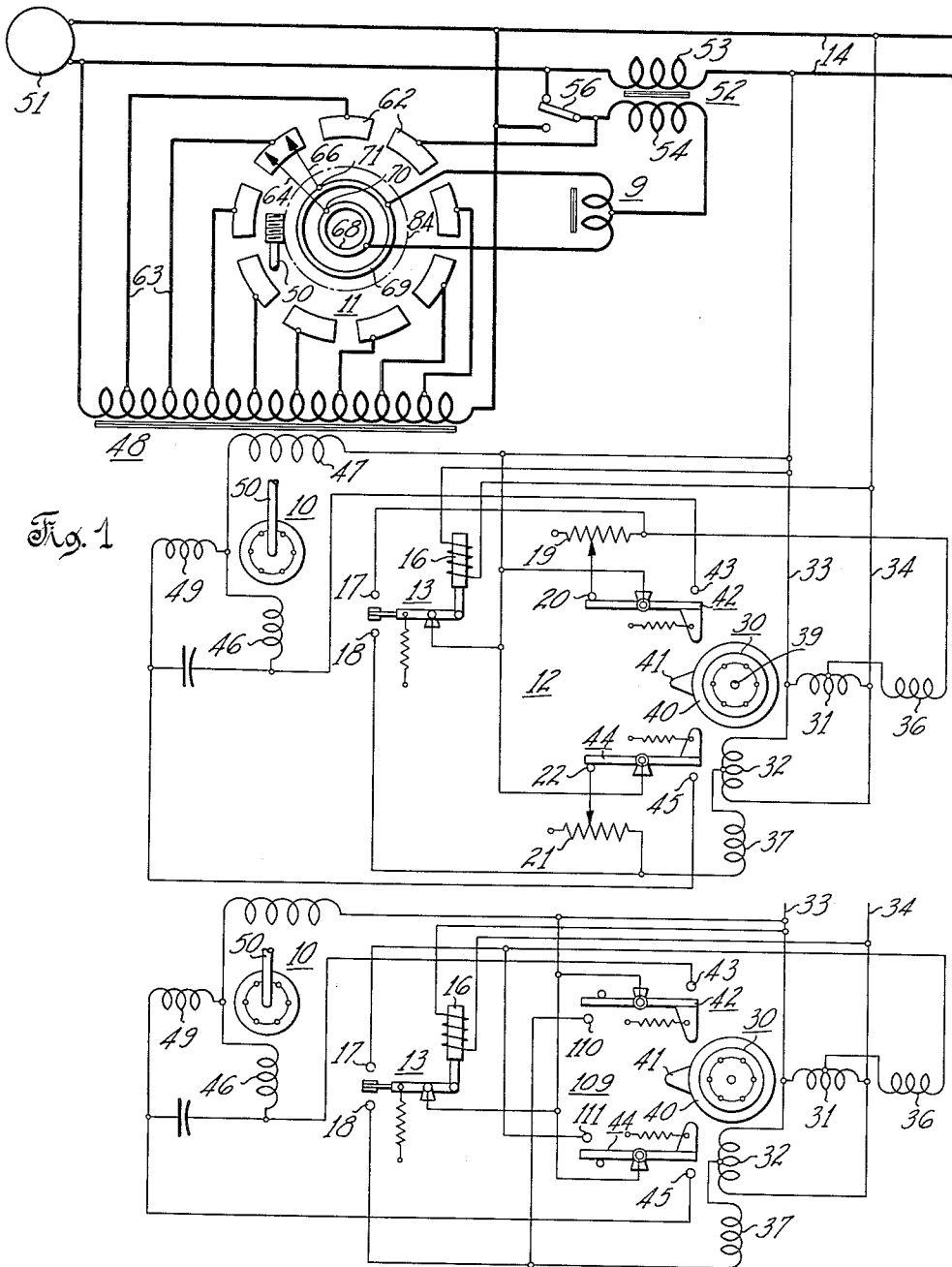


Fig. 4

Inventor
William C. Sealey
by Didier Journeaux
Attorney

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SELECTIVELY RESPONSIVE TO DIFFERENT CONDITIONS

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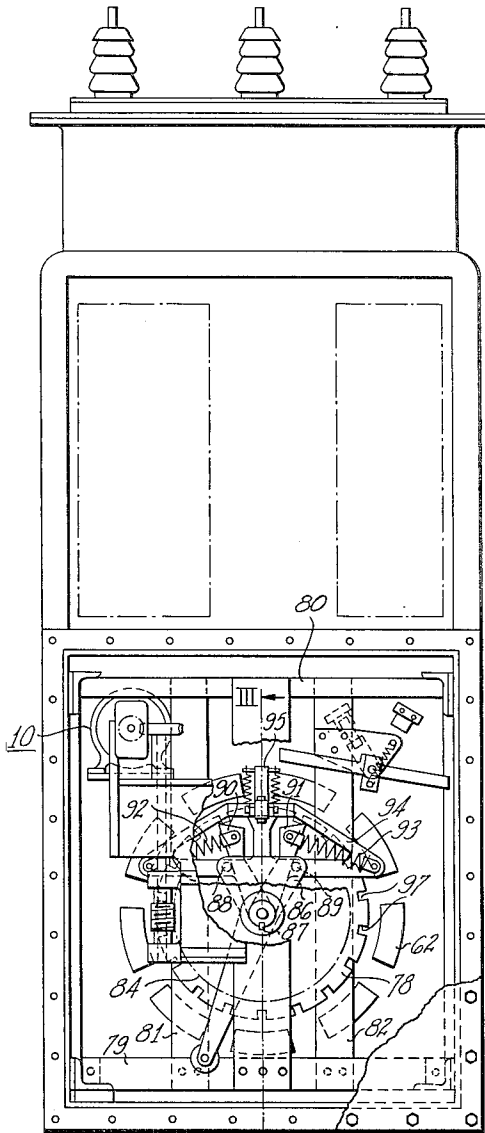


Fig. 2

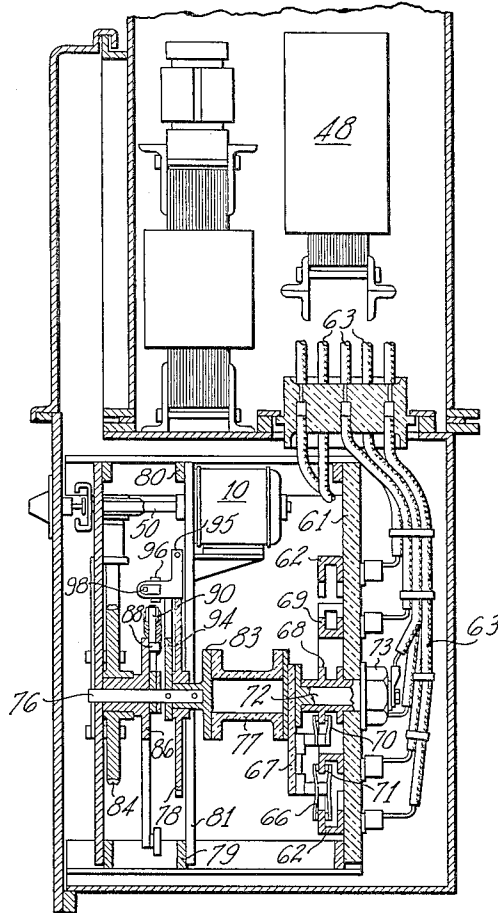
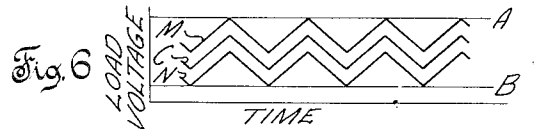
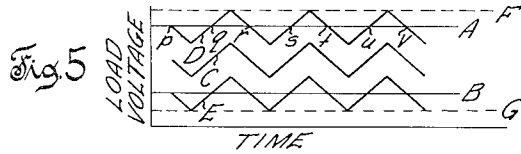


Fig. 3

Inventor
William C. Sealey
by Didier Journeaux
Attorney

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TAP-CHANGING UNDERLOAD SYSTEM WITH TIME DELAY DEVICE SELECTIVELY RESPONSIVE TO DIFFERENT CONDITIONS

William C. Sealey, Wauwatosa, Wis., assignor to Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

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7 Claims. (Cl. 323—43.5)

This invention relates in general to an improved motor control system which is operable in response to a predetermined change of a condition, and in particular to an improved motor control system for a step type voltage regulator.

In step type regulators the load voltage is sought to be maintained between predetermined limits by the system, the voltage being normal when it is between these limits. When the voltage is abnormal the regulator attempts to correct this condition by making a tap change to either increase or decrease the load voltage, depending on the need.

In some prior art step type regulating systems a device is provided in the control system for the tap changer actuating means which distinguishes between a momentary abnormal voltage and abnormal voltages of sufficient duration to require a tap change. When the regulated voltage becomes abnormal a time delay mechanism starts to run and if the voltage remains abnormal the tap changer motor will be energized at the end of the time delay and actuate the tap changer. However, if the regulated voltage returns to normal before the time delay has expired, the motor is not energized, and the timing mechanism starts to run in the opposite direction until it reaches its neutral position. Hence, the regulated voltage can be abnormal for a period of time slightly less than the time delay, return to normal for the same period of time or a greater period and then become abnormal again without a correction being made by the control system. Thus the regulated voltage varies considerably without being compensated for by the tap changer.

It has been found that closer regulation is obtained when the control system for the tap changer motor utilizes a time delay device in which the timing mechanism ceases to operate when the voltage becomes normal rather than returning to its neutral position. In this manner the occurrence of a succession of short voltage deviations in the same direction eventually results in a tap change, and after a first tap change in voltage raising or voltage lowering direction consecutive tap changes in the same direction take place without time delay, and non-consecutive tap changes in the same direction take place with a reduced time delay.

It is, therefore, an object of the present invention to provide an improved control system which controls the extent of movement of a movable element in response to a predetermined change of a condition.

Another object of the present invention is to provide an improved system which controls the direction and extent of movement of a movable element in response to a change of a condition a predetermined time after a change has occurred.

A further object of the present invention is to provide an improved control system which selects the direction of movement of a movable element in response to a change of a condition and after a first time delay moves the element a predetermined extent, and if the change of

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condition still exists, moves the element another predetermined extent without a time delay.

A still further object of the present invention is to provide in a motor operated voltage regulator an improved motor control system utilizing a time delay device which is inoperative when the voltage is normal and operative when the voltage is abnormal.

Objects and advantages other than those mentioned above will become apparent from the following description when read in connection with the drawings in which:

Fig. 1 shows diagrammatically the improved control system used in cooperation with a step type voltage regulating system;

Fig. 2 is a front elevation of the tap changing switch shown diagrammatically in Fig. 1;

Fig. 3 is a partial section view taken on the line III—III of Fig. 2;

Fig. 4 shows another embodiment of the control system of Fig. 1; and

Figs. 5 and 6 compare graphically the regulation obtained by the improved system and a prior art system.

Referring to the drawings, as shown in Fig. 1 the voltage regulating system generally comprises a step type voltage regulator 9, a reversible motor 10 to operate the tap changer switch 11 of regulator 9, and a control system 12 to selectively operate motor 10 in two directions.

Control system 12 comprises a relay 13, which may be a contact making voltmeter, connected to load circuit 14 either directly or through a suitable transformer. Relay 13 has a solenoid 16 and pairs of control contacts 17, 18 selectively actuatable into closed position by solenoid 16 in response to a predetermined change in load voltage. Control system 12 also includes a pair of similarly arranged units for controlling motor 10. Each unit comprises a main winding, an auxiliary winding, a source of voltage, a current limiting means and auxiliary contacts. Control contacts 17 are in series with a current limiting means shown as a variable resistor 19 through auxiliary contacts 20. Control contacts 18 are in series with a current limiting means, shown also as a variable resistor 21, through auxiliary contacts 22.

Main windings 31, 32 of electroresponsive device 30, shown as a reversible split phase motor, are connected across a source of voltage. As shown, the main windings are connected across the regulated load voltage by means of conductors 33, 34 but they may also be energized from a separate source. Auxiliary winding 36 is connected in series with variable resistor 19 through part of main winding 31 and auxiliary contacts 20. Auxiliary winding 37 is connected in series with variable resistor 21 through part of winding 32 and auxiliary contacts 22. Electroresponsive device 30 has a movable member 40 mounted on a shaft 39. Member 40 has an extension 41 which actuates either switch 42 to open auxiliary contacts 20 and close main contacts 43 or switch 44 to open auxiliary contacts 22 and close main contacts 45.

Stator winding 46 of motor 10 is connected in series with secondary winding 47 of transformer 48 through contacts 43. Stator winding 49 of motor 10 is connected in series with secondary winding 47 of transformer 48 through contacts 45.

Motor 10 has a shaft 50 which is adapted to move an element in two directions. As shown in Figs. 1, 2 and 3 the motor is used to operate the tap changing switch 11 of the step type voltage regulator 9. Regulator 9 comprises means of maintaining the voltage supplied by a current supply 51 to a load circuit 14 at a substantially constant value independently of changes in load. Regulation is accomplished by adding to the load circuit 14 or subtracting therefrom the voltage of transformer 52 having one winding 53 in the load circuit and the other winding 54 supplied through the tap changing switch 11.

Winding 54 is connected in boosting or bucking relation to the line voltage dependent upon the position of reversing switch 56. The tap changing mechanism may include a detent mechanism to translate the relatively slow continuous operation of the motor into a rapid snap action or it may include means for driving the mechanism directly.

The tap changer here described is in general of the type disclosed by U. S. Patent 2,177,109 to L. H. Hill, October 24, 1939, Voltage Regulator, and includes a detent mechanism.

Referring to Figs. 2 and 3 the tap changing mechanism has an insulating panel 61 upon which are mounted stationary contacts 62. These contacts are connected to transformer 48 through suitable means such as conductors 63.

The movable contacts 64 and 66 of the tap changer are carried on movable contact carrying member 67. Each of these contacts comprises two spring held contact pieces, one bearing on one face and the other bearing on the other face of the stationary contact 62. Movable contacts 64 and 66 are connected respectively to current collecting rings 68 and 69 by means of brushes 70 and 71, respectively. The shaft 72 is clamped rigidly against panel 61 by means of a nut 73 and carries movable contact carrying member 67. Shaft 72 is coupled to shaft 76 by means of insulating coupling 77.

A notched disk 78 is rigidly supported by two upright members 81, 82, which are rigidly fastened to cross pieces 79 and 80. Notched disk 78 forms a bearing for member 83 and coupling 77. Shaft 76 is suitably connected at one end to the member 83 so as to rotate therewith.

Shaft 50 of motor 10 is geared to gear 84 which is mounted on shaft 76. A substantially triangular member 86 is suitably fastened by a key 87 to gear 84 so as to rotate therewith. Gear 84 and triangular shaped member 86 rotate together freely on shaft 76. Also mounted on member 86 are two stops 88 and 89 which move with the member 86.

Two arms 90, 91 are mounted on shaft 76 and rotate freely relative thereto. The arms 90 and 91 cooperate respectively with the stops 88 and 89 to apply pressure to springs 92 or 93 connected between the outer ends of arms 90 and 91 and a latch carrying member 94.

Latch member 95 is pivoted between upstanding portions of member 94 and is biased to the position shown in Fig. 3 by means of a spring as shown in Fig. 2. Latch member 95 carries a bolt 96, the head of which is engaged by the upper surface of arm 90 or 91 to disengage the latch from notches 97 in the disk 78.

The control circuit for the tap changing motor utilized in the voltage regulating system is shown in the neutral position in Fig. 1, line 14 being originally at normal voltage. Assuming that a change of load voltage has occurred the operation is as follows. Solenoid 16 of contact making voltmeter 13 connected across the load circuit 14 selectively closes either contacts 17 or 18 depending on whether an increase or decrease is needed to compensate for the change.

Assuming that an increase is needed and solenoid 16 is actuated to close contacts 17, variable resistor 19 is shorted out of the circuit containing auxiliary winding 36. This action energizes the windings to unequal extents, increasing the energization of winding 36 over winding 37 which causes member 40 to rotate clockwise as shown. Member 40 is operable when the condition of circuit 14 is abnormal and is inoperable when condition of circuit 14 is normal. After a predetermined time member 41 actuates switch 42 opening auxiliary contacts 20 and closing main contacts 43. Closure of contacts 43 energizes stator winding 46 and causes shaft 50 to rotate.

Clockwise rotation of the shaft 50 slowly rotates the gear 84 and triangular member 86, thereby causing stop 89 to bear against arm 91 and placing spring 93 under

tension. The shaft 76 and the member 94 do not move at first because latch 95 is in a notch 97 of disk 78. Upon further rotation of the detent mechanism to substantially 100% of its travel for one full step, the stop 89 causes the upper surface of arm 91 to bear against bolt 96, rotating the latch 95 counterclockwise about its pivot point 98, thereby releasing the latch from notch 97 in disk 78. Movable contact members 64, 66 are then snapped counterclockwise as viewed in Fig. 2 by means of spring 93 and are stopped at the next notch of disk 78 by the tension placed on spring 92 by arm 90 stopping against the stop 88.

This action increases the voltage of line 14 by one step of the regulator. If the voltage change is not compensated for by one tap change the tap changer takes the necessary number of steps without further time delay until the voltage is returned to normal and the contact making voltmeter 13 opens contacts 17. Opening of contacts 17 open circuits winding 36 since contacts 20 are open. Winding 37 being still energized causes member 40 to rotate counterclockwise allowing switch 42 to reclose auxiliary contacts 20 and open main contacts 43. Reclosure of auxiliary contacts 20 closes the circuit of auxiliary winding 36. By presetting variable resistors 19 and 21 so that both auxiliary winding circuits are energized to equal and opposite extents, member 40 ceases to operate when both windings are in the circuit. In this manner a subsequent tap change in the same direction as previously takes place with a reduced time delay, but a subsequent tap change in the opposite direction takes place after an increased time delay.

However, if it is desired to have a shorter time delay in one direction than the other, resistors 19 and 21 are set so that member 40 creeps towards switch 42 or 44 when the regulated voltage is normal. Assuming that it is desired to have a shorter time delay in the clockwise direction resistor 19 is set to a value smaller than resistor 21. This causes auxiliary winding 36 to be energized more than winding 37 which causes member 40 to creep clockwise. Extension 41 contacts switch 42 but does not open contacts 20 because winding 36 is not energized sufficiently. Closure of contacts 17 shorts resistor 19 out of the circuit of auxiliary winding 36 and energizes auxiliary winding 36 sufficiently to open auxiliary contacts 20 and close main contacts 43. The circuit then operates as previously described.

Another embodiment of the present invention is shown in Fig. 4. Control circuit 109 shown in Fig. 4 controls motor 10 to operate the step type regulator (not shown) of Fig. 1.

In control circuit 109 variable resistors 19 and 20 are omitted and auxiliary contacts 20 and 22 are replaced by auxiliary contacts 110 and 111. Auxiliary winding 36 is then connected in series with auxiliary contacts 111 and auxiliary contacts 110 are connected in series with auxiliary winding 37. Control contacts 17 and 18 are connected in series with auxiliary contacts 111 and 110, respectively.

The control circuit of Fig. 4 is shown in the neutral position, the load circuit 14 (not shown) being originally at normal voltage. Assuming that a change of load voltage has occurred the operation is as follows.

Solenoid 16 of contact making voltmeter 13 connected across the load circuit selectively closes either contacts 17 or 18 depending on whether an increase or decrease is needed to compensate for the change.

Assuming that an increase is needed and solenoid 16 is actuated to close contacts 17 auxiliary winding 36 is energized. This action causes member 40 to rotate clockwise, as shown. After a predetermined time extension 41 of member 40 actuates switch 42 closing contacts 43 and 110. Closure of contacts 110 energizes auxiliary winding 37 of electroresponsive device 30 and since both auxiliary windings 36 and 37 are then

energized member 40 stops. Closure of contacts 43 energizes stator winding 46 of reversible motor 10 and causes it to rotate clockwise. Rotation of motor 10 results in a tap change being made in the manner previously observed.

When the load voltage is returned to normal as the result of the tap change, solenoid 16 opens contacts 17 and open circuits auxiliary winding 36. Auxiliary winding 37 is still energized and causes member 40 to rotate counterclockwise until contacts 110 and 43 are open. Opening of contacts 110 open circuits auxiliary winding 37 causing member 40 to stop rotating.

If another increase in voltage is needed shortly thereafter member 40 moves for a shorter predetermined time in reclosing contacts 110 and 43. If a decrease in voltage is needed member 40 moves for a longer predetermined time in closing contacts 111 and 45.

The advantage of the present invention over prior art control systems can readily be seen by comparing Figs. 5 and 6. In these figures the area between lines A and B represent the band width in which the load voltage is sought to be maintained by the regulator, line A representing the upper limit and line B the lower limit.

In prior art control systems if load fluctuations cause the load voltage to vary in time by a given amount as shown by curve C, a tap change will not occur until the average value of the load voltage has increased or decreased to the extent that the voltage reaches either of the two extreme conditions represented by curves D and E. The periods of time PQ, QR, etc., between points P to V on line A are all identical and equal to the time delay of the control system. The voltage is normal for the periods from P to Q, R to S, and T to U, and abnormal from Q to R, S to T, and U to V. Thus, the value of the load voltage can vary between limit F on curve D and limit G on curve E without being corrected.

However, with the present control system curves D and E of Fig. 5 are replaced by curves M and N as shown in Fig. 6. This is because if the voltage exceeds the limit A during a succession of short periods the time delay device integrates those periods and eventually cause the tap changer to move by one step. If the voltage drops below the limit B during a succession of short periods the tap changer moves by one step in the opposite direction. Limits F and G in Fig. 5 are therefore reduced to the band width limits A, B which shows that the voltage wave cannot vary more than the band width for any length of time without being corrected for.

Although but two embodiments of the present invention have been illustrated and described, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit of the invention or from the scope of the appended claims.

It is claimed and desired to secure by Letters Patent:

1. In combination, an element to be moved in response to a circuit condition and means for moving said element comprising a motor, and means for operating said motor in either direction comprising a first voltage supply and first and second main contacts for connecting said supply to said motor, a control system for selectively operating one of said main contacts to provide for operation of said motor in one direction, said control system comprising a relay having first and second normally open contacts selectively actuatable into closed position in response to said circuit condition, an electroresponsive device comprising a movable member, a first unit providing for movement of said member in one direction and a second unit providing for movement of said member in another direction, each of said units comprising a main winding, an auxiliary winding, a voltage supply for energizing said windings,

current limiting means, and auxiliary contacts actuatable by said member, said current limiting means connected in series with part of said main winding through said auxiliary winding and said auxiliary contacts, said first relay contacts connected in series with said current limiting means through said auxiliary contacts, said units being normally energized to predetermined extents while said relay contacts are open, closure of said first relay contacts in response to said circuit condition shunting said current limiting means and said auxiliary contacts of said first unit to increase the energization of said first unit and cause said member to rotate in a predetermined direction, rotation of said member for a predetermined time opening said shunted auxiliary contacts in said first unit and closing one of said main contacts to energize said motor to move said element, opening of said first relay contacts when said condition is corrected causing said first unit to be energized less than said second unit to rotate said member in said other direction, said member after a second predetermined time opening said closed main contacts, and closing said auxiliary contacts of said first unit causing said first unit to be reenergized to said predetermined extent.

2. In combination, an element to be moved in response to a circuit condition, means for moving said element comprising a motor and detent mechanism for translating the relatively slow uniform continuous operation of said motor into a rapid snap action of said element and means for operating said motor comprising a first voltage supply and first and second main contacts for connecting said motor to said supply, a control system for selectively operating one of said main contacts to provide for operation of said motor in one direction, said control system comprising a relay having first and second normally open contacts selectively actuatable into closed position in response to said circuit condition, an electroresponsive device comprising a movable member, a first unit providing for movement of said member in one direction and a second unit providing for movement of said member in another direction, each of said units comprising a main winding, an auxiliary winding, a voltage supply for energizing said windings, a variable resistor, and auxiliary contacts actuatable by said member, said variable resistor connected in series with part of said main winding through said auxiliary winding and said auxiliary contacts, said first relay contacts connected in series with said variable resistor through said auxiliary contacts, said units being normally energized to predetermined extents while said relay contacts are open, closure of said first relay contacts in response to said circuit condition shunting said resistor and said auxiliary contacts of said first unit to increase the energization of said first unit and cause said member to rotate in a predetermined direction, rotation of said member for a predetermined time opening said shunted auxiliary contacts in said first unit and closing one of said main contacts to energize said motor and bias said detent mechanism to a predetermined extent to move said element with a snap action, opening of said first relay contacts when said condition is corrected causing said first unit to be energized less than said second unit to cause said member to rotate in the opposite direction, said member after a second predetermined time opening said closed main contacts and closing said auxiliary contacts of said first unit causing said first unit to be reenergized to said predetermined extent.

3. In combination, an element to be moved, means for moving said element comprising a motor and means for operating said motor in either direction comprising a first voltage supply and first and second main contacts for connecting said supply to said motor, a control system for selectively operating one of said main contacts to provide for operation of said motor in one direction, said control system comprising a relay having first and second normally open contacts selectively actuatable into closed position in response to a change in a given circuit condition,

an electroresponsive device comprising a movable member, a first unit providing for movement of said member in one direction and a second unit providing for movement of said member in another direction, each of said units comprising a main winding, an auxiliary winding, a voltage supply for energizing said windings, a variable resistor, and auxiliary contacts actuable by said member, said variable resistor connected in series with part of said main winding through said auxiliary winding and said auxiliary contacts, said first relay contacts connected in series with said variable resistor through said auxiliary contacts, said units being normally energized to equal and opposite predetermined extents by said variable resistors while said relay contacts are open, closure of said first relay contacts in response to said change in said circuit condition shunting said resistor and said auxiliary contacts of said first unit to increase the energization of said first unit and cause said member to rotate in a predetermined direction, rotation of said member for a predetermined time opening said shunted auxiliary contacts in said first unit and closing one of said main contacts to energize said motor to move said element, opening of said first relay contacts when said condition is restored causing said first unit to be energized less than said second unit thereby causing said member to rotate in the opposite direction, said member after a second predetermined time opening said closed main contacts and closing said auxiliary contacts of said first unit causing said first unit to be reenergized to said predetermined extent.

4. In combination, an element adapted to be moved, means for moving said element comprising a motor and detent mechanism for translating the relatively slow uniform continuous operation of said motor into a rapid snap action of said element and means for operating said motor comprising a first voltage supply and first and second main contacts for connecting said motor to said supply, a control system for selectively operating one of said main contacts to provide for operation of said motor in one direction, said control system comprising a relay having first and second normally open contacts selectively actuable into closed position in response to a change in a given circuit condition, an electroresponsive device comprising a movable member, a first unit providing for movement of said member in one direction and a second unit providing for movement of said member in another direction, each of said units comprising a main winding, an auxiliary winding, a voltage supply for energizing said windings, a variable resistor, and auxiliary contacts actuable by said member, said variable resistor connected in series with part of said main winding through said auxiliary winding and said auxiliary contacts, said first relay contacts connected in series with said variable resistor through said auxiliary contacts, said units being normally energized to equal and opposite predetermined extents while said relay contacts are open, closure of said first relay contacts in response to said change in said circuit condition shunting said resistor and said auxiliary contacts of said first unit to increase the energization of said first unit and cause said member to rotate in a predetermined direction, rotation of said member for a predetermined time opening said shunted auxiliary contacts in said first unit and closing one of said main contacts to energize said motor and bias said detent mechanism to a predetermined extent to move said element with a snap action, opening of said first relay contacts when said condition is restored causing said first unit to be energized less than said second unit thereby causing said member to rotate in the opposite direction, said member after a second predetermined time opening said closed main contacts and closing said auxiliary contacts of said first unit causing said first unit to be reenergized to said predetermined extent.

5. In combination, an element adapted to be moved, means for moving said element comprising a first reversible motor and means for operating said motor in either di-

rection comprising a first voltage supply and first and second main contacts for connecting said supply to said first motor, a control system for selectively operating one of said main contacts to provide for operation of said first motor in one direction, said control system comprising a relay having first and second normally open contacts selectively actuable into closed position, in response to a circuit condition, a second reversible motor having a shaft, a first unit providing for movement of said second motor in one direction and a second unit providing for movement of said second motor in another direction, each of said units comprising a voltage supply for energizing said second motor, a variable resistor, and auxiliary contacts actuable by said shaft, said variable resistor connected in series with said first motor and said auxiliary contacts, said first relay contacts connected in series with said variable resistor through said auxiliary contacts, said units being normally energized to predetermined extents while said relay contacts are open, closure of said first relay contacts in response to a change in said circuit condition shunting said resistor and said auxiliary contacts of said first unit to increase the energization of said first unit causing said second motor to rotate said shaft in a predetermined direction, rotation of said shaft for a predetermined time opening said shunted auxiliary contacts in said first unit and closing one of said main contacts to energize said first motor to move said element, opening of said first relay contact when said condition is restored causing said first unit to be energized less than said second unit causing said second motor to rotate said shaft in the opposite direction, said shaft after a second predetermined time opening said main contacts causing said first unit to be reenergized to said predetermined extent.

6. In a step type regulating system having a plurality of contact positions and a movable contact, the combination of means for moving said movable contact comprising a motor and detent mechanism for translating the relatively slow uniform continuous operation of said motor into a rapid snap action of said movable contact, and means for operating said motor comprising a first voltage supply and first and second main contacts for connecting said motor to said supply, a control system for selectively operating one of said main contacts to provide for operation of said motor in one direction, said control system comprising a relay having first and second normally open contacts selectively actuable into closed position in response to a change in a given circuit condition, an electroresponsive device comprising a movable member, a first unit providing for movement of said member in one direction and a second unit providing for movement of said member in another direction, each of said units comprising a main winding, an auxiliary winding, a voltage supply for energizing said windings, a variable resistor, and auxiliary contacts actuable by said member, said variable resistor connected in series with part of said main winding through said auxiliary winding and said auxiliary contacts, said first contacts of said relay connected in series with said variable resistor through said auxiliary contacts, said units being normally energized to predetermined extents while said relay contacts are open, closure of said first relay contacts in response to said change in said circuit condition shunting said resistor and said auxiliary contacts of said first unit to increase the energization of said first unit and cause said member to rotate in a predetermined direction, rotation of said member for a first predetermined time opening said shunted auxiliary contacts in said first unit and closing one of said main contacts to energize said motor and biasing said detent mechanism to a predetermined value to move said movable contact with a snap action, opening of said first relay contacts when said condition is restored causing said first unit to be energized less than said second unit thereby causing said member to rotate in the opposite direction, said member after a second predetermined time opening said main

contacts causing said first unit to be reenergized to said predetermined extent.

7. In combination, an element to be moved in response to a circuit condition, a motor for moving said element, means for energizing said motor, first contact means for connecting said motor energizing means to said motor, a winding energizing means, an electroresponsive device comprising an auxiliary winding, current limiting means in circuit with said winding to limit the energization thereof to a predetermined extent, second contact means interconnecting said winding energizing means and said winding, a member adapted to remain stationary when said winding is energized to said predetermined extent, adapted to be moved in one direction when said winding is energized to a greater extent, and adapted to be moved in another direction when said winding is energized to a lesser extent, a relay operable from one position to another in response to said condition to render said current limiting means inoperable to cause said winding to be energized to

said greater extent and move said member in said one direction, movement of said member in said one direction for a predetermined time operating said first and second contact means causing said motor to be energized to move said element, and causing said winding to be energized to said lesser extent when said condition is corrected and said relay returns to said one position, energization of said winding to said lesser extent causing said member to move in said other direction for a time less than said predetermined time to operate said first contacts to deenergize said motor and to operate said second contacts to cause said winding to be again energized to said predetermined extent.

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