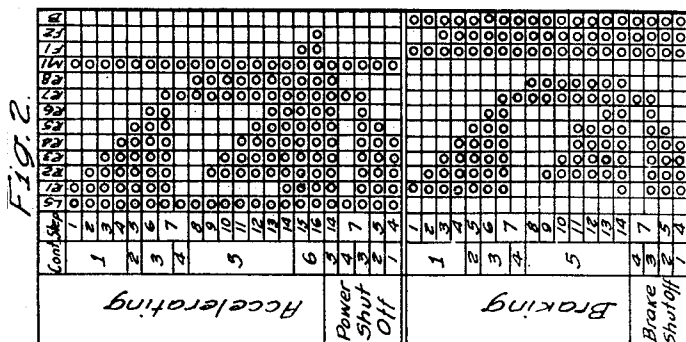
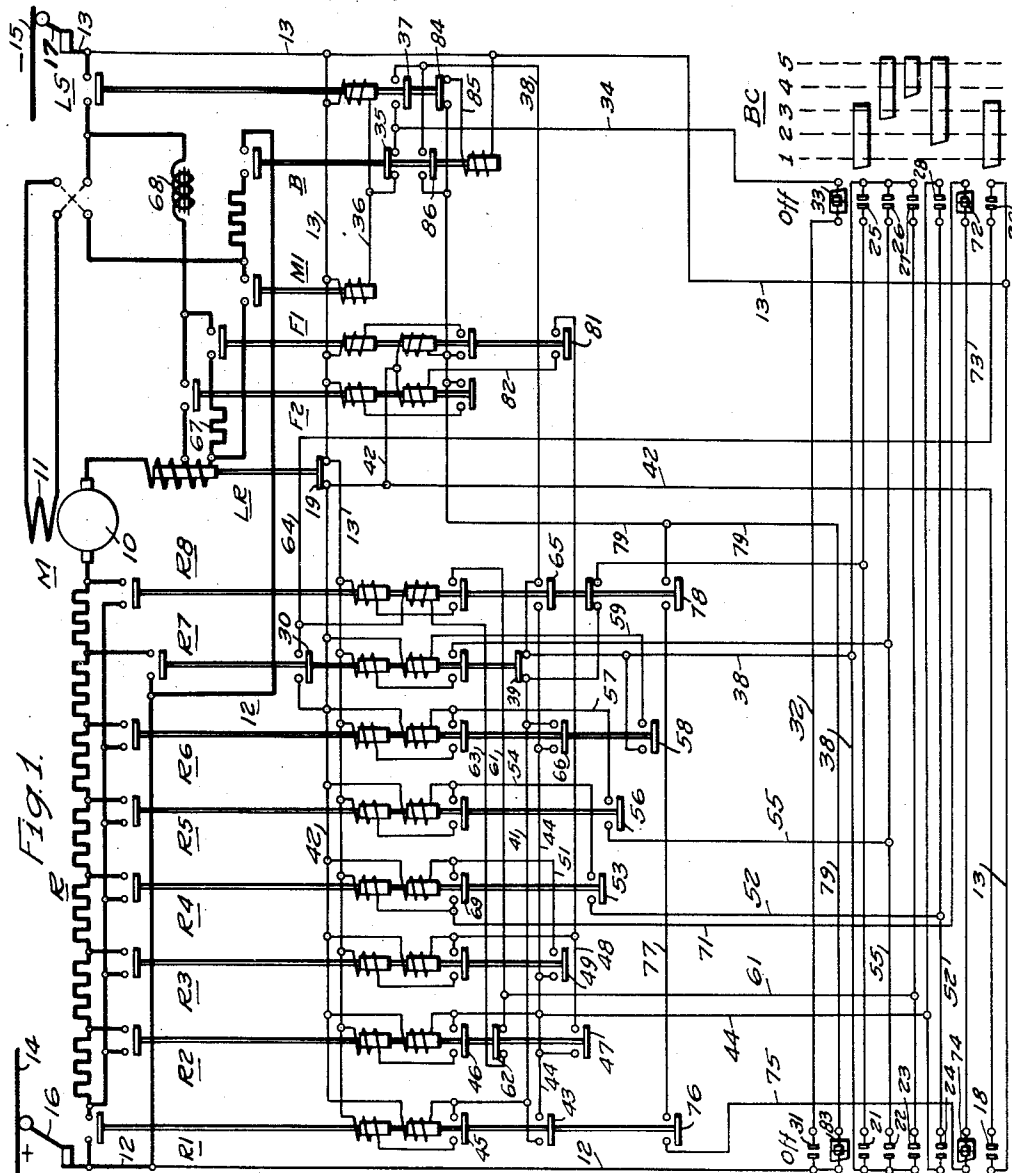


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MOTOR CONTROL SYSTEM

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My invention relates, generally, to motor control systems and, more particularly, to systems for controlling the operation of the propelling motors of electric vehicles, such as trolley cars and coaches.

In order to prevent discomfort to the passengers on electric vehicles it is necessary that the vehicles decelerate smoothly as well as accelerate smoothly. Modern equipment has been devised which provides relatively smooth acceleration of electrically propelled vehicles and one object of my invention is to provide smooth deceleration, both when power is shut off during motoring and when the braking action is discontinued during dynamic braking.

Another object of my invention is to enable an electric vehicle, such as a trolley coach, to be started under severe load conditions without having too much speed once the coach is started.

Other objects of my invention will be explained fully hereinafter or will be apparent to those skilled in the art.

In accordance with my invention, a cushioned shut-off of power is obtained by causing the same devices used during automatic acceleration to function in the reverse order to insert resistance in the motor circuit in steps which will so soften the loss of tractive effort that it will not be uncomfortable to the passengers. Likewise, a cushioned shut-off of the electric brake is obtained in a manner similar to the power shut-off. The first few steps of acceleration may be taken independently of the current limit relay and without actuating the controller to its last position, thereby obtaining sufficient power to start the vehicle under heavy loads without having too much speed after it is started.

For a fuller understanding of the nature and objects of my invention, reference may be had to the following detailed description, taken in conjunction with the accompanying drawing, in which:

Figure 1 is a diagrammatic view of a control system embodying my invention, and

Fig. 2 is a chart showing the sequence of operation of the control switches shown in Fig. 1.

Referring to the drawing, the system shown therein comprises a motor M having an armature winding 10 and a series field winding 11, switches LS, M1 and R1 for connecting the motor across power conductors 12 and 13 which are energized from trolley conductors 14 and 15 through current collectors 16 and 17, respectively, and additional switches B and F1 for establishing dynamic braking connections for the motor. The switch

F1 is also utilized for shunting the field winding 11 of the motor during a portion of the accelerating period and an additional switch F2 is also provided for field shunting purposes. The motor M is of a series type suitable for propelling a trolley bus or other electric vehicle (not shown).

In order to control the motor current during the accelerating and dynamic braking periods of operation, a resistor R is connected in the motor circuit. A plurality of resistor shunting switches R2, R3, R4, R5, R6, R7 and R8 are provided for shunting the resistor R from the motor circuit step-by-step during both acceleration and dynamic braking. The switch R1 is also utilized for resistor shunting purposes.

As shown in the drawing, the switches R1 to R8, inclusive, F1 and F2 are each provided with a closing coil for actuating the switch to the closed position and a holding coil for retaining the switch in the closed position after it has been closed by the closing coil. The sequence of operation of the resistor shunting switches is controlled by interlock progression in a manner well known in the art.

Under normal operating conditions the operation of the resistor shunting switches is automatically controlled by a current limit relay LR which is responsive to the motor current. In order to permit the vehicle to be started under severe load conditions, contact members 18 are provided on an accelerating controller AC and connected in parallel-circuit relation to contact members 19 on the limit relay LR. The contact members 18 are closed during the first three operating positions of the controller AC, thereby permitting the switches R1 to R7, inclusive, as indicated by the sequence chart in Fig. 2, to be closed independently of the operation of the limit relay LR. In this manner a sufficient amount of resistance may be shunted from the motor circuit to permit it to start a heavy load without having too much speed once the vehicle is started, as was the case in former control systems of the present type.

A braking controller BC is provided for controlling the dynamic braking operation. As indicated in the chart in Fig. 2, the resistor shunting switches are operated in the same sequence during dynamic braking as during acceleration. The operation of the resistor shunting switches during dynamic braking is normally under the control of the limit relay LR.

In order to provide for a cushioned shut-off of power during acceleration of the vehicle and also for a cushioned shut-off of the electric brake

during dynamic braking, thereby avoiding discomfort to the passengers of the vehicle by the sudden loss of tractive effort or of the braking effect, the controller AC is provided with contact members 21 to 24 connected in parallel-circuit relation to contact members 25 to 28, respectively, on the controller BC which cooperate with the interlocks on the resistor shunting switches to cause these switches to be operated in a sequence during power and brake shut-offs which is the reverse of the sequence of operation of the switches during accelerating and braking, as will be described more fully hereinafter. With a view to permitting the reclosing of certain of the resistor shunting switches to secure the reverse sequence of operation, the controller BC is provided with contact members 29 which are closed during the first three operating positions of the controller to parallel the contact members 19 of the relay LR through an interlock 30 on the switch R7. Thus, if the controller BC is returned to one of its first three positions during dynamic braking, the proper sequence of operation of the switches for gradually inserting resistances into the motor circuit to secure an easy shut-off of the braking effect is obtained independently of the operation of the limit relay LR.

In order that the functioning of the foregoing apparatus may be more clearly understood, the operation of the system will now be described in more detail. If it is desired to accelerate the vehicle in a normal manner under the control of the limit relay, the accelerating controller AC may be immediately actuated to its last operating position, thereby causing the switches LS, R1 and M1 to be closed to connect the motor across the power conductors and the switches R2 to R3, inclusive, to be closed in the sequence indicated in the sequence chart to shunt the resistor R from the motor circuit. As explained hereinbefore, the sequence of operation of the switches is controlled by interlocks provided on the switches and the switches are normally closed in a step-by-step manner under the control of the limit relay, thereby limiting the current supplied to the motor. Thus, it is impossible for the next step in the progression to be taken until the motor current is reduced to a value permitting the limit relay to close its contact members to complete the energizing circuit for the next switch in the progression. The foregoing automatic control of the operation of a plurality of resistor shunting switches is well known in the art and it is believed to be unnecessary to describe it in detail in the present specification.

If it is desired to increase the motor current beyond the amount normally permitted by the limit relay LR, thereby increasing the power delivered by the motor to enable it to start the vehicle under a heavy load, the controller AC may be actuated to any one of the first three positions depending upon the amount of current it is desired to supply the motor. In this manner a predetermined number of resistor shunting switches may be closed independently of the operation of the limit relay LR without increasing the vehicle speed an undesirable amount after the vehicle is once started. When the vehicle is started, the controller may then be actuated to the desired operating position, thereby permitting the progression of the switches to continue in the normal manner under the control of the limit relay.

Assuming that the controller AC is actuated to position three, the switches LS, R1 and M1 are

closed to connect the motor across the power conductors 12 and 13 in series-circuit relation with the resistor R and the switches R2 to R7, inclusive, are then closed by interlock progression to shunt portions of the resistor R from the motor circuit step-by-step independently of the operation of the relay LR. The energizing circuit for the switch LS may be traced from the positive conductor 12 through contact members 31 on the controller AC, conductor 32, contact members 33 on the controller BC, conductor 34, an interlock 35 on the switch B, conductor 36 and the actuating coil of the switch LS to the negative conductor 13. The energizing circuit for the switch M1 extends from the conductor 36 through the actuating coil of the switch M1 to the negative conductor 13. Following the closing of the switch LS the energizing circuit for the switch R1 is established from the conductor 34 through an interlock 37 on the switch LS, conductor 38, an interlock 39 on the switch R7, conductor 41, the closing coil of the switch R1, conductor 42 and the contact members 18 of the controller AC to the negative conductor 13.

Upon the closing of the switch R1, an energizing circuit for the switch R2 is established from the conductor 41 through an interlock 43 on the switch R1, conductor 44, the closing coil of the switch R2, conductor 42 and the contact members 18 of the controller AC to the negative conductor 13.

It will be noted that the holding coil for each one of the resistor shunting switches is energized upon the closing of the switch. Thus, the holding coil for the switch R1 is energized through an interlock 45 carried by the switch R1 and the holding coil for the switch R2 is energized through an interlock 46 carried by the switch R2. Likewise, the holding coils for the remaining resistor shunting switches and the field shunting switches F1 and F2 are energized through interlocks carried by the respective switches.

Following the closing of the switch R2, the closing coil of switch R3 is energized through a circuit which extends from the conductor 44 through an interlock 47 on the switch R2, conductor 48, the closing coil of the switch R3, conductor 42 and the contact members 18 of the controller AC to the negative conductor 13. The energizing circuit for the switch R4 is then established from conductor 44 through an interlock 49 on the switch R3, conductor 51, the closing coil of the switch R4, conductor 42 and the contact members 18 of the controller AC to the negative conductor 13.

Since it has been assumed that the controller AC is on position three, an energizing circuit for the switch R5 is next established from conductor 44 through contact members 24 of the controller AC, conductor 52, an interlock 53 on the switch R4, conductor 54, the closing coil of the switch R5, conductor 42 and the contact members 18 of the controller AC to the negative conductor 13.

Likewise, an energizing circuit for the switch R6 is established upon the closing of the switch R5. This circuit may be traced from the conductor 38, through contact member 22 of the controller AC, conductor 55, an interlock 56 on the switch R5, conductor 57, the closing coil of the switch R6, conductor 42 and the contact members 18 of the controller AC to the negative conductor 13. Following the closing of the switch R6, the closing coil of the switch R7 is energized

through a circuit which extends from the conductor 38, through an interlock 58 on the switch R8, conductor 59, the closing coil of the switch R7, conductor 42 and the contact member 18 of the controller AC to the negative conductor 13.

Since it has been assumed that the controller AC is on position three the progression of the resistor shunting switches is stopped at this time. As explained hereinbefore, the controller AC may be actuated to any one of the remaining positions four, five or six, depending upon the accelerating rate desired, after the vehicle is started. The progression of operation of the remaining resistor shunting switches is now placed under the control of the limit relay, which functions in the normal manner to limit the current supplied to the motor as the vehicle accelerates.

Assuming that the controller AC is actuated to position six, the switches R1 to R6 are opened, as indicated in the sequence chart in Fig. 2, and the switch R8 is then closed to connect two portions of the resistor R in the motor circuit in parallel-circuit relation. The energizing circuit for the closing coil of the switch R8 may be traced from conductor 38 through contact members 23 of the controller AC, conductor 61, an interlock 62 on the switch R2, conductor 63, the closing coil of the switch R8, conductor 64, the interlock 30 on the switch R7, conductor 42, and the contact members 19 of the relay LR to the negative conductor 13.

Following the closing of the switch R8, the switches R2 to R6, inclusive, are reclosed as indicated in the sequence chart. The energizing circuit for the closing coil of the switch R2 extends from the conductor 38 through an interlock 65 on the switch R8, conductor 44, the closing coil of the switch R2, conductor 42 and the contact members 19 of the relay LR to the negative conductor 13. The closing coils of the switches R3, R4, R5 and R6 are energized by interlock progression through circuits previously traced.

Following the closing of the switch R6, the switch R1 is reclosed to complete the shunting of the resistor R from the motor circuit. The energizing circuit for the closing coil of the switch R1 extends from the conductor 38 through the interlock 65 on the switch R8, conductor 44, an interlock 66 on the switch R6, conductor 41, the closing coil of the switch R1, conductor 42 and the contact members 19 of the relay LR to the negative conductor 13.

Upon the closing of the switch R1, the field shunting switch F1 is closed to shunt the field winding 11 of the motor M through a resistor 67 and a reactor 68. The energizing circuit for the switch F1 may be traced from the conductor 51 through an interlock 69 on the switch R4, which is closed at this time, conductor 71, contact members 72 on the controller BC, conductor 73, contact members 74 on the controller AC, conductor 75, an interlock 76 on the switch R1, conductor 77, an interlock 78 on the switch R8, conductor 79, the closing coil of the switch F1, conductor 42, and the contact member 19 of the relay LR to the negative conductor 13.

Following the closing of the switch F1, the switch F2 is closed to short the resistor 67 from the field shunting circuit, thereby shunting the field winding 11 through only the reactor 68 which causes the motor to operate at its maximum speed in a manner well known in the art.

The energizing circuit for the closing coil of the switch F2 extends from the conductor 48

through an interlock 81 on the switch F1, conductor 82, the closing coil of the switch F2, conductor 42 and the contact members of the relay LR to the negative conductor 13. The closing of the switch F2 completes the accelerating cycle for the motor.

If it is desired to remove power gradually from the motor during the accelerating period in order to avoid discomfort to the passengers of the vehicle, the controller AC may be gradually returned towards the "off" position. If the controller is returned toward the "off" position the contact members on the controller and the interlocking members on the resistor shunting switches cause the switches to be operated in the reverse sequence from that taking place during acceleration of the motor. The reverse operation of the switches causes the resistor R to be gradually inserted in the motor circuit to decrease the motor current. If the controller is stopped on any intermediate position, the sequence of operation of the switches is stopped accordingly, as indicated in the sequence chart in Fig. 2. Thus if the controller is stopped on position three, the parallel connection for the resistor is removed and a portion of the resistor is connected in the motor circuit in series-circuit relation. By returning the controller to position two, the switches R6 and R7 are opened to insert more of the resistor in the motor circuit. When the controller is returned to position one, the switch R5 is opened to insert still more resistance in the motor circuit. If it is desired to disconnect the motor from the power circuit completely, the controller AC may be actuated to the "off" position.

If it is desired to decelerate the vehicle by dynamic braking, it is necessary to return the accelerating controller to the "off" position which causes the closing of the switches B, F1 and R1 to establish a dynamic braking circuit for the motor. The energizing circuit for the switch B may be traced from the positive conductor 12 through contact members 83 on the controller AC, conductor 79, an interlock 84 on the switch LS, which is in the open position at this time, conductor 85 and the actuating coil of switch B to the negative conductor 13. The energizing circuit for the switch F1 extends from the conductor 79 through the closing coil of the switch F1, conductor 42 and the contact members 19 of the relay LR to the negative conductor 13. Following the closing of the switch B, the closing coil of the switch R1 is energized through a circuit which extends from the conductor 79 through an interlock 86 on the switch B, conductor 38, the interlock 39 on the switch R7, conductor 41, the closing coil of switch R1, conductor 42 and the contact members 19 of the relay LR to the negative conductor 13.

By actuating the braking controller BC to any one of the braking positions, depending upon the braking rate desired, the resistor shunting switches may be closed under the control of the limit relay LR in accordance with the position to which the controller is actuated, as indicated in the sequence chart in Fig. 2. If the controller is actuated to position five to obtain the maximum braking rate the switches run through their complete sequence of operation in the same order and in the same manner as described hereinbefore for the acceleration of the vehicle. The operation of the switches is under the control of the limit relay, thereby limiting the braking current permitted to circulate through the motor.

With a view to preventing the discomfort to the passengers which would result from a sudden removal of the braking effect should the dynamic braking connection suddenly be removed, provision is made for causing the resistor shunting switches to be operated in reverse sequence during the brake shut-off in a manner similar to that previously described for a power shut-off. In this manner the resistor R is gradually inserted in the braking circuit to gradually decrease the braking current and hence the braking effect.

As explained hereinbefore, the contact members 25, 26, 27 and 28 on the braking controller BC are connected in parallel-circuit relation to the contact members 21, 22, 23 and 24, respectively, of the controller AC, which contact members function in cooperation with the interlocks on the resistor shunting switches to cause the reverse sequence of operation of the switches if the braking controller is returned toward the "off" position. Since it is necessary for certain of the switches to be reclosed in order to maintain the proper sequence of operation during the braking shut-off and there is a possibility that the limit relay LR would operate to prevent the reclosal of these switches at the desired time, the contact members 29 on the braking controller bypass the contact members 19 of the limit relay LR as explained hereinbefore to permit the reclosing of these switches independently of the operation of the relay. In this manner smooth deceleration of the vehicle at all times is assured.

From the foregoing description, it is apparent that I have devised an automatic control system which provides for manual control of the first few steps of power independently of the current limit relay which normally controls the automatic operation of the system, thereby permitting sufficient power to be applied to the motor of a vehicle to start it under heavy load conditions without so interfering with the normal operation of the system that an excessive amount of speed is obtained once the vehicle is started. Furthermore, the present system provides for a cushioned shut-off of power and electric brake by making the same devices used with automatic acceleration function in the reverse order to insert resistance in the motor circuit in steps during both the power and brake shut-offs to soften the loss of tractive effort or the loss of braking effect, thereby assuring both smooth acceleration and deceleration of the vehicle.

Since many modifications may be made in the apparatus and arrangement of parts without departing from the spirit of my invention, I do not wish to be limited other than by the scope of the appended claims.

I claim as my invention:

1. In a motor control system, in combination, a motor, switching means for connecting the motor to a source of power, a controller for controlling the operation of said switching means, a resistor for controlling the motor current, a plurality of switches for shunting said resistor step-by-step, a relay responsive to the motor current for controlling the operation of said switches, and means on said controller for causing the operation of a predetermined number of said switches independently of said relay.

2. In a motor control system, in combination, a motor, switching means for connecting the motor to a power source, a controller for controlling the operation of said switching means, a resistor for controlling the motor current, a plurality of switches for shunting said resistor

step-by-step, a relay responsive to the motor current for controlling the operation of said switches, and means actuated by said controller for causing the operation of a predetermined number of said switches independently of said relay.

3. In a motor control system, in combination, a motor, a power conductor, switching means for connecting the motor to the power conductor, a controller for controlling the operation of said switching means, a resistor for controlling the motor current, a plurality of switches for shunting said resistor step-by-step, a relay responsive to the motor current for controlling the operation of said switches, and means actuated by said controller for causing the operation of a predetermined number of said switches independently of said relay, and interlocking means on said switches for determining their sequence of operation.

4. In a motor control system, in combination, a motor, switching means for connecting the motor to a power source, a controller for controlling the operation of said switching means, control means for controlling the motor current, a relay responsive to the motor current for normally controlling the operation of said control means, and means actuated by said controller for controlling the operation of said control means independently of said relay.

5. In a motor control system, in combination, a motor, a power conductor, switching means for connecting the motor to the power conductor, a controller for controlling the operation of said switching means, control means for controlling the motor current, a relay responsive to the motor current for normally controlling the operation of said control means, and means on said controller for operating said control means independently of said relay under abnormal conditions.

6. In a motor control system, in combination, a motor, a power conductor, switching means for connecting the motor to the power conductor, an accelerating controller for controlling the operation of said switching means, additional switching means for establishing dynamic braking connections for the motor, a braking controller for controlling the operation of said additional switching means, a resistor for controlling the motor current during acceleration and dynamic braking, a plurality of switches for shunting said resistor step-by-step, interlocking means on said switches, contact members on said controllers cooperating with said interlocking means to operate said switches in a predetermined sequence during acceleration and dynamic braking and in the reverse sequence during power and brake shut-offs, a relay responsive to the motor current for normally controlling the operation of said switches, and means actuated by said controllers for controlling the operation of said switches independently of said relay.

7. In a motor control system, in combination, a motor, a power conductor, switching means for connecting the motor to the power conductor, an accelerating controller for controlling the operation of said switching means, additional switching means for establishing dynamic braking connections for the motor, a braking controller for controlling the operation of said additional switching means, a resistor for controlling the motor current during acceleration and dynamic braking, a plurality of switches for shunting said resistor step-by-step, interlocking

means on said switches, contact members on said controllers cooperating with said interlocking means to operate said switches in the same sequence during acceleration and dynamic braking and in the reverse sequence to shut off power from the motor and to release dynamic braking, a relay responsive to the motor current for normally controlling the operation of said switches, and means actuated by said controllers for controlling the operation of said switches independently of said relay.

8. In a motor control system, in combination, a motor, a power conductor, switching means for connecting the motor to the power conductor, an accelerating controller for controlling the operation of said switching means, additional switching means for establishing dynamic braking connections for the motor, a braking controller for controlling the operation of said additional switching means, a resistor for controlling the motor current during acceleration and dynamic braking, a plurality of switches for shunting said resistor step-by-step, interlocking means on said switches, contact members on said controllers cooperating with said interlocking means to operate said switches in a predetermined sequence during acceleration and dynamic braking and in the reverse sequence during power and brake shut-offs, said contact members being connected in parallel-circuit relation, a relay responsive to the motor current for normally controlling the operation of said switches, and means actuated by said braking controller for controlling the operation of said switches independently of said relay during the release of dynamic braking.

9. In a motor control system, in combination, a motor, a power conductor, switching means for connecting the motor to the power conductor, an accelerating controller for controlling the op-

eration of said switching means, additional switching means for establishing dynamic braking connections for the motor, a braking controller for controlling the operation of said additional switching means, a resistor for controlling the motor current during acceleration and dynamic braking, a plurality of switches for shunting said resistor step-by-step, interlocking means on said switches, contact members on said controllers cooperating with said interlocking means to operate said switches in the same sequence during acceleration and dynamic braking and in the reverse sequence to shut off power from the motor and to release dynamic braking, said contact members being connected in parallel-circuit relation, a relay responsive to the motor current for normally controlling the operation of said switches, and means actuated by said braking controller for controlling the operation of said switches independently of said relay during the release of dynamic braking.

10. In a motor control system, in combination, a motor, switching means for establishing dynamic braking connections for the motor, a controller for controlling the operation of said switching means, a resistor for controlling the motor current during dynamic braking, a plurality of switches for shunting said resistor step-by-step, interlocking means on said switches cooperating with said controller to operate said switches in a predetermined sequence to brake the motor dynamically and in the reverse sequence to release dynamic braking, a relay responsive to the motor current for controlling the operation of said switches during dynamic braking of the motor, and means on said controller for controlling the operation of said switches independently of said relay during the release of dynamic braking.

BASCUM O. AUSTIN.