Nov. 26, 1940. W. BOEKER 2,223,163

CONTROL SYSTEM

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Fig. 1.

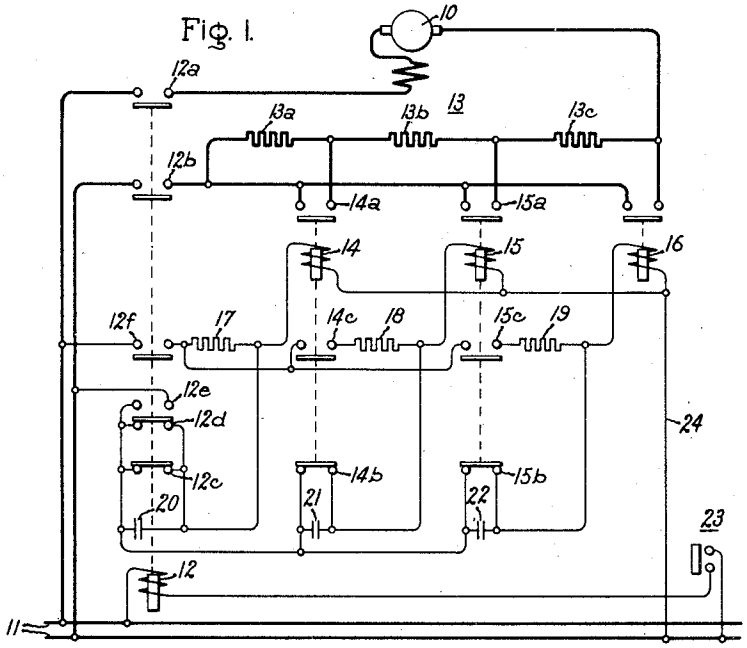
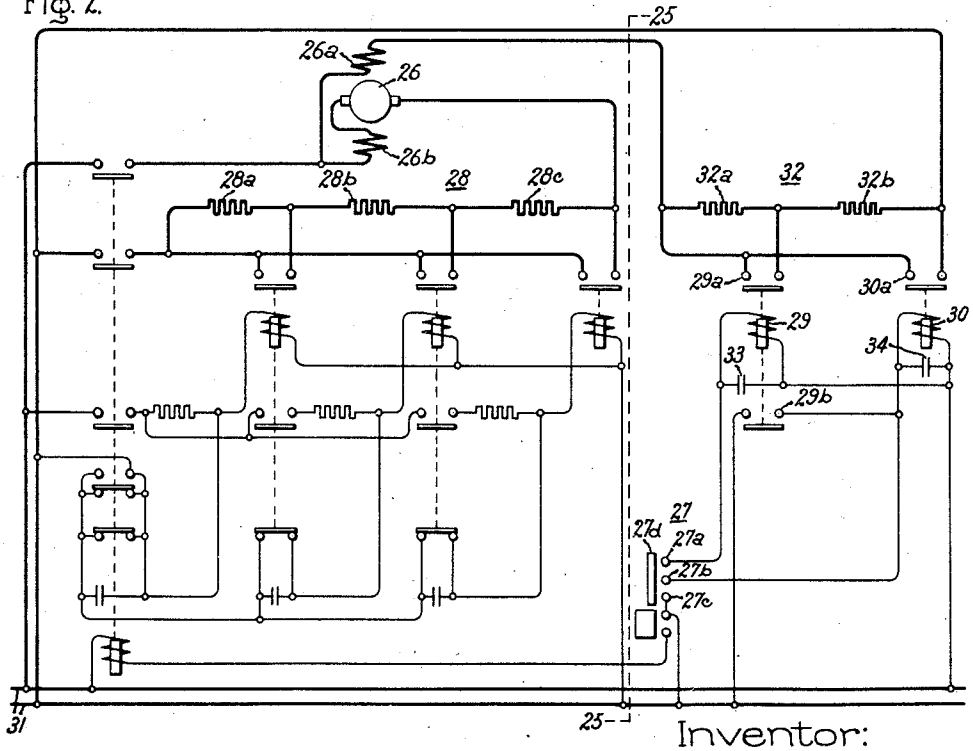


Fig. 2.



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CONTROL SYSTEM

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4 Claims. (Cl. 172—288)

This invention relates to control systems, more particularly to systems for controlling the operation of electric motors, and it has for an object the provision of a simple, reliable, and improved system of this character.

More specifically, the invention relates to systems for controlling the starting of electric motors, and a more specific object of the invention is the provision of inexpensive improved means for producing time intervals between the steps of connecting the motor to a source of supply and short circuiting the accelerating resistor.

Heretofore special timing relays have been employed for producing these time intervals. These special relays, however, are expensive, are subject to deterioration, and some of them are incapable of producing time delays of sufficient duration for the larger size motors. Accordingly, a further object of the invention is the elimination of special timing relays with their attendant disadvantages.

In carrying the invention into effect in one form thereof, the desired time intervals are produced by utilizing ordinary standard relays and connecting condensers in parallel with their operating coils and resistors in series therewith. By this means, the rise of voltage applied to the operating coils to a value sufficient to operate the contacts, is delayed for an interval of time the length of which depends upon the capacity of the condensers.

In illustrating the invention in several forms thereof, it is shown as embodied in starters for a series-wound, direct-current motor and for a compound-wound motor.

For a better and more complete understanding of the invention, reference should now be had to the following specification and to the accompanying drawing in which Fig. 1 is a simple schematic diagram of an embodiment of the invention, and Fig. 2 is a simple schematic diagram of a modification.

Referring now to the drawing, a motor 10 is to be connected to a source of supply 11 and accelerated from rest to full speed. A suitable contactor 12 having main contacts 12_a and 12_b is provided for connecting the motor 10 in series with an accelerating resistor 13 to the supply source 11. Accelerating resistor 13 is illustrated as comprising three sections 13_a, 13_b, and 13_c, but it may, if desired, comprise either a greater or lesser number of sections.

A plurality of suitable switching devices illustrated as a plurality of electromagnetically actuated contactors 14, 15 and 16 are provided for successively short circuiting the sections 13_a, 13_b, 13_c of the accelerating resistor 13. As indicated in the drawing, line contactor 12 is provided with normally closed auxiliary contacts 12_c and 12_d and with normally open auxiliary contacts 12_e and 12_f, and these contacts are so arranged that when line contactor 12 is energized and picks up, contacts 12_c and 12_d are opened before contacts 12_e and 12_f are closed.

A plurality of control resistors 17, 18, 19 are arranged to be connected in series relationship with the operating coils of accelerating contactors 14, 15, 16 respectively when these operating coils are connected to the source for energization. A similar plurality of condensers 20, 21, 22 are respectively associated with the operating coils of accelerating contactors 14, 15, 16 respectively and are arranged to be connected in parallel with these operating coils respectively following the closing of the line contactor 12. These conductors 20, 21, 22 are normally short circuited when the line contactor 12 and accelerating contactors 14 and 15 are open. When contactors 12, 14, and 15 are closed, the short circuits about these condensers 20, 21, and 22 are removed. A master control switching device 23 is provided for energizing the operating coil of the line contactor 12 and initiating the accelerating operation of the motor 10.

With the foregoing understanding of the elements and their organization in the system, the operation of the system itself will readily be understood from the following description: Closing the contacts of the master control switching device 23 connects the operating coil of line contactor 12 across the source 11. Contactor 12 closes its main contacts 12_a, 12_b in response to energization and connects motor 10 in series with accelerating resistor 13 to the supply source 11. Since the entire accelerating resistor 13 is in series with the motor when the motor is first connected to the source, the motor current is limited to a safe value. Simultaneously with the closing of main contacts 12_a, 12_b, line contactor 12 opens its auxiliary contacts 12_c, 12_d and subsequently closes auxiliary contacts 12_e and 12_f. The opening of auxiliary contacts 12_c and 12_d removes the short circuit which hitherto existed about condenser 20. The closing of auxiliary contact 12_f connects the upper terminal of the operating coil of accelerating contactor 14 through control resistor 17 to the upper side of the supply source 11. Simultaneously therewith, by the closing of contact 12_e one terminal of each of the condensers 20, 21, 22 is connected to the lower side of the

supply source 11 to which the corresponding terminals of the operating coils of contactors 14, 15, 16 are also connected by means of conductor 24. Since one terminal of each of the condensers 20, 21, 22 is connected to one terminal of a corresponding operating coil of the contactors 14, 15, 16 respectively and since the closing of contact 12_e connects the opposite terminal of each of these condensers to the other terminal of each of these operating coils, the condensers 20, 21, and 22 are respectively connected in parallel with the operating coils of contactors 14, 15, 16. At this point in the operation, the operating coil of contactor 14 is connected to the supply source, and the operating coils of contactors 15, 16 are disconnected therefrom. The voltage applied to the operating coil of contactor 14 depends upon the voltage drop across the resistor 17. Initially, when contacts 12_e and 12_f are closed, the charging current of the condenser 20 is large and this produces a correspondingly large voltage drop across the control resistor 17 so that a low voltage is applied to the operating coil of contactor 14. As the condenser 20 becomes charged, the voltage drop across resistor 17 decreases, and the voltage applied to the operating coil of contactor 14 increases up to the value at which the contactor attracts its armature. The rate at which the condenser 20 charges, and therefore the time required for the voltage applied to the coil of contactor 14 to build up to this value, depends upon the capacity of the condenser 20 which may be any desired value to give any desired time. When the voltage applied to the operating coil of contactor 14 reaches the pick-up value, the contactor closes its main contacts 14_a to short circuit section 13_a of the accelerating resistor and thereby to increase the speed of the motor 10. Simultaneously, contactor 14 opens its auxiliary contacts 14_b to remove the short circuit about the condenser 21 and subsequently closes its auxiliary contacts 14_c to connect the left-hand terminal of the control resistor 18 to the upper side of the supply source 11. The operating coil of contactor 15 is thus connected to the supply source 11 through the control resistor 18, and the condenser 21 is in parallel with the operating coil. As explained in connection with contactor 14, after an interval of time determined by the capacity of condenser 21 and the ohmic value of resistor 18, contactor 15 picks up and closes its main contacts 15_a and opens its auxiliary contacts 15_b. The closing of main contacts 15_a short circuits section 13_b of the accelerating resistor thereby to increase the speed of the motor, and the opening of auxiliary contacts 15_b removes the short circuit which hitherto existed about condenser 22. Subsequent to the opening of auxiliary contacts 15_b, auxiliary contacts 15_c are closed to connect the left-hand terminal of control resistor 19 to the upper side of the supply source and after an interval of time determined by the capacity of condenser 22 and the ohmic resistance of resistor 19, contactor 16 closes its contacts to short circuit the last section 13_c of the accelerating resistor with the result that the motor 10 is accelerated to full speed.

The motor 10 is stopped by opening the contacts of the master switching device 23 to deenergize the line contactor 12. Contactor 12 drops out in response to deenergization and opens main contacts 12_a, 12_b and auxiliary contacts 12_e and 12_f, and closes auxiliary contacts 12_c and 12_d. As a result, resistors 17, 18, and 19 are disconnected from the upper side of the supply source 11, and the parallel connection of each of the condensers 20, 21, 22 with the operating coil of a corresponding contactor 14, 15, 16 is interrupted. The opening of these parallel condenser circuits prevents the condensers from discharging through the operating coils of the contactors. If the condensers were permitted to discharge through the operating coils of the contactors, the contactors would remain picked-up for an interval of time after the disconnection of the coils from the source, and such time delay in the dropping out of the contactors would be undesirable. The result, therefore, of opening the parallel condenser circuits of the contactor coils is that the contactors drop out immediately. Condenser 20 discharges through the short circuit produced by the closing of contacts 12_c, and condensers 21 and 22 discharge through the short circuit formed by auxiliary contacts 14_b and 15_b. Thus the control is immediately reset for a subsequent operation.

The modified system of Fig. 2 is very similar to the system of Fig. 1 and differs from it primarily in that the control is arranged for a compound-wound motor, and the master switch has a second operative position which effects several steps of field weakening of the shunt field. As shown in Fig. 2 of the drawing, all of the control apparatus on the left-hand side of the dotted line 25—25 is identical with the control apparatus shown in Fig. 1 with the exception that the motor 26 is a compound-wound motor and is, therefore, additionally provided with a shunt field winding 26_a in addition to the series field winding 26_b.

The operation is as follows: Movement of the master switch 27 from its off position to its first operative position causes the sections 28_a, 28_b, and 28_c of the accelerating resistor 18 to be successively short circuited with suitable time intervals between the successive steps in a manner identical with that described for the Fig. 1 modification. Simultaneously, the operating coils of field contactors 29, 30 are connected to the supply source 31 through the fingers 27_a, 27_b, 27_c of the master switch bridged by the segment 27_d.

Contactors 29 and 30 close their main contacts 29_a and 30_a respectively and thereby short circuit shunt field resistor sections 32_a, 32_b of field weakening resistor 32. As a result, the shunt field winding 26_a is connected directly across the source 31 and is fully energized to provide maximum starting torque.

Condensers 33 and 34 which are connected in parallel with the operating coils of contactors 29 and 30 respectively become charged as a result of their connection across the supply source 31. Contactor 29 is provided with auxiliary contacts 29_b for completing a holding circuit for the operating coil of contactor 30 that is independent of the master switch 27 so that the contactor 30 will remain energized and closed until after the contactor 29 has been deenergized and opened.

Movement of the master switch 27 to the second operative position interrupts the energizing circuit for the operating coil of contactor 29. After an interval of time required for the condenser 33 to discharge through the operating coil of contactor 29, the contactor drops out and opens its main contacts 29_a to insert resistor section 32_a in the shunt field circuit of motor 26 thereby to weaken the field and to increase the speed of the motor.

Contactor 29 in dropping out also opens auxiliary contacts 29_b to interrupt the energizing circuit for the operating coil of contactor 30.

After an interval of time required for condenser 34 to become sufficiently discharged, contactor 30 opens its contacts 30a and inserts section 32b of the resistor in the shunt field circuit of the motor thereby to weaken the field of the motor and to increase its speed. The motor is now operating at full speed.

If desired, condenser 33 may be omitted so that contactor 29 will open and insert section 32a of the field weakening resistor immediately upon movement of the master switch to its second operative position. Although only two steps of field weakening are disclosed in Fig. 2, the invention obviously includes a greater number of steps if desired.

If it is desired to vary the drop out time of the contactors, this can be done by connecting variable resistances in parallel with the operating coils of the contactors so that the discharge time of the condensers is varied. The invention may be adapted to alternating-current installations by employing D. C. operating coils on the contactors and including a suitable rectifier in series relationship with each coil.

Although in accordance with the provisions of the patent statutes this invention is described as embodied in concrete form and the principle thereof explained, together with the best mode in which it is now contemplated applying that principle, it will be understood that the apparatus and connections shown are merely illustrative and that the invention is not limited thereto, since alterations and modifications will readily suggest themselves to persons skilled in the art without departing from the true spirit of this invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A starting control system for electric motors comprising in combination, an electric motor, a resistor connected in the armature circuit of said motor, means for short circuiting said resistor comprising an electroresponsive device provided with an operating coil, a condenser, a second resistor, a line contactor for connecting said motor to a source of supply, contacts on said contactor for connecting said operating coil in series relationship with said second resistor to a source of supply, and contacts on said contactor for completing a short circuit about said condenser when said contactor is open and interrupting said short circuit and connecting said condenser in parallel with said operating coil when said contactor is closed thereby to delay the operation of said electroresponsive device to short circuit said current limiting resistor for an interval of time after the closing of said contactor.

2. A starting control system for electric motors comprising in combination, an electric motor, a starting resistor, a line contactor for connecting said motor in series with said resistor to a source of supply, means for short circuiting portions of said resistor comprising a plurality of switching devices each provided with an operating coil, means for effecting energization of said coils in response to operation of said contactor to effect sequential operation of said switching devices, means for producing a time interval between the successive operations of said switching devices comprising a condenser connected in parallel with each of said operating coils and a control resistor connected in series therewith, contacts on said line contactor for connecting the operating coil of one of said switching devices in series with its associated control resistor to a cource and contacts on said contactor for normally short circuiting the associated condenser when said line contactor is open and for interrupting the short circuit when said contactor is closed and contacts on said one switching device for connecting the operating coil of a second of said switching devices in series with its control resistor to a source of supply and other contacts on said first switching device for short circuiting the condenser associated with said second switching device when said first switching device is open and for interrupting the short circuit when said first switching device is closed.

3. A starting control system for electric motors comprising in combination, an electric motor, a starting resistor connected in the armature circuit of said motor, a plurality of accelerating contactors for short circuiting said resistor in steps, a plurality of condensers, one for each of said contactors, a plurality of control resistors, one for each of said contactors, a line contactor for connecting said motor in series with said starting resistor to a source of supply, said line contactor being provided with contacts for connecting the operating coil of the first of said accelerating contactors in series with its control resistor to a source of supply and provided with contacts for normally completing a short circuit around the condenser associated with said accelerating contactor and for interrupting said short circuit connecting said condenser in parallel with the operating coil of said accelerating contactor when said line contactor is closed thereby to delay the closing of said accelerating contactor for an interval of time after the closing of said line contactor, contacts on said first accelerating contactor for connecting the operating coil of a second of said accelerating contactors in series with its control resistor to a source of supply and contacts on said first contactor normally short circuiting the condenser associated with said second contactor and for interrupting the short circuit when said first contactor closes thereby to delay the closing of said second contactor for an interval of time after the closing of said first contactor.

4. A starting control system for an electric motor provided with a shunt field winding comprising an accelerating resistor in the armature circuit of said motor, a speed regulating resistor in the shunt field circuit, a master control device having an off position and a plurality of operating positions, a switching device for connecting said motor to a source of supply in response to actuation of said master device from said off position to one of said operating positions, means for short circuiting said accelerating resistor comprising an electromagnetically actuated contactor provided with an operating coil arranged to be connected to a source of supply in response to said actuation of said master device and means for delaying the closing of said contactor for an interval of time after the connection of said motor to said source comprising a control resistor connected in series with said coil and a condenser connected in parallel therewith in response to said actuation of said master device, means controlled by said master device for normally short circuiting said condenser when said master device is in said off position, a second contactor for short circuiting said regulating resistor upon operation of said master device to said first position and for removing the short circuit upon

operation of said master device to a second position having an operating coil arranged to be connected to a source of supply in response to actuation of said control device to said first position and to be disconnected from said source in response to actuation of said master device to said second position, and a condenser connected in parallel with said operating coil to prevent deenergization thereof and opening of said second contactor for an interval of time after the short circuiting of said accelerating resistor.

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