DYNAMIC BRAKING CONTROL

Filed June 20, 1950

Fig. 1.

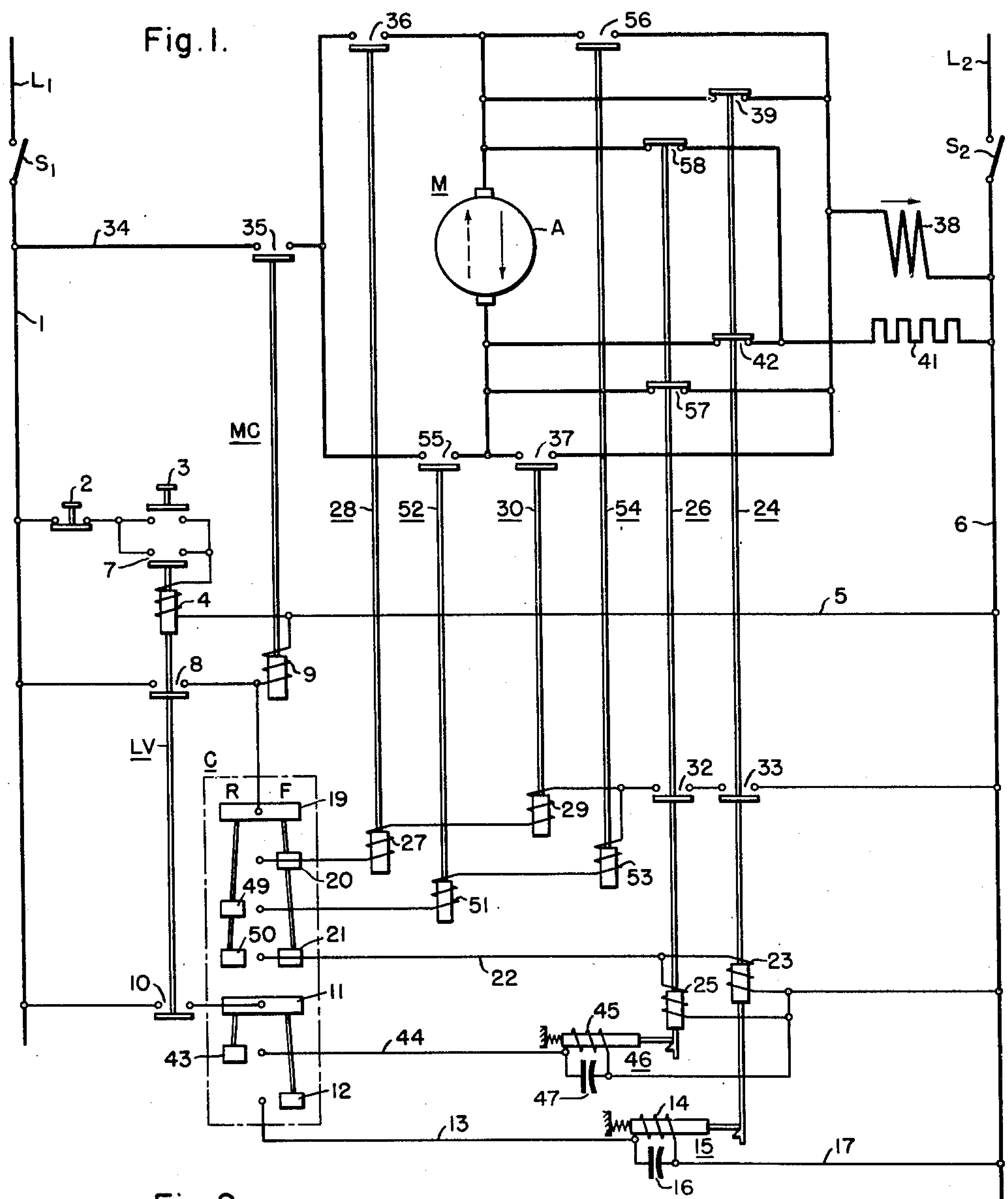


Fig. 2.

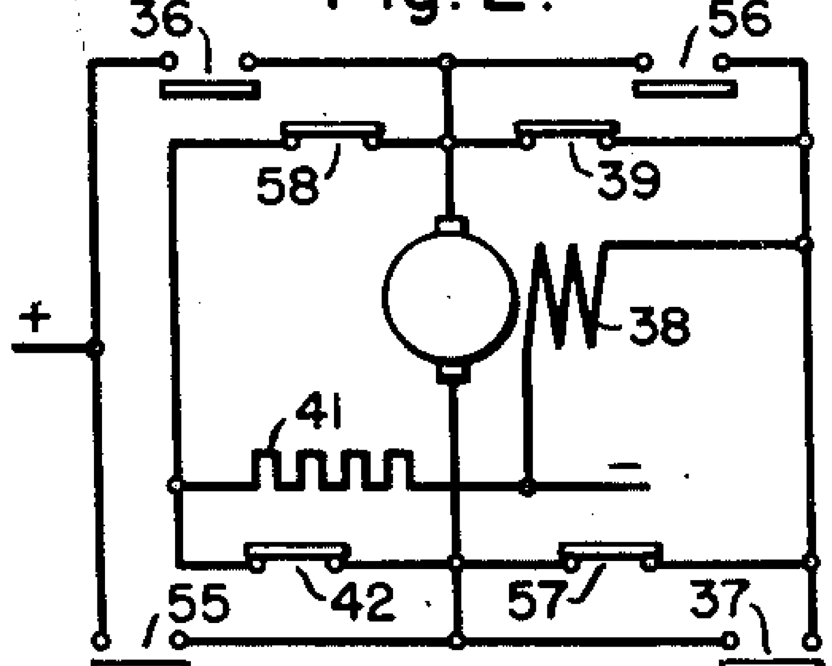
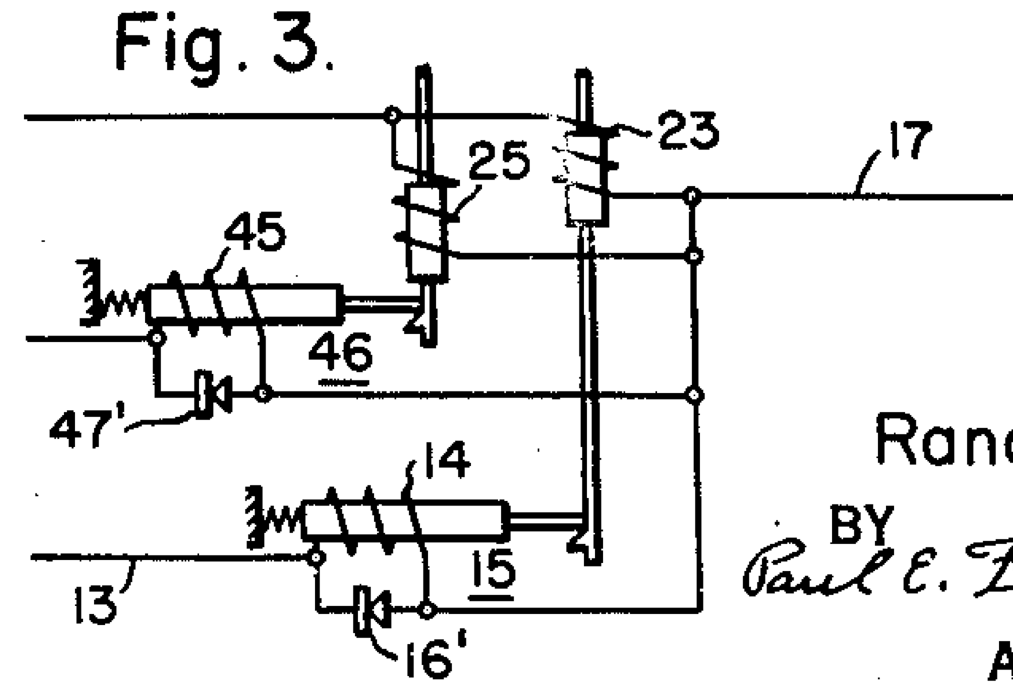


Fig. 3.



INVENTOR
Randal P. Barnes.
BY Paul E. Friedemann
ATTORNEY

Patented Feb. 24, 1953

2,629,849

UNITED STATES PATENT OFFICE

2,629,849

DYNAMIC BRAKING CONTROL

Randal P. Barnes, San Francisco, Calif., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Application June 20, 1950, Serial No. 169,276

16 Claims. (Cl. 318—246)

1

My invention relates to motor braking circuits and more particularly to dynamic braking controls for series wound motors.

In the iron and steel industry the specifications covering steel mill cranes require dynamic braking on the bridge drive motor for all bridge speeds in excess of three hundred feet a minute.

One broad object of my invention is the provision of effective dynamic braking of a series wound motor.

A more specific object of my invention is the provision of effective series field excitation of a series motor during dynamic braking.

A still more specific object of my invention is the provision of series field excitation that does not change in directional sense during dynamic braking of a series wound reversible motor regardless of the direction of operation of the motor just prior to initiation of the dynamic braking.

Other objects and advantages of my invention will become more apparent from a study of the following specification and the accompanying drawing, in which:

Figure 1 is a diagrammatic showing of my invention as applied to a series wound motor;

Fig. 2 is a simplified showing of the bridge circuits and dynamic braking circuits shown in Fig. 1, and

Fig. 3 shows the circuit arrangement of a modified detail of my invention.

While my invention has general utility it nevertheless is especially useful in the operation of high-speed heavy bridges used in steel mills. The motor M is a series wound motor of generally conventional design normally coupled to drive a crane bridge, not shown.

In the showing in Fig. 1, the series field 38 is, for clarity of presentation, not shown adjacent the motor armature. Further, the motor in actual practice will be provided with a starting resistor system controlled from the controller C. The starting resistors, and a number of other items part of a control system as used, have not been shown because these items and the starting resistors do not constitute part of my invention.

The main controller C is of well known type and by suitable operation of the controller to either the forward position F or the reverse position R, the directional contactors 28 and 30, or 52 and 54, are caused to operate.

By operation of the controller C from one of its operating positions to the off position, the directional contactors that were picked up are caused to drop out and the operation of the dynamic braking contactors 24 and 26 is so effected that the direction of the excitation of the series field 38 remains the same.

2

A better understanding of my invention can probably be had from a study of typical operating cycles.

In operation the leads L_1 and L_2 are energized and the switches S_1 and S_2 are closed to energize the buses 1 and 6. If the attendant wishes to effect operation of the motor M, he actuates the start switch 3 to closed position, whereupon a circuit is established from the positive bus 1 through the stop switch 2, the start switch 3, the actuating coil 4 of the low voltage protective relay LV, and conductor 5 to the negative bus 6.

Operation of the relay LV effects the closing of contacts 7, 8 and 10. The closure of contacts 7 establishes a holding circuit for the protective relay LV, which holding circuit may be traced from the positive bus 1 through stop switch 2, contacts 7 and coil 4 to the negatively energized conductor 5. The closure of contacts 8 establishes a circuit from bus 1 through actuating coil 9 of the main contactor MC to the energized conductor 5. The main contactor thus operates to close contacts 35.

The closure of contacts 8 also effects the energization of controller segments 19, 20, 21, 49 and 50, of controller C for a purpose that will become apparent hereinafter. The closure of contacts 10 effects the energization of controller segments 11, 12, and 43, for a purpose that will become apparent as the description proceeds.

As long as the controller remains in the off position nothing further takes place. By moving the controller to the F, of forward, position, for example, several energizing circuits are established. One circuit may be traced from bus 1 through contacts 10 of the relay LV, through controller segments 11 and 12, conductor 13, actuating coil 14 of the latch 15, and also the capacitor 16 connected in parallel to coil 14, and the conductor 17 to the bus 6. The latch stem of the latch 15 thus moves to the left and upon deenergization of coil 14 remains in the left-hand position for a time period determined by the time of discharge of the capacitor 16 through coil 14.

A second circuit is established from bus 1 through contacts 8, controller segments 19, 20 and 21, conductor 22, actuating coils 23 and 25, connected in parallel, of the dynamic braking contactors 24 and 26, to the bus 6.

It is important that the dynamic braking contacts 24 and 26 operate before the directional contactors are operated, otherwise the operation of the directional contactors would effect a "dead short" across the motor armature at contacts 58 and 42, and 39 and 57. By placing the contacts 32 and 33 in series with the actuating coils 27 and 29, and 51 and 53, the directional contactors can not be energized until after the dynamic braking contactors have picked up.

Thus the closure of contacts 32 and 33 establishes a third circuit through the controller C. This third circuit may be traced from energized segment 20, through the actuating coil 27 of forward directional contactor 28, the actuating coil 29 of forward directional contactor 30, contacts 32 and 33 to the negative bus 6.

The operation of the forward directional contactors 28 and 30 effects the closing of contacts 36 and 37, to establish an energizing circuit for the motor M. The motor energizing circuit may be traced from bus 1 through conductor 34, contacts 35 and 36, the motor armature A, contacts 37, and the series field winding 38 to the bus 6. The current through the armature A and the series field winding 38 is in the direction indicated by the full-line arrows shown associated with the armature and series field, respectively. The motor will thus operate in the forward direction.

In case of the movement of the controller C to the off position, or in the event of a voltage failure, the terminal voltage of the motor will be as indicated by the broken-line arrow associated with the motor armature. In the event of a voltage failure, or in case the attendant operates the controller to the off position to stop the motor, the energizing circuits, from the supply buses, to the coils 14, 23, 25, 27 and 29, are interrupted. The contacts 36 and 37, immediately open and the contacts 39 and 42 immediately close, but the contacts 57 and 58 remain open.

This is effected for the following reasons: The energization of coil 14 is also accompanied by the energization of the capacitor 16. When the energization of coil 23 ceases, the dynamic braking contactor 24 drops out immediately because the capacitor 16 discharging through coil 14 keeps the latch actuated by coil 14 out of the path of the dog on the armature of the contactor 24, but since neither the coil 45 nor the capacitor 47 is energized, the latch 46, normally actuated by coil 45, remains in the position under the dog on the armature of the contactor 26 after this contactor is operated, as above pointed out, to open the contacts 57 and 58.

This drop-out of the dynamic braking contactor 24 and the failure of the drop-out of the dynamic braking contactor 26 establishes a dynamic braking circuit for the motor M. This dynamic braking circuit may be traced from the upper motor armature terminal through contacts 39, the series field 38, bus 6, dynamic braking resistor 41, contact 42, and the motor armature back to the upper armature terminal. It will be noted that the excitation of the series field 38 remains in the same direction, hence the dynamic braking current generated by the motor maintains the excitation of the series field for very effective dynamic braking of the motor.

For reverse operation, the controller C is moved to the R position. This operation of the controller C establishes several energizing circuits. One circuit may be traced from bus 1 through contacts 10 of the relay LV, through controller segments 11 and 43, through conductor 44, actuating coil 45 of the latch 46, and also the capacitor 47 connected in parallel to coil 45, to the bus 6. The stem of the latch 46 thus moves to the left and upon deenergization of the coil 45 remains in the left-hand position for a time period determined by the time of discharge of the capacitor 47 through coil 45.

A second circuit is established from bus 1 through contacts 8, controller segments 19, 49 and 50, conductor 22, actuating coils 23 and 25, connected in parallel, of the dynamic braking contactors 24 and 26, to bus 6. Again the dynamic braking contactors operate ahead of the directional contactors, to close the contacts 32 and 33.

The closure of contacts 32 and 33 establishes a third circuit through the controller C. This third circuit may be traced from the energized segment 49, through the actuating coil 51 of reverse directional contactor 52, the actuating coil 53 of the reverse directional contactor 54 and the contacts 32 and 33 to the bus 6.

The operation of the reverse directional contactors effects the closing of contacts 55 and 56, to establish an energizing circuit for the motor M. The motor energizing circuit may be traced from bus 1 through conductor 34, contacts 35, contacts 55, the motor armature A, in the direction indicated by the broken-line arrow, contacts 56, the series field 38 in the direction indicated by the adjacent full-line arrow, to the bus 6. The motor thus operates in the reverse direction.

In the event of a voltage failure, or in case the attendant operates the controller C to the off position to stop the motor, the energizing circuits from the supply buses to the coils 45, 23, 25, 51 and 53 are interrupted. The contacts 55 and 56 immediately open and the contacts 57 and 58 immediately close, but the contacts 39 and 42 remain open.

This is effected for the following reasons: The energization of coil 45 is also accompanied by the energization of capacitor 47. When the circuit for coil 45 is interrupted from the supply, the coil 45 remains energized from the discharge current of the capacitor 47 and in consequence the latch 46 is held out of the path of the armature of contactor 26 and this contactor drops out to close contacts 57 and 58, but coil 14 for the latch 15 was not energized. The latch 15 thus holds the contactor 24 in the pick-up position to hold contacts 39 and 42 open.

This drop-out of the dynamic braking contactor 26 and the failure of the drop-out of dynamic braking contactor 24 establishes a dynamic braking circuit for the motor. This circuit may be traced from the lower motor armature terminal through contacts 57, the series field 38, bus 6, dynamic braking resistor 41, contacts 58, and the motor armature back to the lower armature terminal. It will be noted that again the excitation of the series field 38 remains in the same direction, to effectively brake the motor.

To simplify the showing and thus facilitate the understanding of my invention, I have shown in Fig. 2 how the motor armature A is connected to the diagonal junctions of a first bridge circuit including the switch contacts 36, 56, 37 and 55 in the legs of the bridge and how the motor armature A is connected to the diagonal junctions of a second bridge circuit including the switch contacts 58, 39, 42 and 57 in the legs of the second bridge. The showing in Fig. 2 also illustrates in an effective manner how the dynamic braking circuits may be connected to the motor armature to excite the field 38 always in the same sense.

While the use of latch coils as 14 and 45 with coacting capacitors 16 and 47 provides an effective control for the dynamic braking contactors, my invention is not limited to this apparatus for controlling the dynamic braking contactor.

In Fig. 3, I show the details of a modified control for the dynamic braking contactors. In this showing it will be noted that the capacitor 16 is replaced by a rectifier 16′. The best type of rectifier to be used is one of the dry metallic type as a copper oxide rectifier.

In place of the capacitor 47, a rectifier 47′ is used. Since the coils 14 and 45 when deenergized, will tend to maintain the current flowing, it is apparent that the coils will discharge respectively through the rectifiers 16′ and 47′. The discharge time will suffice to keep the latches 15 and 46, depending on which one is being used, out of the paths of the armatures of the dynamic braking contactors 24 and 26, to effect the desired operation.

While I have shown but one embodiment of my invention and one modification of a detail, it is apparent that other modifications are possible all within the spirit of my invention. The scope of my claim to invention includes such other modifications.

I claim as my invention:

1. In a system of control for a series wound motor, in combination, a motor having armature windings and series field windings, means for establishing power connections for the motor so that the armature windings are energized in a given sense and the series field windings are energized for a given direction of flux, a dynamic braking circuit including the motor armature, the series field windings, a dynamic braking resistor, and switching means, control means for interrupting the power connections, and means, responsive to the operation of the control means, to interrupt the power connections, for controlling said swtiching means to connect said dynamic braking circuit to the motor armature windings so that the counterelectromotive force of the motor excites the series field winding for said given direction of flux.

2. In a system of control for a series wound motor, in combination, a direct current series wound motor having an armature and a series field, a dynamic braking circuit including the armature, series field, and a dynamic braking resistor, supply terminals energized with direct current potential, two electromagnetically operable directional contactors each having switch contacts for connecting one armature terminal to one supply terminal and the other armature terminal through said series field to the other supply terminal, two dynamic braking contactors each having switch contacts disposed in similar relation to the motor armature than the disposition of the contacts of the directional contactors, controller means adapted upon operation from a given position to one of its operating positions to sequentially connect both the dynamic braking contactors and then the directional contactors to said terminals, whereby contacts of the dynamic braking contactors are opened and the motor armature and series field are connected to said terminals to cause a current flow through the armature and series field in a given direction, said controller means upon operation back to said given position adapted to cause drop-out of the actuated directional contactors and the drop-out of only one dynamic braking contactor, whereby the motor is disconnected from the supply terminals and the dynamic braking circuit is established.

3. In a control for a dynamo-electric machine having an armature and a series field, the combination of, a first bridge circuit having a switch in each of the four legs thereof, a second bridge circuit having a switch in each of the four legs thereof, circuit means connecting said armature across one pair of diametrically opposite junctions of each bridge circuit, energizing circuit means including said series field connected to the remaining pair of diametrically opposite junctions of the first bridge circuit, and an impedance circuit connecting said series field across one remaining junction of the second bridge circuit and the last remaining two junctions of the first and second bridge circuit.

4. In a control for a dynamo-electric machine having an armature and a series field, the combination of, a first bridge circuit having a normally open switch in each of the four legs thereof, a second bridge circuit having a normally closed switch in each of the four legs thereof, circuit means connecting said armature across one diagonal of each bridge circuit, energizing circuit means including said series field connected to the remaining diagonals of the first bridge circuit, an impedance circuit connecting said series field across one remaining diagonal of the second bridge circuit and the remaining diagonals of the first and second bridge circuit, and control means having a neutral position and operating positions for opening all of the switches in the second bridge circuit while closing a selected pair of switches in the opposite legs of the first bridge circuit when in one of the operating positions and including means for delaying closure of a selected pair of switches in said second bridge circuit when returned to the neutral position.

5. In a control for a dynamo-electric machine comprising a direct-current series motor having an armature and a series field, the combination of, a first bridge circuit having a normally open switch in each of the four legs thereof, a second bridge circuit having a normally closed switch in each of the four legs thereof, circuit means connecting said armature across one diagonal of each bridge circuit, energizing circuit means including a supply terminal and including said series field connected to one pair of the remaining diagonals of the first and second bridge circuits, an impedance circuit connecting the supply terminal to the one remaining diagonal of the second bridge circuit, a second supply terminal connected to the remaining diagonal of the first bridge circuit, and control means for opening all of the switches of the second bridge circuit while closing a selected pair of switches in the opposite legs of the first bridge circuit.

6. In a control circuit for a dynamo-electric machine having an armature winding and a series field, the combination of, a first bridge circuit having an electromagnetically operable normally open switch in each of the four legs thereof, a second bridge circuit having an electromagnetically operable normally closed switch in each of the four legs thereof, circuit means connecting

said armature winding across one pair of diagonal junctions of each bridge circuit including a pair of supply terminals and an energizing circuit, including said series field, said series field having one of its terminals connected to one supply terminal and the other of its terminals connected to one pair of the remaining diagonal junctions of said first and second bridge circuit, an impedance circuit connecting the remaining diagonal junction of said second bridge circuit to the other supply terminal, and control means for simultaneously energizing one pair of the electromagnetically operable switches in opposite legs of the first bridge circuit and all of the electromagnetically operable switches in the second bridge circuit.

7. In a control circuit for a dynamo-electric machine having an armature winding and a series field, the combination of, a first bridge circuit having an electromagnetically operable normally open switch in each of the four legs thereof, a second bridge circuit having an electromagnetically operable normally closed switch in each of the four legs thereof, a circuit means connecting said armature winding across one pair of diagonal junctions of each bridge circuit, an energizing circuit, including a pair of supply terminals and including said series field having one of its terminals connected to one supply terminal and the other of its terminals connected to one pair of the remaining diagonal junctions of said first and second bridge circuits with the other remaining diagonal junction of the first bridge being connected to the other supply terminal, an impedance circuit connecting the remaining diagonal junction of said second bridge circuit to the other supply terminal, control means for simultaneously energizing one pair of the electromagnetically operable switches in opposite legs of the first bridge circuit and all of the electromagnetically operable switches in the second bridge circuit, and including means for delaying the drop-out of a selected pair of switches in opposite legs of the second bridge circuit upon operation of said control means to deenergize the electromagnetically operable switches.

8. In a system of control for a series direct-current motor, namely, one having an armature winding and a series field winding, in combination, positive and negative supply terminals, a bridge circuit including directional switches in each of its four legs and having its first junction connected to one of the supply terminals and its third junction, namely the junction diametrically opposite to the first junction, connected to one terminal of the series field winding with the other terminal of the series field winding being connected to the other supply terminal, a second bridge circuit having dynamic braking switches in each of its four legs, a dynamic braking resistor having its first terminal connected to the first junction of the second bridge circuit and having its second terminal connected to the second, or other, supply terminal, the second, third, and fourth junctions of the second bridge circuit being connected respectively to the second, third, and fourth junctions of the first bridge circuit, control means for effecting the closing of the directional switches in the first and third leg of the first bridge circuit, and means, responsive to the operation of the control means to open the directional switches in the first and third leg of the first bridge circuit, for substantially at the same time closing the dynamic braking switches

in the second and fourth legs of the second bridge circuit.

9. In a system of control for a series direct-current motor, namely, one having an armature winding and a series field winding, in combination, positive and negative supply terminals, a bridge circuit including directional switches in each of its four legs and having its first junction connected to one of the supply terminals and its third junction, namely the junction diametrically opposite to the first junction, connected to one terminal of the series field winding with the other terminal of the series field winding being connected to the other supply terminal, a second bridge circuit having dynamic braking switches in each of its four legs, a dynamic braking resistor having its first terminal connected to the first junction of the second bridge circuit and having its second terminal connected to the second, or other, supply terminal, the second, third, and fourth junctions of the second bridge circuit being connected respectively to the second, third, and fourth junctions of the first bridge circuit, control means for effecting the closing of the directional switches in the second and fourth leg of the first bridge circuit, and means, responsive to the operation of the control means for effecting the opening of the directional switches in the second and fourth legs of the first bridge circuit for substantially at the same time effecting the closing of the dynamic braking switches in the first and third leg of the second bridge circuit.

10. In a system of control for a series direct-current motor, namely, one having an armature winding and a series field winding, in combination, positive and negative supply terminals, a bridge circuit including directional switches in each of its four legs and having its first junction connected to one of the supply terminals and its third junction, namely the junction diametrically opposite to the first junction, connected to one terminal of the series field winding with the other terminal of the series field winding being connected to the other supply terminal, a second bridge circuit having dynamic braking switches in each of its four legs, a dynamic braking resistor having its first terminal connected to the first junction of the second bridge circuit and having its second terminal connected to the second, or other, supply terminal, the second, third, and fourth junctions of the second bridge circuit being connected respectively to the second, third, and fourth junctions of the first bridge circuit, control means when operated in one sense for selectively effecting the operation of either the directional switches in the first and third or the second and fourth legs of the first bridge circuit, and means, responsive to the operation of the control means in an opposite sense to open the particular pair of directional switches which have been selectively closed, for effecting the closing of the dynamic braking switches in the legs of the second bridge circuit that correspond to the legs adjacent to those in the first bridge the circuits of which are being opened.

11. In a control circuit for a dynamo-electric machine having an armature winding and a series field winding, the combination of, a first bridge circuit having an electromagnetically operable normally open switch in each of the four legs thereof, a second bridge circuit having an electromagnetically operable normally closed switch in each of the four legs thereof, circuit means connecting said armature winding across

one pair of diagonal junctions of each bridge circuit, an energizing circuit, including a pair of supply terminals and including said series field winding, said series field winding having one of its terminals connected to one supply terminal and the other of its terminals connected to one pair of the remaining diagonal junctions of said first and second bridge circuits, an impedance circuit connecting the last remaining diagonal junction of said second bridge circuit to the other supply terminal, control means for simultaneously energizing one pair of the electromagnetically operable switches in opposite legs of the first bridge circuit and all of the electromagnetically operable switches in the second bridge circuit, and switch drop-out control means for the electromagnetically operable switches of the second bridge circuit for latching the switches in the legs of the second bridge circuit, corresponding to said opposite legs of the first bridge circuit, in open position upon deenergization of said electromagnetically operable switches.

12. In a control circuit for a direct-current dynamo-electric machine having an armature winding and a series field winding, in combination, a first bridge circuit, switching means in each leg of the bridge circuit for closing and opening the circuit through the legs of the bridge circuit, a second bridge circuit, switching means in each leg of the second bridge circuit for opening and closing the circuit through the legs of the second bridge circuit, circuit means for connecting the armature winding across diametrically opposite corresponding junctions of both bridge circuits, a dynamic braking circuit, including an impedance connected in series with the series field winding, connected across one pair of corresponding and joined junctions of both bridge circuits and the remaining junction of the second bridge circuit, and energizing circuit means including two supply terminals, one of said supply terminals being connected to the remaining junction of the first bridge circuit and the other supply terminal being connected to the dynamic braking circuit between the impedance and the series field winding.

13. In a control circuit for a direct-current dynamo-electric machine having an armature winding and a series field winding, in combination, a first bridge circuit, switching means in each leg of the bridge circuit for closing and opening the circuit through the legs of the bridge circuit, a second bridge circuit, switching means in each leg of the second bridge circuit for opening and closing the circuit through the legs of the second bridge circuit, circuit means for connecting the armature winding across diametrically opposite corresponding junctions of both bridge circuits, a dynamic braking circuit, including an impedance connected in series with the series field winding, connected across one pair of corresponding and joined junctions of both bridge circuits and the remaining junction of the second bridge circuit, energizing circuit means including two supply terminals, one of said supply terminals being connected to the remaining junction of the first bridge circuit and the other supply terminal being connected to the dynamic braking circuit between the impedance and the series field winding, and control means for said switching means for effecting, upon operation in one sense, the opening of all the switching means of the second bridge circuit and the closing of one pair of switching means in opposite legs of the first bridge circuit and, upon operation in an opposite sense, for effecting the opening of said one pair of switching means and for effecting the closing of the switching means in the non-corresponding legs of the second bridge circuit.

14. In a control circuit for a direct-current dynamo-electric machine having an armature winding and a series field winding, in combination, a first bridge circuit, switching means in each leg of the bridge circuit for closing and opening the circuit through the legs of the bridge circuit, a second bridge circuit, switching means in each leg of the second bridge circuit for opening and closing the circuit through the legs of the second bridge circuit, circuit means for connecting the armature winding across diametrically opposite corresponding junctions of both bridge circuits, a dynamic braking circuit, including an impedance connected in series with the series field winding, connected across one pair of corresponding and joined junctions of both bridge circuits and the remaining junction of the second bridge circuit, energizing circuit means including two supply terminals, one of said supply terminals being connected to the remaining junction of the first bridge circuit and the other supply terminal being connected to the dynamic braking circuit between the impedance and the series field winding, and control means for said switching means for effecting an open circuit condition at the same time in one selected pair of corresponding legs in both bridge circuits.

15. In a control for a dynamo-electric machine comprising a direct-current series motor having an armature and a series field, the combination of, a first bridge circuit having a normally open switch in each of the four legs thereof, a second bridge circuit having a normally closed switch in each of the four legs thereof, circuit means connecting said armature across one diagonal of each bridge circuit, energizing circuit means including a supply terminal and including said series field connected to one pair of the remaining diagonals of the first and second bridge circuits, an impedance circuit connecting the supply terminal to the one remaining diagonal of the second bridge circuit, a second supply terminal connected to the remaining diagonal of the first bridge circuit, control means having a neutral, or off, position and an operating position, means responsive to movement of the control means from the off position to its operating position for effecting the closing of two of the normally open switches disposed in two opposite legs in the first bridge circuit and for effecting the opening of all the normally closed switches, latching means, actuated by the operation of the control means, for locking the pair of switches disposed in the legs of the second bridge circuit corresponding to the legs of the first bridge circuit which include the normally open switches actuated to closed position upon operation of the control means from the off position to its operating position, whereby a dynamic braking circuit for the motor is established upon movement of the control means back to the off position.

16. In a control system for a direct-current series motor, in combination, two supply terminals, a master controller having an off position, a forward position, and a reverse position, a dynamic braking circuit, a pair of electromagnetically operable normally closed dynamic braking contactors each having an operating coil, normally unenergized when the master controller

is in the off position, circuit means for energizing both coils when the master controller is moved from the off position to the forward position, two spring actuated latches one for each dynamic braking contactor each normally acting to latch the dynamic braking contactor with which it is associated in an open position after having been actuated by its energizing coil to open position, electromagnetic means including an actuating coil for each latch for holding the latches in non-latching position upon energization of the coils, circuit means responsive to the movement of the master controller from the off position to the forward position for energizing one actuating coil for one of the latches to thus hold the latch in its non-latching position, said electromagnetic means having a time constant whereby its effect causes one dynamic braking contactor to drop out to establish the dynamic braking circuit upon movement of the master controller back to the off position.

RANDAL P. BARNES.

No references cited.