E. S. LAMMERS, JR.

MOTOR CONTROL SYSTEM.

APPLICATION FILED JUNE 13, 1917.

1,392,255. **Patented Sept. 27, 1921.**

3 SHEETS—SHEET 1.

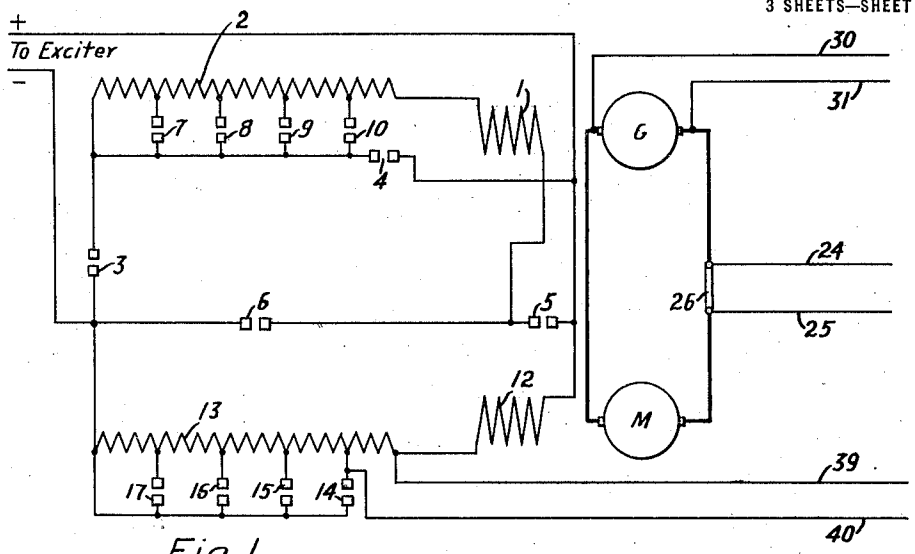


Fig. 1.

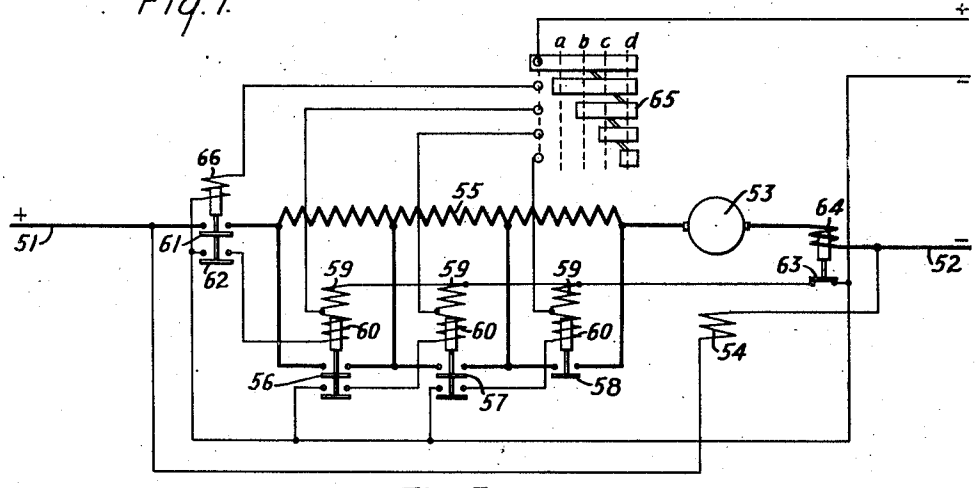


Fig. 3.

SWS	Points								
	a	b	c	d	e	f	g	h	i
3	o	o	o	o	o	o	o	o	o
4									
5	o	o	o	o	o	o	o	o	o
6									
7		o	o	o	o	o	o	o	o
8			o	o	o	o	o	o	o
9				o	o	o	o	o	o
10					o	o	o	o	o
14	o	o	o	o	o				
15	o	o	o	o	o	o			
16	o	o	o	o	o	o	o		
17	o	o	o	o	o	o	o	o	

Fig. 2.

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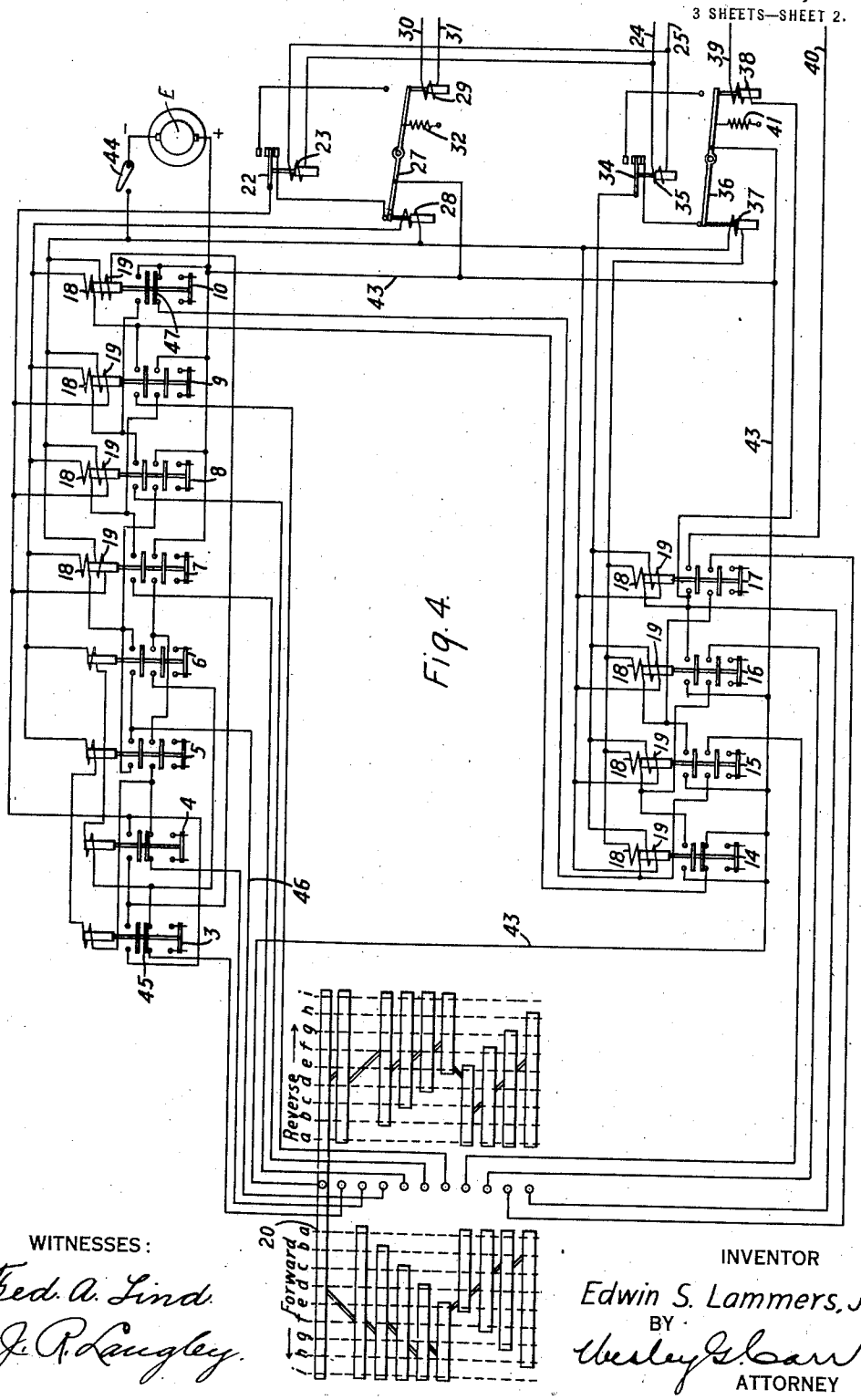


Fig. 4.

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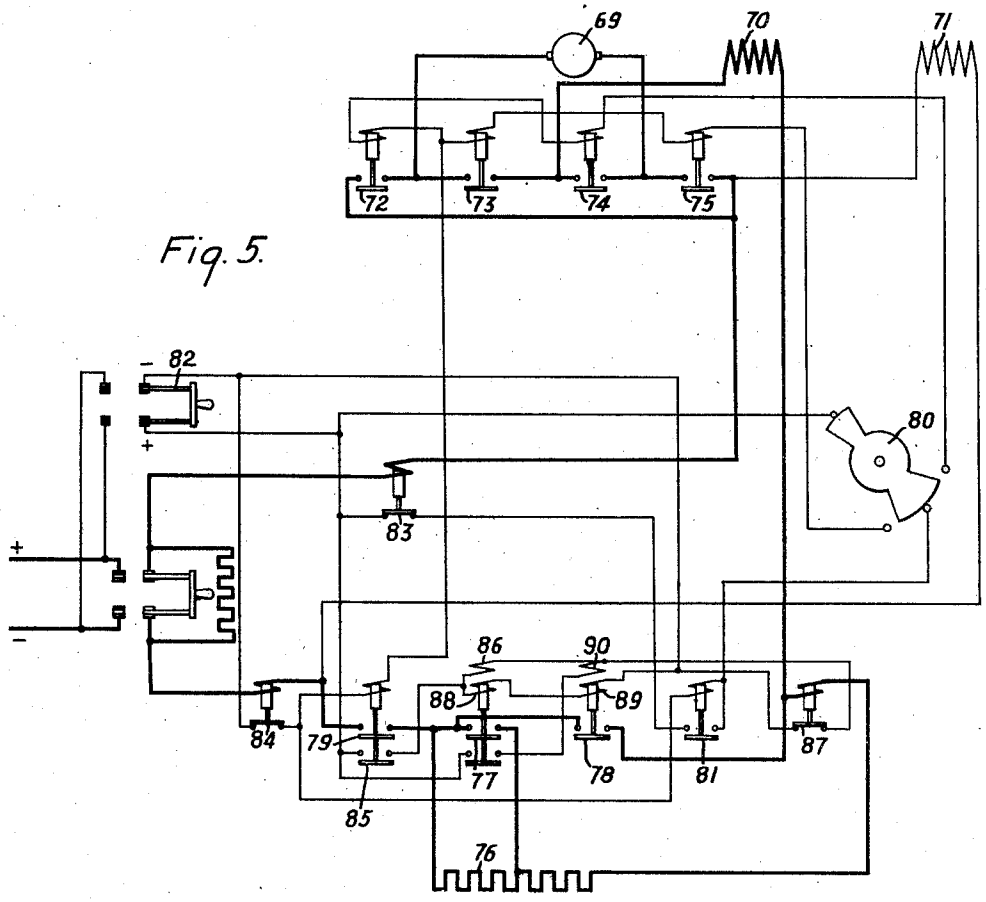
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3 SHEETS—SHEET 3.

Fig. 5.



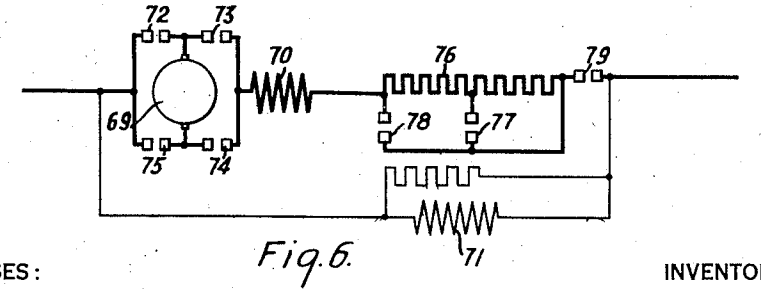


Fig. 6.

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MOTOR-CONTROL SYSTEM.

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To all whom it may concern:

Be it known that I, EDWIN S. LAMMERS, Jr., a citizens of the United States, and a resident of Wilkinsburg, in the county of Allegheny and State of Pennsylvania, have invented a new and useful Improvement in Motor-Control Systems, of which the following is a specification.

My invention relates to motor-control systems and it has for its object to provide a simple and effective arrangement for insuring the operation of a series of electromagnetically operable switches in a predetermined sequence.

My invention comprises a series of progressively actuated switches, each of which is provided with a pair of coils of substantially equal ampere-turns. It is necessary that both coils of any switch shall be energized in order to effect the closing of the switch. Either of the coils, when energized, exerts a pull that is sufficient to retain the switch in its closed position.

A series of switches arranged in the manner described above may be employed in various ways. For example, they may be embodied in a system for controlling the field excitation of dynamo-electric machines employed in connection with reversing blooming mills for rolling steel. They may also be employed in connection with electric motors for operating mine hoists or other machines in which it is desirable that the controlling switches operate in a predetermined sequence either automatically or in accordance with the position of a manually operable controller.

In the accompanying drawings, Figure 1 is a diagrammatic view of the main and field circuits of a generator and an electric motor such as are employed in connection with steel mill operations. Fig. 2 is a chart indicating the sequence of operation of the various switches of the system shown in Fig. 1. Fig. 3 is a diagrammatic view of circuits and apparatus illustrating my invention applied to the circuits of an electric motor. Fig. 4 is a diagrammatic view of the circuits and apparatus for controlling the various switches shown in the system of Fig. 1. Fig. 5 is a diagrammatic view of a series of switches arranged in accordance with my invention for automatically controlling the circuits of an electric motor. Fig. 6 is a schematic arrangement of the principal circuits of the system shown in Fig. 5.

Referring particularly to Fig. 1, a generator G and a motor M are permanently connected in a closed circuit. The generator G is provided with a field-magnet winding 1. The circuit of the field-magnet 1, which comprises a resistor 2, is controlled by reversing switches 3, 4, 5 and 6 and by a series of progressively actuated switches 7, 8, 9 and 10. The motor M is provided with a field-magnet winding 12 which is in circuit with a resistor 13. The resistor 13 is controlled by a second series of progressively actuated switches 14, 15, 16 and 17.

Reference may now be had to Fig. 4, in which the circuits and apparatus for controlling the several switches embodied in the system of Fig. 1 are diagrammatically illustrated. Similar reference numerals are employed to designate corresponding parts. Each of the several switches 7, 8, 9, 10, 14, 15, 16 and 17 is provided with a pair of magnet coils 18 and 19. The coils 18 and 19 are of substantially equal ampere-turns. It is necessary that both members of a pair of coils shall be energized in order to effect the closing of the corresponding switch. The switch, when closed, may be retained in that position when either of the coils is energized.

The coils 18 are arranged to be energized in order in accordance with the position of the manually operable master switch or controller 20. The circuits of the respective coils 18 are arranged to be controlled by the preceding switch to close in order that the switches may close in the predetermined sequence regardless of the rate at which the controller 20 is actuated to its full running position. The coils 19, which are connected in parallel circuit relation to each other, are arranged to be energized simultaneously.

Current for the various control circuits and for supplying energy to the respective field-magnet windings of the generator and of the motor is furnished by an exciter generator E. The circuits of the coils 19 of switches 7, 8, 9 and 10 are controlled by a relay 22 having an actuating coil 23 which is connected, by means of conductors 24 and 25, across the terminals of a resistor 26 that is in series-circuit relation with the generator and the motor armature windings. The

relay 22 accordingly controls the circuits of the coils 19 in accordance with the value of the current traversing the main circuit.

The effect of the operation of the relay 22 is controlled by a relay 27 which normally occupies its illustrated position. The relay 27 is controlled by a coil 28 that is in series with the coils 18 of switches 7, 8, 9 and 10 and is energized in accordance with the number of coils 18 that are connected in circuit by the controller 20. The relay 27 is controlled also by a coil 29 which is connected by means of conductors 30 and 31 across the terminals of the generator G. The coil 29 opposes the force of the coil 28 with a force that is proportional to the value of the voltage of the generator G.

A spring 32 tends to retain the relay 27 in its illustrated position. During the operation of the controlling switches, the position of the relay is dependent upon the value of the voltage of the generator corresponding to the portion of the resistor 2 which is in circuit, as determined by the position of the controller 20, relatively to the actual voltage of the generator as measured by the degree to which the coil 29 is energized. The coils 28 and 29 tend to actuate the relay 27 in opposite directions.

A relay 34, which is similar to the relay 22, controls the circuits of the coils 19 of the switches 14, 15, 16 and 17. The relay 34 is provided with an actuating coil 35 that is connected across the terminals of the resistor 26. The effect of the operation of the relay 34 is controlled by a relay 36 which normally occupies its illustrated position.

The relay 36 comprises actuating coils 37 and 38 which respectively tend to actuate the switch toward and from the position in which it is illustrated. The coil 37 is connected in series with the coils 18 of the switches 14, 15, 16 and 17. The coil 37 is accordingly energized to a degree depending upon the number of coils 18 that are in circuit.

The coil 38 is connected, by means of conductors 39 and 40, across the terminals of a section of the resistor 13. The coil 38 is energized, therefore, in accordance with the value of the current traversing the field-magnet winding 12 of the motor. A spring 41 tends to retain the relay 36 in its illustrated position.

It may be assumed that the generator is driven at any desired speed and that its voltage is substantially of zero value. It may be assumed further that the motor is stationary. When the various relays and switches occupy their respective illustrated positions, a control switch 44 is closed and the coils 19 of the switches 7, 8 and 9 are energized by a circuit which extends from the positive terminal of the exciter E through a portion of conductor 43, relays 27 and 22, coils 19, which are in parallel relation, and switch 44 to the negative terminal of the exciter. The coils 18 of these switches are deënergized because their respective circuits are open at the master controller.

The corresponding coils 19 of the switches 14, 15, 16 and 17 are energized by a circuit which extends from the positive terminal of the exciter E through a portion of conductor 43, relays 36 and 34, coils 19, which are in parallel relation, to the negative terminal of the exciter. The switches 14, 15, 16 and 17 are closed when the controller is in its "off" position. When the switch 10 is open, a circuit for the coil 18 of switch 14 is completed which extends from the positive terminal of the exciter E through an interlock connected to switch 10, coil 18 of switch 14 and coil 37 to the negative terminal of the exciter.

Since both the coils 18 and 19 of switch 14 are energized, this switch closes to complete a shunt circuit for the corresponding section of the resistor 13. The coils 18 of switches 15, 16 and 17 are respectively controlled by interlocks connected to the preceding switch to close, and the closing of switch 14 accordingly effects the closing of switches 15, 16 and 17 in the order named. The major portion of the resistor 13 is shunted by these switches and the motor is provided with a strong magnetic field for starting.

An interlock connected to switch 17 completes a circuit for connecting the coil 38 across the terminals of that section of the resistor 13 that is not controlled by the switches 14, 15, 16 and 17. The coil 38 is energized to a maximum degree because the value of the field current is a maximum. The force of the coil 38 predominates over that of the coil 37 and the spring 41 and the relay is overbalanced. It assumes its other operative position in which the coils 19 of the switches 14, 15, 16 and 17 are deënergized so long as the relay 34 remains in its illustrated position.

To accelerate the motor in the forward direction, the controller 20 is actuated to the left, as viewed in Fig. 4. When the controller occupies position *a*, a circuit is completed which extends from the positive terminal of the exciter through conductor 43, controller 20, interlock 45 of switch 3, actuating coils of reversing switches 4 and 6 and coil 28 of relay 27 to the negative terminal of the exciter E.

As best shown in Fig. 1, the closing of the switches 4 and 6 establishes a circuit for the field-magnet winding 1 of the generator which extends from the positive terminal of the exciter, through switch 4, resistor 2, field-magnet winding 1 and switch 6 to the negative terminal of the exciter.

In position *b* of the controller 20, a circuit is completed which extends from the controller 20, which is connected to the positive terminal of the exciter, through conductor 46, interlock connected to switch 6, coil 18 of switch 7 and coil 28, to the negative terminal of the exciter. The switch 7 is now closed since both of its operating coils 18 and 19 are energized.

The closing of switch 7 partly completes a circuit for the actuating coil 18 of switch 8 and the latter switch closes when the controller 20 is actuated to the succeeding position *c*. The switches 8, 9 and 10 accordingly close in order as the controller is actuated to its successive positions *c*, *d* and *e*. Substantially the entire resistor 2 is shunted and the voltage of the generator has increased to a corresponding degree. Each of the switches 8, 9 and 10, upon closing, completes a holding circuit for the coil 18 of the preceding switch to close and the switch 7, upon closing, completes a holding circuit for the coils of the reversing switches. The function of these holding circuits is to control the sequential operation of the switches during deceleration.

Upon the closing of switch 10, an interlock 47, which is mechanically connected thereto, opens the circuit previously traced for the coil 18 of switch 14. The latter switch does not open, however, because an interlock connected to switch 15 controls the holding circuit for the coil 18. The actuation of the controller to position *f* effects the opening of the holding circuit for coil 18 of switch 14 through the interlock connected to switch 15. As there is one less coil 18 in circuit with the coil 37, the force of the coil 37 is overbalanced by that of the coil 38, causing the relay 36 to open, thereby to open the circuits of the coils 19. The switch 14 opens to insert the corresponding section of the resistor 13 in series with the field-magnet winding 12 to further accelerate the motor. The actuation of the controller to its succeeding positions effects the opening of switches 15, 16 and 17 in order to further weaken the field of the motor and thereby effect its acceleration to its normal speed.

The operation of the system has been described upon the assumption that the controller 20 is actuated in a step-by-step manner from its "off" position to its full running position. In actual practice, however, the controller 20 may be actuated from the one position to the other by a comparatively quick continuous movement. In such case, the operation of the reversing switches 4 and 6 and the switches 7, 8, 9 and 10 occurs automatically and in the order described above. The relay 27, which controls the circuits of the coils 18 of the latter group of switches, does not operate to interrupt the circuit connections of the coils 18 because the coil 28 of the relay is always energized to a greater degree than the opposing coil 29. The number of coils 18 that are connected in circuit is such that the coil 28 is energized to maintain the relay in its illustrated position. The generator voltage does not increase simultaneously with the operation of the switches for increasing the field excitation of the generator.

The switches 14, 15, 16 and 17 open in order upon the closing of switch 10 since the holding circuits for the coils 18 of these switches are opened at the controller 20, and these coils are accordingly deënergized in order upon the opening of the preceding switch. The opening of switch 17 opens the shunt circuit for a section of resistor 13 and the coil 38 is accordingly deënergized. The coil 37 is deënergized also since none of the coils 18 of the latter group of switches are in circuit. The relay 36 accordingly assumes its normal position to complete circuits for the coils 19 in preparation for the closing of the switches.

The operation of the switches described above occurs without interruption in case the current traversing the main circuit of the motor and the generator does not exceed a predetermined value. In case, however, the voltage of the generator is increased at such rate that the current traversing the main circuit exceeds the predetermined value, the coil 23 is energized to open the relay 22 and thereby open the circuits of the coils 19 of switches 7, 8, 9 and 10.

The switches that are closed remain in this position because the corresponding coils 18 exert a pull that is sufficient to retain them in the closed positions. The relay 22 occupies its open position so long as the current traversing the main circuit exceeds the predetermined value, and the operation of the switches is accordingly interrupted for a corresponding period. When the current falls to the predetermined value, the relay 22 closes and the closing of the switches continues in order unless the current again exceeds the predetermined value.

In the same manner, the operation of the switches 14, 15, 16 and 17 is interrupted by the operation of relay 34 in case the coil 35 is sufficiently energized to actuate the relay to its upper position. When the relay 34 occupies its upper position, the circuits of the coils 19 are completed through the relay 36, and the opening of the switches to insert the resistor 13 in series with the field-magnet winding 12 is interrupted until the current traversing the main circuit falls to the predetermined value.

It will be readily understood that the controller may be actuated to its full running position by a continuous movement and that the operation of the system will occur automatically. The operation of the controlling

switches is interrupted automatically upon the occurrence of abnormal current conditions, but the operation of the switches is resumed when normal conditions again obtain. The voltage of the generator is thus increased and the field excitation of the motor is decreased at such rates that the motor is accelerated at a maximum rate consistent with safety.

To decelerate the motor, the controller is actuated toward its "off" position. When the controller occupies position *h*, the coil 18 of switch 17 is again energized by means of a circuit which comprises the coil 37 of relay 36. The coils 19 of the motor controlling switches are energized when the relay occupies its illustrated position.

The switch 17 accordingly closes to complete a shunt circuit for the corresponding section of resistor 13. The closing of switch 17 completes the circuit of coil 38 and, when the current traversing the field circuit of the motor reaches a value corresponding to the adjustment of the controller, the coil 38 predominates and the relay 36 is actuated to open the circuit of the coils 19.

When the controller occupies position *g*, the coil 18 of switch 16 is energized and the coil 37 of relay 36 again predominates to actuate the relay to its illustrated position and thereby complete a circuit for the coils 19, whereupon the switch 16 closes. The operation of the relay 36 occurs between the closing of the successive switches in order to prevent the shunting of the resistor at a rate faster than that at which the field current increases.

When all of the motor controlling switches are closed, the motor operates with a field maximum strength and its speed is accordingly decreased. The closing of switch 14 opens the holding circuit of coil 18 of switch 10 and restores the control of the latter switch to the controller 20.

When the controller occupies position *d*, the coil 18 of switch 10 is deënergized and the pull exerted by the coil 28 is decreased to a corresponding degree. The force exerted by the coil 29 is a maximum since the generator voltage is at its normal value. The coil 29 predominates and the relay 27 is accordingly actuated to its other operative position to open the circuits of the coils 19 that are controlled by it. The switch 10 accordingly opens to insert the corresponding section of resistor in circuit with the generator field-magnet winding.

The coil 29 of relay 27 predominates so long as the generator voltage exceeds the value corresponding to that for which the controller is adjusted. If the generator controlling switches are opened at a relatively rapid rate, the generator voltage is reduced to a value below that of the motor and the latter operates as a generator. If the current traversing the main circuit exceeds the predetermined value at which the relay 22 operates, the latter is actuated to its upper position to close the circuits of the coils 19 and thereby interrupt the operation of the switches to weaken the generator field.

The switches 9, 8 and 7 open in order as the controller is actuated to its successive positions unless the current traversing the main circuit exceeds the predetermined value at which the relay 22 operates. The effect of weakening the generator field and thereby decreasing the generator voltage while the speed of the motor is decreasing tends to maintain the current traversing the main circuit at a maximum value and the speed of the motor is accordingly decreased at a maximum rate.

The operation of the motor in the reverse direction is effected by actuating the controller to the right, as viewed in Fig. 4. Reversing switches 3 and 5 operate to complete the circuit of generator field-magnet winding 1 with the connections of the latter reversed with respect to the terminals of the exciter E. The operation of the several switches and relays differs in no material respect from that described in connection with the operation of the motor in the forward direction.

It will be noted that, in the system illustrated in Figs. 1 and 4, I provide a series of progressively actuated switches for controlling the respective field circuits of an electric generator and an electric motor. Each of the switches is provided with a pair of actuating coils both of which must be energized to effect the closing of the switch and either of which, when energized, retains the switch in its closed position.

One member of each pair of coils is controlled by a manually operable master switch and by the preceding and succeeding switches to operate. The other coils are controlled simultaneously by a relay that is actuated in accordance with the value of the current traversing the main circuit comprising the motor and the generator armatures.

The effect of the operation of this relay is controlled by a second relay having coils which tend to actuate it in opposite directions. One of the coils is energized in accordance with the number of operating coils connected in circuit by the master switch. In the case of the switches for controlling the field circuit of the generator, the second coil is connected across the terminals of the generator. The corresponding relay is accordingly controlled in accordance with the actual generator voltage relatively to the value of the voltage corresponding to the adjustment of the controller.

In the case of the relay which coacts with the switches for controlling the motor field circuit, one of the opposing coils is connected

in series with the coils controlled by the master switch and the other coil is so connected as to be energized in accordance with the current traversing the field circuit of the motor. This relay operates, therefore, in accordance with the actual value of the current traversing the motor field circuit relatively to the value of the current corresponding to the adjustment of the master switch.

Reference may now be had to Fig. 3, in which a modification of my invention is diagrammatically illustrated. Line conductors 51 and 52 supply current to an electric motor, the armature of which is indicated at 53 and which has a shunt field-magnet winding 54. A starting resistor 55 is controlled by a series of progressively actuated switches 56, 57 and 58.

The switches 56, 57 and 58 are respectively provided with actuating coils 59 and 60, both of which must be energized to effect the closing of the switch, but either of which exerts a pull of sufficient strength to maintain the switch in its closed position. The motor circuit is controlled by an electromagnetically operable line switch 61. An interlock 62 connected to the line switch 61 controls the circuits of the coils 60. A relay 63, having a coil 64 in series with the motor armature, controls the circuits of the coils 59. A master switch 65 controls the operation of the several switches.

To start the motor, the controller is actuated to the left, as viewed in Fig. 3. In position *a*, the coil 66 of line switch 61 is energized and the latter closes to complete the armature circuit of the motor through resistor 55. The interlock 62 partially completes the circuits of the respective coils 60. In position *b* of the master switch, the coils 59 and 50 of switch 56 are energized and the switch 56 accordingly closes. The closing of switches 57 and 58 is effected upon the actuation of the master switch 65 to its succeeding positions.

The closing of the switches in the order named is insured by the provision of interlocks connected to the switches 56 and 57 for controlling the circuits of the coils 60 of the succeeding switches to close. The master switch 65 may accordingly be actuated from its illustrated position to its full running position by a rapid movement. The switches then close in order in case the current traversing the motor circuit does not exceed a predetermined value.

In case the current traversing the motor circuit reaches a value at which the coil 64 is energized to operate the relay 63, the several coils 59, which are energized upon the actuation of the master switch 65 to its full running position, are deënergized. If, for example, the switch 56 is closed, the operation of the relay 63 does not effect the opening of switch 56 since the coil 60 exerts a force that is sufficient to retain it in its closed position. The coil 60 of switch 57 is also energized but the switch cannot be closed until the coil 59 is energized. The closing of switch 57 occurs, however, upon the closing of relay 63. All of the coils 59 and 60 are deënergized upon the actuation of the controller to its "off" position and the opening of line switch 61.

The arrangement illustrated in Fig. 3 may be controlled either manually by the adjustment of the master switch 65 to its running position in a step-by-step manner or the operation may occur automatically upon the actuation of the master switch to its full running position. While the operation of the motor is arranged for one direction only, it will be understood that my invention is applicable equally as well to systems in which reversing mechanism is embodied for the purpose of operating the motor in opposite directions.

Referring now to Fig. 5, a second modification of my invention embodies an arrangement which operates automatically to accelerate an electric motor when such action is initiated upon the operation of a manually operable master switch. An electric motor 69 has a series field-magnet winding 70 and a shunt field-magnet winding 71. The armature circuit of the motor is controlled by reversing switches 72, 73, 74 and 75. A starting resistor 76 is controlled by switches 77 and 78, each of which is provided with a pair of operating coils similar in all material respects to the corresponding coils of the systems previously described. The motor circuit is controlled by an electromagnetically operable line switch 79. The control circuit is controlled by a master switch 80 and a low-voltage relay 81 which is closed when the master switch occupies its off position and a control switch 82 is closed.

To start the motor, the master switch 80 may be actuated, for example, in a clockwise direction, as viewed in Fig. 5, for the operation of the motor in the forward direction. A circuit is completed which extends from the positive side of control switch 82, through overload relay 83, low-voltage relay 81, master switch 80, coils of reversing switches 75 and 73, actuating coil of line switch 79, and overload relay 84, to the negative side of the control switch 82. The reversing switches 73 and 75 close to complete the armature circuit of the motor, and line switch 79 closes to connect the motor to the line.

The closing of line switch 79 effects the completion of a circuit which extends from the positive terminal of the control switch 82 through an interlock 85, which is mechanically connected to switch 79, coil 86 of

switch 77, and accelerating relay 87, to the negative terminal of the control switch 82. A second circuit, which is completed by the interlock 85, extends through coils 88 and 89. The switch 77 is closed since both coils 86 and 88 are energized. The closing of switch 77 completes a circuit for a coil 90 of switch 78 and the latter closes to complete a shunt circuit for the resistor 76. The operation of the switches thus occurs automatically upon the actuation of the master switch to the one or the other of its operative positions.

If the current traversing the motor circuit exceeds a predetermined value during the acceleration of the motor, the operation of the controlling switches 77 and 78 is interrupted by the accelerating relay 87, the actuating coil of which is in series with the armature of the motor. The accelerating relay 87 is adjusted to operate when the current traversing the motor circuit corresponds to the normal load value. The closing of switch 78 shunts the actuating coil of the relay 87.

The operation of overload relays 83 and 84, which are adjusted for abnormal current values, effects the opening of the reversing switches, the line switch 79, low-voltage relay 81 and switches 77 and 78. It is then necessary to return the master switch 80 to its "off" position to again initiate the starting operation.

I claim as my invention:

1. In a motor-control system, the combination with a generator and a motor in series circuit relation, each of said dynamo-electric machines having a field-magnet winding, and a resistor in circuit with each of said field-magnet windings, of means for controlling said resistors, said means comprising a plurality of electro-magnetically operable switches each of which is provided with a pair of magnet coils both of which must be energized to close the corresponding switch, and means for insuring the energization of one member of each pair of coils in a definite sequence.

2. In a motor-control system, the combination with a plurality of progressively actuated switches, of a pair of operating coils for each of said switches, both of which must be energized to effect the closing of the corresponding switch, either of said coils being effective to retain said switch in its closed position, means for collectively controlling corresponding coils of each pair and means for selectively controlling other coils of each pair.

3. In a motor-control system, the combination with a plurality of progressively actuated switches, of a pair of operating coils for each of said switches both of which must be energized to effect the closing of the corresponding switch, either of said coils being effective to retain said switch in its closed position, said coils and said switches being so connected as to insure the opening and the closing of said switches in a predetermined sequence, and means for initiating the operation of said switches.

4. In a motor-control system, the combination with a plurality of progressively actuated switches, of a pair of operating coils for each of said switches both of which must be energized to effect the closing of the corresponding switch, either of said coils being effective to retain said switch in its closed position, one member of each pair of coils, except that for the first switch to operate, being controlled by the preceding switch to operate, a controller for the said members of the pairs of coils, and automatic means for controlling the energization of the other coils.

5. In a motor-control system, the combination with a dynamo-electric machine and a plurality of progressively actuated switches operatively associated therewith, of a pair of operating coils for each of said switches, the circuit of one member of each pair of coils being controlled by the preceding switch to operate, manually operable means for controlling said circuits, and means for controlling the circuits of the other coils in accordance with the value of the current traversing the circuit of said dynamo-electric machine.

6. The combination with a plurality of progressively actuated switches, of means for insuring the opening and the closing of said switches in a predetermined order, said means comprising a master switch, an actuating coil for each of said switches in circuit with said master switch, each of said coils except that for the first of said switches to close being controlled by the preceding switch to operate, and each of said coils except that for the last of said switches to close being controlled by the succeeding switch to operate.

7. In a motor-control system, the combination with a dynamo-electric machine and a plurality of progressively actuated switches operatively associated therewith, of a pair of operating coils for each of said switches, the circuit of one member of each pair of coils being controlled by the preceding switch to operate, manually operable means for controlling said circuits, automatic means for controlling the other members of said pairs of coils in accordance with the value of the current traversing said dynamo-electric machine, and means for controlling the effect of the operation of said automatic means.

8. In a motor-control system, the combination with a dyanmo-electric machine and a plurality of progressively actuated switches operatively associated therewith, of

a pair of operating coils for each of said switches, manually operable means for controlling one member of each pair of coils, and a relay for automatically controlling the other coils in accordance with the value of the current traversing said dynamo-electric machine.

9. The combination with an electric circuit and a plurality of progressively actuated switches for controlling the same, of a pair of operating coils for each of said switches, manually operable means for controlling one member of each pair of coils, a relay for automatically controlling the other coils in accordance with the value of the current traversing said circuit, and a second relay for controlling the effect of the operation of the other relay in accordance with the actual circuit conditions produced by said manually operable means relatively to the circuit conditions corresponding to the adjustment of said manually operable means.

10. In a motor-control system, the combination with a dynamo-electric machine and a plurality of progressively actuated switches operatively associated therewith, of a pair of operating coils for each of said switches, manually operable means for controlling one member of each pair of coils, and means for controlling the circuits of the other coils in accordance with the value of the current traversing the circuit of said dynamo-electric machine and in accordance with the actual voltage conditions obtaining in the circuit of said dynamo-electric machine relatively to the voltage conditions corresponding to the adjustment of the manually operated means.

11. In a motor-control system, the combination with an electric circuit and a plurality of progressively actuated switches for controlling the same, of a pair of operating coils for each of said switches, manually operable means for controlling one member of each pair of coils, and means comprising a relay for controlling the other coils, said relay having opposing coils one of which is in series with the coils controlled by the manually operable means and the other of which is energized in accordance with the value of the current traversing said circuit.

12. The combination with an electromagnetic switch having a pair of actuating coils, of a switch in circuit with one of said coils and having an actuating coil in circuit with said other coil.

13. The combination with a dynamo-electric machine and a plurality of switches for controlling said machine and having actuating coils in parallel relation to each other, of a switch for controlling the operation of said switches and having an actuating coil in series with said first-named coils.

14. The combination with a dynamo-electric machine having a resistor associated therewith, of a switch for controlling said resistor and having two actuating coils, a pair of double-throw switches adapted to close the circuit of one of said coils normally and when both of said switches occupy their abnormal positions, an actuating coil for one of said pair of switches responsive to the current of said machine and a pair of opposing actuating coils for the other of said pair of switches respectively responsive to the voltage of said machine and in circuit with the other of said two actuating coils.

15. The combination with a dynamo-electric machine having a resistor associated therewith and a plurality of switches for controlling a portion of said resistor, each having an actuating coil, of a relay for controlling said plurality of switches and having opposing actuating coils that are respectively energized in accordance with the number of switch-actuating coils that are energized and the value of the voltage across a portion of said resistor.

16. The combination with a dynamo-electric machine having a resistor associated therewith, of a switch for controlling a portion of said resistor and having two actuating coils, and a switch for controlling the circuit of one of said coils and having a pair of actuating coils respectively in circuit with the other of said two coils and connected across a portion of said resistor.

17. The combination with a pair of dynamo-electric machines each having a resistor associated therewith, of a switch for controlling each of said resistors and each having a pair of actuating coils, both of which coils must be energized to effect the operation of the corresponding switch, means for closing the circuits of one coil of each of said switches, and means controlled by one of said switches for closing the other coil of said other switch.

18. The combination with a dynamo-electric machine, of a switch for controlling said machine and having opposing actuating coils, means for selectively controlling the energization of one of said coils, said one coil being adapted to overpower the other during the acceleration of said machine, and the other of said coils being energized in accordance with the value of the voltage applied to said machine and adapted to overpower the one coil during the deceleration of said machine.

19. The combination with an electric circuit, of a pair of switches for controlling said circuit, and a switch for controlling said pair of switches and having opposing actuating coils each in circuit with one of said pair of switches.

20. The combination with a pair of dy-

namo-electric machines each having a resistor associated therewith, of a switch for controlling each of said resistors, and interlocking means controlled by each of said switches for insuring their successive operation.

21. The combination with a pair of dynamo-electric machines each having a resistor associated therewith, of a switch for controlling each of said resistors and each having an actuating coil, means controlled by one of said switches for closing the circuit of the coil of said other switch when said one switch occupies an inoperative position, a switch for controlling the flow of current through the resistor which is controlled by said one switch, and means controlled by said controlling switch for closing the circuit of the coil of said one switch.

In testimony whereof, I have hereunto subscribed my name this 29th day of May, 1917.

EDWIN S. LAMMERS, JR.