H. E. FROST.

MOTOR CONTROL SYSTEM.

APPLICATION FILED OCT. 1, 1910.

1,005,638. Patented Oct. 10, 1911.

2 SHEETS—SHEET 1.

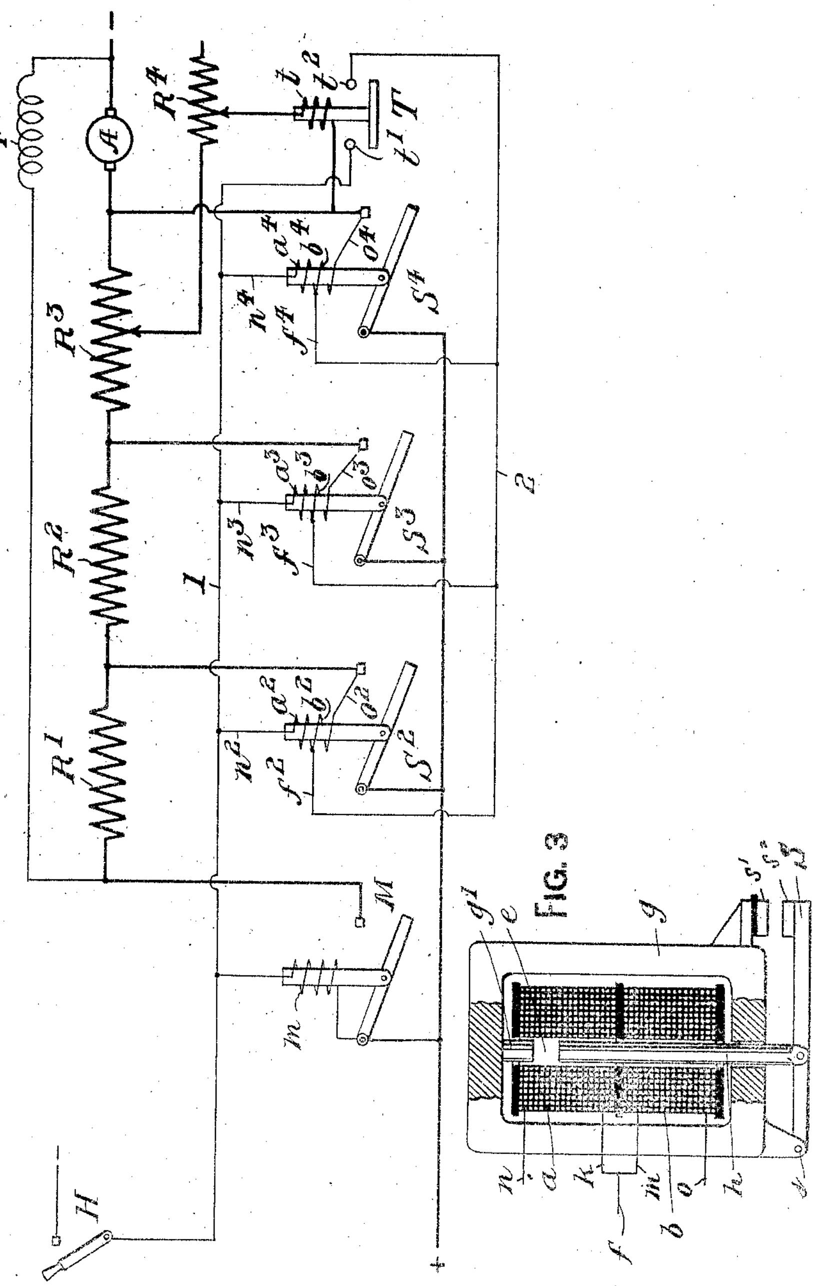

FIG. 1

FIG. 3

WITNESSES

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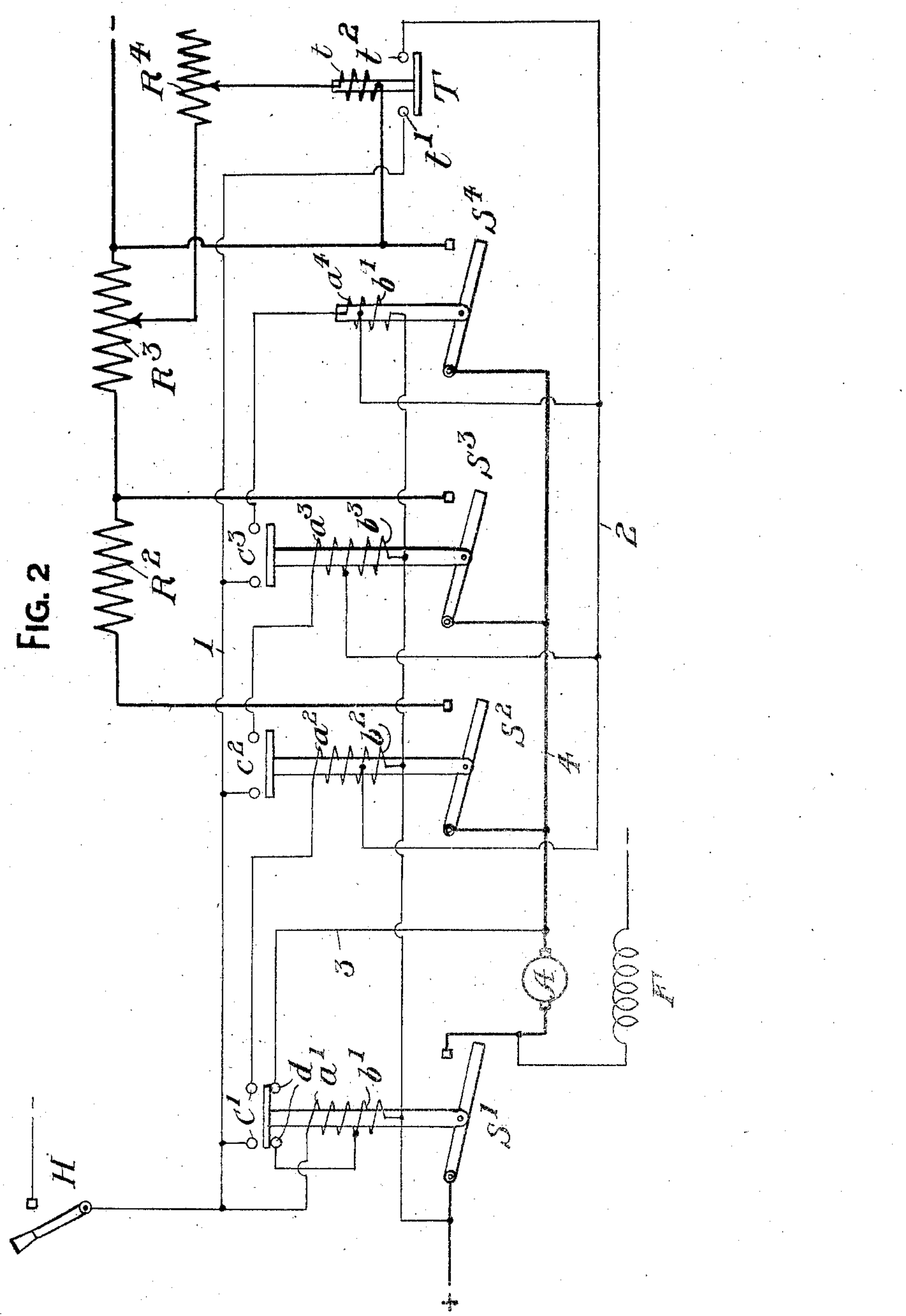
2 SHEETS—SHEET 2.

FIG. 2



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MOTOR-CONTROL SYSTEM.

1,005,638. Specification of Letters Patent. **Patented Oct. 10, 1911.**

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To all whom it may concern:

Be it known that I, Homer E. Frost, a citizen of the United States, residing at Cleveland, in the county of Cuyahoga and State of Ohio, have invented new and useful Improvements in Motor-Control Systems, of which the following is a specification.

My invention relates to electric motor controllers, particularly to that type in which magnetically operated switches are used to control the motor, the switches being controlled from a distant point by means of a master switch, and operating automatically to vary the resistance in the motor circuit without attention from the operator.

The object of my invention is to supply a system without the use of the numerous contacts in the control circuits which are now used on such controllers, and to provide for the protection of the magnetic switch coils from overheating without the use of auxiliary resistance units.

Referring to the accompanying drawings, Figures 1 and 2 are wiring diagrams of two forms of controllers embodying my invention, and Fig. 3 is a drawing of the type of switch I prefer to use.

Referring first to Fig. 3, I show the open frame g of magnetic material which surrounds the windings a and b connected together at their adjacent ends by their terminals k and m, the point of their junction being connected to the wire f. The remaining terminals of the windings are marked n and o. The switch arm S is pivoted to the frame at s and connected pivotally to the plunger h located axially in the windings. When the switch contacts s' and s^2 are open, as shown, the top of the plunger is separated by the air-gap e from the boss or pole g' projecting from the frame into the upper end of the winding a. When the plunger is attracted to the boss g', the switch contacts are caused to close. I have found that, with the windings so proportioned as to close the switch contacts when the windings are connected in series across a source of supply, the winding b will not cause the switch to close in case the winding a is short-circuited; but that, after the windings have operated in series to close the switch, the winding b will maintain the switch closed if the winding a is subsequently short-circuited, because the air-gap e has become much smaller.

The parts marked a, b, f, n, o, and S on Fig. 3 are on the diagrammatic drawing, Fig. 1, provided with numerical exponents 2, 3, and 4 to correspond with the exponents of the resistance switches S^2, S^3, S^4 each analogous to the switch S of Fig. 3. For example, all windings with the letter a are the same as the one marked a on Fig. 3, the exponents being used on Fig. 1 merely to designate the switch with which the windings are associated.

On Fig. 1, M is a main switch for connecting the motor armature A across a source of supply and in series with the resistance sections R', R^2, and R^3. The switches S^2, S^3, and S^4 are arranged in an obvious manner so as to short-circuit the resistance sections successively so that upon the closure of the switch S^4, the armature A is connected directly across the source of supply. The throttle T closes its contacts t', t^2, by the action of the winding t which is in a shunt of the motor-circuit and has both terminals connected to the motor circuit, one terminal being adjustably connected to the resistance section R^3. Preferably the adjustable resistance R^4 is connected in the shunt circuit. The terminals n^2, n^3, and n^4 are connected in multiple to the wire 1; the terminals o^2, o^3, and o^4 are connected, respectively, to the fixed contacts of the switches S^2, S^3, and S^4; and the terminals f^2, f^3, and f^4 are connected in multiple to the wire 2. The throttle T when actuated by the winding t bridges the contacts t' and t^2, thereby connecting the wires 1 and 2 in series. The wire 1 is connected to the negative source of supply by the hand switch H. The main switch M is actuated by the winding m connected across the source of supply by the switch H. Upon closing the switch H, current flows from the positive main through the winding m and the switch H to the negative. This current energizes the winding m, which causes the switch M to close the motor circuit which is as follows: From the positive main through the switch M, the resistance sections R', R^2, and R^3 in series, and the armature A to the negative main. The closing of the switch M also permits current to flow through the shunt motor-field F. These two circuits cause the motor to start at its slowest speed. As soon as the switch M closes, a current will flow from the positive main through the switch M, the resistance section R′, the wire o^2, the windings b^2 and a^2 in series, the wires n^2 and 1, and the switch H to the negative provided the throttle T does not close its contacts t' and t^2 by reason of there passing through the winding t a current greater than a predetermined value, fixed by adjustments on the resistance R^3 or R^4 or otherwise. The pairs of a and b windings are each adjusted so that when current flows through them in series, they will actuate their switches when the voltage impressed on each of them is the line voltage minus the drop caused by the motor current flowing through the preceding resistance section. The throttle T being supposed to be open, the described current flowing in series through the windings a^2 and b^2 has impressed thereon the line voltage less the drop due to the resistance section R′; consequently these windings will cause the switch S^2 to close, thereby short-circuiting the resistance section R′ and causing the motor speed to increase. The current flowing in series in each of the pairs a^3, b^3, and a^4, b^4 of the windings for the switches S^3 and S^4 will not close prior to the closing of the switch S^2 because the voltage impressed on each pair of windings is less than that required to cause them to actuate their switches, because the impressed voltage in the pair a^3, b^3 is less than the line voltage by the drop due to the resistance sections R′ and R^2 and the impressed voltage in the pair a^4, b^4 is less than the line voltage by the drop due to all the resistance sections.

If, when the switch M closes, the motor current has too great a value to permit the resistance R′ to be cut-out with safety, the throttle T will close its contacts, which will cause a current to flow from the positive through the switch M, the resistance section R′, the wire o^2, the winding b^2, the wires f^2 and 2, the contacts t^2 and t' of the throttle T, and the wire 1 to the negative, thereby short-circuiting the winding a^2. The switch S^2 remains open as the winding b^2 is not able alone to actuate it. When the motor has speeded up and the current has fallen to a predetermined safe value, the throttle T opens and current will flow in series through the windings a^2 and b^2, as already explained, causing the switch S^2 to close its contacts. The closure of the switch S^2, by short-circuiting the resistance R′, increases the current in the motor circuit, thereby causing the throttle T to close again and short-circuit the winding a^3, the current flowing from the positive through the switch S^2, the resistance section R^2, the wire o^3, the winding b^3, the wires f^3 and 2, the contacts t^2 and t', the wire 1 and the switch H to the negative. The closure of the throttle T will not open the switch S^2 because the winding b^2 is able alone to maintain this switch closed since the air gap (Fig. 3) has been much reduced by the movement of the plunger h toward the boss g'. When the current again diminishes at the point when the throttle opens its contacts, the shunt circuit of the winding a^3 is removed, and the current in series in the windings a^3 and b^3 will close the switch S^3 since the impressed voltage therein is that of the line minus the drop through the resistance section R^2. The closure of the switch S^3 short-circuits the resistance section R^2, which again increases the motor current and the speed of the motor. The throttle T is caused to close its contacts again and short-circuit all the windings a^2, a^3, and a^4. The current in the windings b^2 and b^3 is sufficient to maintain the switches S^2 and S^3 closed but the winding b^4 cannot close the switch S^4. The winding a^4 is short-circuited through the switch S^3, the resistance R^3, the wire o^3, the winding b^4, the wires f^4 and 2, and the throttle to the negative at the switch H. When the motor current again diminishes so as to permit the throttle T to open, current will flow in series through the windings a^4 and b^4 by way of the wires o^4 and n^4 and cause the switch S^4 to close, because the impressed voltage on the windings a^4 and b^4 is equal to the line voltage minus the drop caused by the motor current through the resistance section R^3. The closing of the switch S^4 short-circuits the resistance section R^3 and also the winding t of the throttle. The armature A is now connected directly across the line. The pairs of the a and b windings are connected in multiple across the line, the members of each pair carrying the current in series across the line. It is intended that, when they are so connected, the current in the coils will not cause them to overheat. When it is desired to stop the motor the switch H is opened, thereby deënergizing the winding m and causing the switches M, S^2, S^3, and S^4 to open, disconnecting the motor from the source of supply.

In Fig. 2 I have shown a system of motor control in which the main switch S′ has coils a', b' so connected as to form an electrical interlock to prevent the switch S′ from closing if any of the switches S^2, S^3, and S^4 remain closed for any reason such as sticking due to heavy arcing at the contacts. In this system I have shown the resistance switches controlled by means of auxiliary contacts on the previous switch to give the proper sequence of operation. Upon the closure of the master switch H the coils a', b' will be connected across the source of supply, causing the switch S′ to close its contacts providing all the switches S^2, S^3, and S^4 are in their open position, as shown. If one of the switches is closed, such as switch S^4, the lower end of the coil a' is connected to the negative side of the line through the auxiliary contacts d, the conductors 3 and 4, and the switch S^4 to the negative. The upper end of the coil a' is connected to the negative through the master switch H, and the switch S′ can therefore not operate, it being short-circuited through the contacts d and the switch S^4. If, however, the switches S^2, S^3, and S^4 are open, the switch S′ operates as above stated. This causes the auxiliary contacts c' to close and also connects the shunt field F across the source of supply. Upon the closure of contacts c', the winding a^2, b^2 is connected across the source of supply, causing the switch S^2 to close its contacts, which connects the motor across the line in series with the resistance sections R^2 and R^3, and causes the throttle T to close its contacts t' t^2 if the current is above a predetermined value. When the switch S^2 operates, it closes its auxiliary contacts c^2 which connects the winding a^3 b^3 across the line, but the closure of the contacts of the throttle T has short-circuited the winding a^3, preventing the switch S^3 from operating. As soon as the motor speeds up and the motor current decreases to a predetermined value, the throttle T opens its contacts, removing the short-circuit through the winding a^3, allowing the switch S^3 to close its contacts and short-circuit the resistance section R^2. This increases the current through the motor and causes the throttle T to close its contacts. The closure of the switch S^3 also closes its auxiliary contacts c^3 but the winding a^4 remains short-circuited until the throttle again opens its contacts due to a diminishing of the motor current, at which time the short-circuit is removed from the winding a^4, allowing the switch S^4 to operate and short-circuit resistance R^3 and the winding t of the throttle T. This connects the motor armature current directly across the source of supply, allowing it to operate at its maximum speed. If the wire 3 were connected directly to the lower terminal of the coil a', the closure of the switch S^4 would short-circuit the coil a' and cause an increased amount of current to flow continually through the coil b', which might cause it to overheat. I have, therefore, provided the auxiliary contacts d to open the wire 3 when the switch S′ operates, thus placing the coils a' and b' in series, and preventing their becoming overheated. To stop the motor the master switch H is opened, which causes all of the switches S′ to S^4 to open their contacts, disconnecting the motor from the source of supply.

I have shown my invention in connection only with the control of a shunt-wound motor, but it will be understood by those skilled in the art that other types of motors may be controlled in a similar manner, and that my invention may be applied to reversing controllers and other forms of control systems.

I claim—

1. In combination, a series of switches adapted to close in a predetermined sequence, actuating windings for the switches and a limit switch for short-circuiting a part of each of the windings to prevent their closure when the said limit switch is closed.

2. In a current varying controller, a circuit containing a resistance, a set of switches for controlling said resistance adapted to close in a predetermined sequence, each of said switches having a coil in two portions, and means for short-circuiting one of said portions to retard the sequential closure of said switches.

3. In a current varying controller, a circuit, a resistance for controlling said circuit, a set of resistance controlling switches adapted to close in a predetermined sequence, each having a coil which, if a part is short-circuited, prevents the operation of the switch, and means for short-circuiting said part of the coil when the current in said circuit is above a predetermined value.

4. In a motor control system, the combination of a series of switches adapted to close in a predetermined sequence, an operating winding for each switch and means for retarding their closure, said means consisting of a limit switch which when closed causes current to flow in a part only of the operating winding of said switches when the current in the motor circuit is above a predetermined value.

5. In a motor control system, a motor, a circuit therefor containing a resistance, a set of switches for controlling said resistance, a main switch, an actuating winding therefor, and means for short-circuiting a part of the winding of said main switch when any of the resistance controlling switches is closed.

6. In a motor control system, a motor, a circuit therefor, a resistance for controlling said circuit, a set of switches for controlling said resistance, a main switch having a winding which, if partially short-circuited, will prevent the switch from closing, means for short-circuiting a part of said winding when any of the resistance controlling switches is closed, and means for opening said short-circuit when the main switch is closed.

7. In a motor control system, a motor circuit, sections of resistance therein, magnetically-operated switches arranged to vary the resistance in the said circuit, means for closing the switches in a predetermined se-

quence, means responsive to the current in the motor circuit for short-circuiting a portion of each switch-operating winding to prevent its associated switch from closing, said last means being arranged to open the short circuit when the current in the motor circuit is below a predetermined value.

Signed at Cleveland, Ohio, this 27th day of September A. D., 1910.

HOMER E. FROST.

Witnesses:
J. H. HALL,
W. M. DIEMER.