Nov. 10, 1931. R. P. HIGBEE 1,831,069

CONTROL SYSTEM

Filed Sept. 7, 1926 2 Sheets-Sheet 1

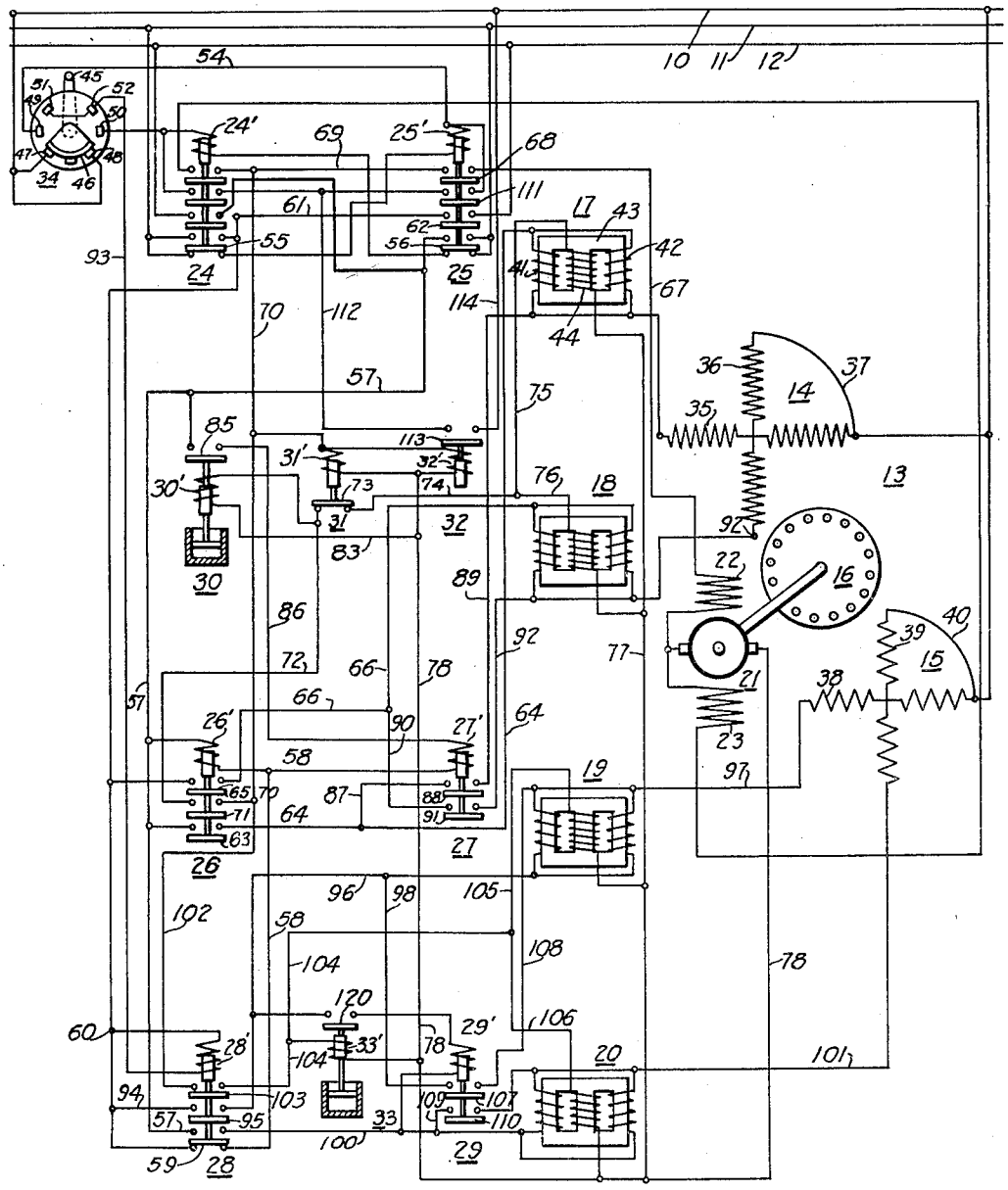

Fig. 1.

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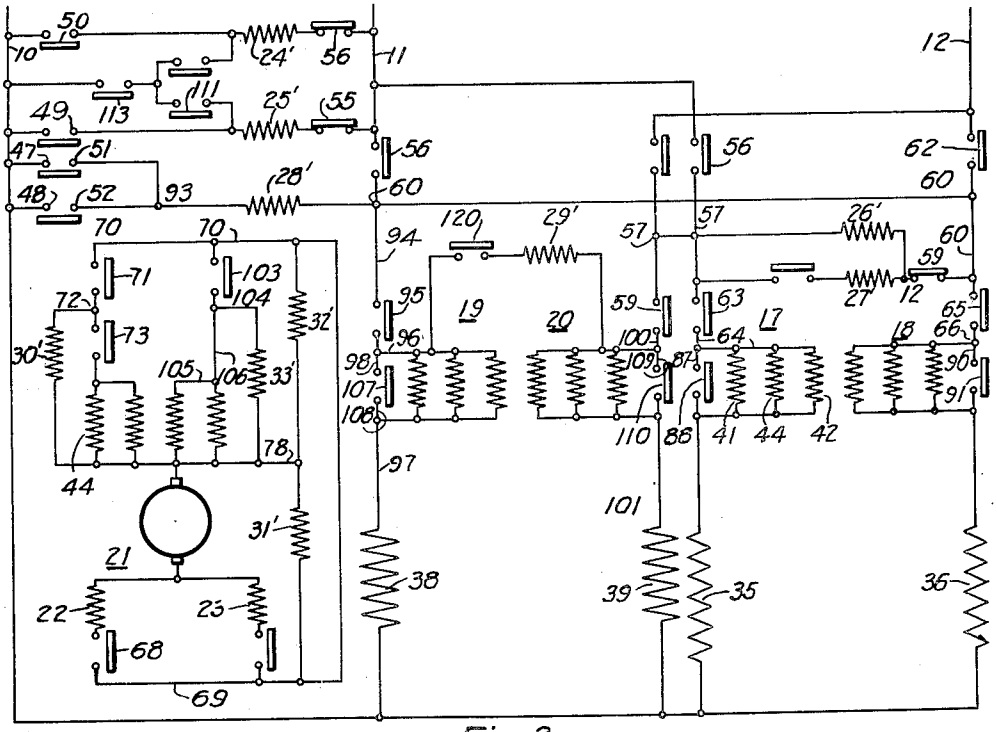

Fig. 2.

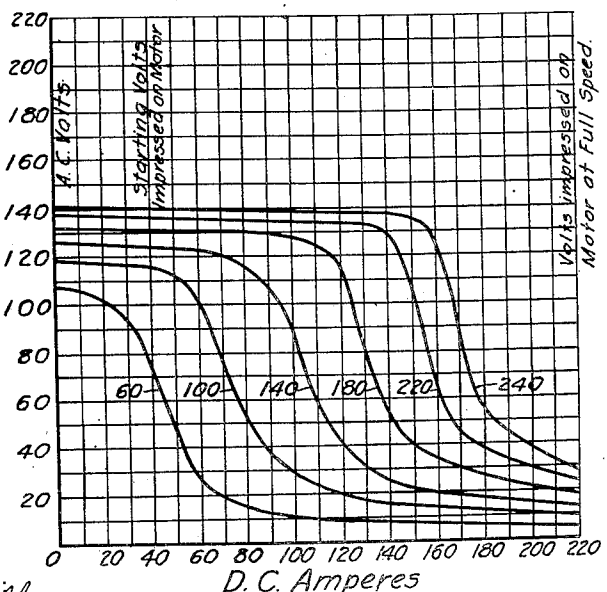

Fig. 3.

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UNITED STATES PATENT OFFICE

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CONTROL SYSTEM

Application filed September 7, 1926. Serial No. 133,803.

My invention relates to control systems and it has special relation to two-speed control systems particularly adapted for elevator or hoist applications.

One object of my invention is to provide a control system of the above-indicated character in which a motor winding is adapted to utilize electric current of a given character, namely, alternating current, a reactive device or the like being connected in circuit with the motor winding and being governed to control the energization thereof by applying current of a different character, namely, direct current, to the reactive device.

More specifically stated, it is an object of my invention to provide a control system of the class under consideration in which a plural-legged core is provided with both alternating-current and direct-current coils, the direct-current energization being so applied as to reduce the total volt-amperes or impedance drop of the entire reactive device, so that a motor may be smoothly accelerated or decelerated without the use of external rheostats.

A further object of my invention is to provide a control system, of the type outlined and having either one or two running speeds, in which the energization of the direct-current section of the reactive device is varied in accordance with the speed of the motor, preferably by means of a generator that is driven directly by the motor.

Other objects of my invention relate to the use of special relay devices for governing the relative operation of the direct and alternating-current portions of my reactive devices, as hereinafter described in detail.

Further objects of my invention will become evident from the following detailed description, taken in conjunction with the accompanying drawings, in which

Figure 1 is a diagrammatic view of a two-speed system of control organized in accordance with the principles of my present invention;

Fig. 2 is a straight line diagram corresponding to the more complicated diagram of Fig. 1; and

Fig. 3 is a curve chart showing the resultant volt-ampere or impedance drop characteristics of a variable reactive device utilized in accordance with my present invention.

My present invention is particularly adapted for controlling the induction type of motors, especially those having two stator windings, such as motors often employed for elevators and hoist applications. By means of a variable reactive device employing both direct and alternating-current windings, a variable voltage is applied to the primary winding of a motor in such manner as to obtain smooth acceleration and deceleration.

The reactance of an iron-core reactor depends upon the core flux density, by reason of the variable permeability of the iron. Thus, if the mean flux density of the core be controlled by a combination of alternating and direct-current excitation, the effective reactance of the apparatus may be controlled as desired in that, by the use of the direct-current winding, any degree of saturation of the iron core within the working range of the reactor may be secured.

The approximate voltage range that may be obtained by means of reactors of the type in question is indicated by the curves shown in Fig. 3. The lowest limit of the voltage consumed, that is, the difference between the line voltage and the voltage applied to the motor winding, would be, of course, fixed by the impedance of the coils of the reactor without the iron core. It will be noted that, as the direct-current excitation of the reactor is increased, the volt-ampere capacity or effective impedance thereof is materially reduced. For example, taking the second curve from the left, designated as corresponding to 100 amperes of alternating current, (line voltage being 220), it will be noted that, whereas the starting volts (alternating current) required by the reactor are about 116 without direct-current excitation, by the application of 80 amperes direct current the voltage drop due to the reactor is decreased to 50 volts; and by the continued increase of the direct current to 220 amperes, the voltage

drop due to the reactor is decreased to approximately 9 volts.

It should be noted that the ratio between alternating-current and direct-current amperes, as indicated by the above figures, is not a power ratio. The direct current power that is required is that necessary to meet the copper loss and is, therefore, only of the order of one or two percent of the volt-ampere rating of the reactor.

Referring to Figs. 1 and 2 of the drawings, the system here shown comprises a polyphase supply circuit including conductors 10, 11 and 12; a two-speed induction motor 13, having a low-speed stator winding 14 and a high-speed stator winding 15, both adapted to cooperate with a squirrel-cage rotor 16; a pair of reactive devices 17 and 18 that are associated with the low-speed stator winding 14; a second pair of reactive devices 19 and 20 that are associated with the high-speed stator winding 15; a generator or exciter 21 that is driven by the squirrel-cage rotor 16 and is provided with directional field windings 22 and 23, respectively; a plurality of switches or contactors 24 to 29, inclusive, a plurality of controlling relays 30 to 33, inclusive, and a master switch or controller 34.

Whereas, for the sake of simplicity and clearness, I have shown my invention as applied to a two-phase, three-wire system, it should be understood that the invention may be readily applied to a three-phase system, by the addition of two reactive devices for cooperating with the third phase windings of the stator.

The low-speed stator winding 14 comprises two independent phase windings 35 and 36 which have a common terminal conductor 37. Similarly, the high-speed stator winding 15 comprises two separate phase windings 38 and 39 having a common terminal conductor 40.

Each of the reactive devices 17 to 20, inclusive, comprises a three-legged core 43, upon the outer legs of which are wound alternating-current coils 41 and 42 and upon the intermediate leg of which a direct-current coil 44 is mounted. The alternating-current coils 41 and 42 are opposingly wound, but have the same number of turns, so that no alternating-current flux will pass through the middle leg of the core or its associated direct-current coil. Any other suitable scheme for effecting this result may be employed, it being essential that the direct-current circuit be protected against high alternating-current voltages, inasmuch as the direct-current winding 44 necessarily employs a relatively large number of turns and very high voltages would otherwise be induced in that coil.

The master controller 34 comprises a suitable handle 45 for actuating a drum or disc-type contact-carrying member 46, which cooperates with a plurality of stationary contact members or control fingers 47 to 52, inclusive.

Assuming that the various devices occupy their illustrated positions, the motor 13 may be started as follows: By actuating the controller 34 into a position to energize the control finger 49, a circuit is completed from supply conductor 10 through control fingers 48 and 49, conductor 54, actuating coil 25' of the reversing switch 25, interlock 55 of the other reversing switch 24 and thence to supply-circuit conductor 11.

The closure of reversing switch 25 establishes a circuit from supply conductor 11, through switch member 56 of the reversing contactor, conductor 57, actuating coil 26' of switch 26, conductor 58, interlock or auxiliary contact member 59 of switch 28, conductors 60 and 61, switch member 62 of reversing switch 25, and thence to supply circuit conductor 12.

The closure of switch 26 establishes a circuit from conductor 57, through contact member 63 of switch 26, conductor 64, the parallel-connected alternating-current coils 41 and 42 of reactive device 17, and thence through low-speed phase winding 35 to the supply-circuit conductor 10.

A similar circuit is established from conductor 60, through contact member 65 of switch 26, conductor 66, the parallel-connected alternating-current coils of reactive device 18, and thence through low-speed phase winding 36 to supply-circuit conductor 10.

The low-speed windings of the motor 13 are thus initially energized to start acceleration of the motor, which drives the generator 21 and thus gradually increases the voltage thereof in accordance with the motor speed.

A circuit is thus established from one terminal of the generator 21, through field winding 22 thereof which corresponds to the then direction of rotation of the generator, conductor 67, interlock 68 of reversing switch 25, conductors 69 and 70, interlock 71 of switch 26, conductor 72, contact member 73 of relay 31 in its lower or normal position, and conductor 74, where the circuit divides, one branch including conductor 75 and the direct-current winding 44 of reactive device 17, while the other branch includes conductors 76 and the direct-current coil of the reactive device 18, the circuit being continued through conductors 77 and 78 to the opposite terminal of generator 21.

As the motor speed increases, the voltage of the generator and the current traversing the direct-current coils of the reactive device correspondingly increase to effect a gradual reduction of the effective volt-amperes or impedance of the reactive devices 17 and 18 (as previously explained in connection with Fig. 3), which are connected in

circuit with the respective low-speed phase windings of the motor 13.

A further circuit is completed from conductor 72, through the actuating coil 30′ of relay 30, and conductor 83 to direct-current return conductor 78. Consequently, the relay 30 is closed after a predetermined time interval, dependent upon the setting of the dash-pot of the relay, this time interval being adjusted to correspond to the motor reaching a speed substantially corresponding to the maximum speed that can be produced by the low-speed phase windings of the motor. Upon the closure of relay 30, a circuit is established from conductor 57, through contact member 85 of relay 30, conductor 86, actuating coil 27′ of switch 27, and thence through conductor 58 to supply-circuit conductor 12, as previously traced.

The closure of switch 27 establishes two new circuits, one extending from conductor 64, through conductor 87, contact member 88 of switch 27, and conductor 89 directly to the phase winding 35. The second circuit extends from conductor 66, through conductor 90, contact member 91 of switch 27, and conductor 92 directly to the phase winding 36. In this way the alternating-current coils of the reactive devices 17 and 18 are short-circuited or excluded from circuit to permit the low-speed phase windings of the motor to bring the motor to the normal slow speed.

To effect further acceleration of motor 13, the master controller 34 may be actuated to a position in which the control finger 51 is energized, whereby a circuit is established through control finger 52, conductor 93 and the actuating coil 28′ of switch 28 to conductor 60.

The closure of switch 28 establishes a circuit from conductor 60, through conductor 94, contact member 95 of switch 28, conductor 96, the parallel-connected alternating-current coils of reactive device 19, and conductor 97 to high-speed phase winding 38 of the stator winding 15, and thence to supply circuit conductor 10. A similar circuit is completed from conductor 57, through contact member 59 of switch 28 in its upper position, conductor 100, the parallel-connected alternating-current coils of reactive device 20, and conductor 101 to the other high-speed phase winding 39 of the motor 13.

The motor thus accelerates in accordance with this replacement of phase windings 35 and 36 by windings 38 and 39; and, at this time, switches 26 and 27 are opened by reason of the exclusion of contact member 59 of switch 28 from the actuating circuits of their coils.

A direct-current circuit is concurrently established from one terminal of the generator 21, through field winding 22, as previously traced, to conductor 70, whence a circuit is continued through conductor 102, contact member 103 of switch 28, conductor 104, where the circuit divides, one branch including conductor 105 and the direct-current coil of reactive device 19, and the other branch including conductor 106 and the direct-current coil of reactive device 20, a common circuit being continued through conductor 78 to the opposite terminal of the generator.

Another auxiliary circuit is established, upon the closure of switch 28, from conductor 104, through the actuating coil 33′ of relay 33, and thence to the direct-current return-circuit conductor 78. Relay 33 is adapted to close after a predetermined interval, corresponding to the reaching of approximately full speed by the motor 13, and after the increase in the direct-current traversing the reactive devices 19 and 20, by reason of the increased acceleration of the motor, has reduced the effective volt-ampere or impedance values of these reactive devices to a relatively low figure. The closure of relay 33 completes the circuit of the energizing coils 29′ of switch 29, through the relay contact member 120, as will be noted.

The closure of switch 29 establishes two new circuits, one extending from conductor 96, through conductor 98, contact member 107 of the switch, and conductors 108 and 97 directly to high-speed phase winding 38, while the other circuit extends from conductor 100, through conductor 109, contact member 110 of a switch 29 and conductor 101 directly to the other high-speed phase winding 39.

In this manner, the motor is brought to its full speed condition, as the alternating-current coils of the reactive devices 19 and 20 are thus excluded from circuit.

In order to decelerate the motors, the master switch handle 45 may be returned to its "off" position in which control fingers 49 and 51 are deenergized. Contactors 28 and 29, corresponding to high-speed operation, thus immediately open, but a circuit through reversing contactor 25 is maintained by means of a circuit extending from supply conductor 11, interlock 55 of reversing switch 24, actuating coil 25′ of reversing switch 25, contact member 111 of that switch, conductor 112, contact member 113 of relay 32, and thence to supply-circuit conductor 10.

The actuating coil 32′ of relay 32 is energized from the generator armature, being connected in parallel to the actuating coil 31′ of relay 31 between conductors 70 and 78, and thus maintains the circuit just traced until the speed of the motor and generator is reduced to a point slightly greater than normal slow speed of the motor.

The opening of contactor 28 again closes interlock 59 through the previously-traced circuit to complete circuits through the low-speed stator windings 35 and 36 and the

alternating-current coils of reactive devices 17 and 18, as previously traced. The maximum voltage drop caused by these reactive devices is required only until the motor speed is reduced to some intermediate value, usually corresponding to about one-half of the full speed value. The relay 31 is adjusted to drop at this value and to close the previously-traced circuit through the direct-current coils of the reactive devices 17 and 18. By reason of the inherent time lag in a device of large reactance, such as the devices 17 and 18, the saturation of the cores will be effected gradually, so that the voltage drop across the alternating-current motor windings will likewise be reduced in a relatively gradual and smooth manner.

The closure of contactor 26, upon the opening of switch 28 (as previously described) again completes a circuit to relay 30 through the auxiliary contact member 71 of the contactor. The dash-pot adjustment on relay 30 is such as to delay the closing of the actuating-coil circuit of contactor 27 until the voltage drop in the alternating-current coils of the devices 17 and 18 has become fully effective. In this manner the short-circuiting of these coils is delayed to the proper point, and a very smooth regenerative braking torque is obtained.

It will be seen that I have thus provided a control system, especially adapted for two-speed alternating-current motors, in which a smoo h and gradual acceleration and deceleration may be effected without the use of rheostats. The action of the control system is automatic and the characteristics of the system will be found to be particularly advantageous in the case of certain elevator and hoist applications.

I do not wish to be restricted to the specific circuit connections or arrangement of parts herein set forth, as various modifications thereof may be effected without departing from the spirit and scope of my invention. I desire, therefore, that only such limitations shall be imposed as are indicated in the appended claims.

I claim as my invention:

1. A control system comprising a motor having a plurality of phase windings, a plurality of mechanically and magnetically independent reactive devices connected in circuit with the respective windings, a direct-current generator driven by said motor, and means comprising a plurality of switches for selectively connecting said generator to the respective reactive devices for governing the energization of said phase windings.

2. A control system comprising a motor having a plurality of phase winding groups for obtaining two pole numbers, a plurality of independent reactive devices severally having cores and a plurality of sets of coils wound thereon, the respective sets of one kind of coils being successively connected in circuit with said phase winding groups, a direct-current generator driven by said motor, and means comprising a plurality of switches for selectively connecting said generator to the respective sets of the other kind of coils for governing the successive energization of said phase winding groups.

3. A control system comprising a motor having a plurality of sets of phase windings respectively corresponding to different operating speeds of the motor, a plurality of reactive devices severally having cores and a plurality of oppositely wound coils thereon, the respective sets of coils being connected in circuit with said phase windings, an additional coil mounted on each core, a direct-current generator driven by said motor, and means comprising a plurality of switches for selectively connecting said generator to said additional coils for governing the energization of said phase windings.

4. A control system comprising a motor having a plurality of phase windings, a plurality of mechanically and magnetically independent reactive devices connected in circuit with the respective windings, a direct-current generator driven by said motor, means comprising a plurality of switches for selectively connecting said generator to the respective reactive devices for governing the energization of said phase windings, and time-element means energized from said generator for selectively excluding the respective reactive devices from circuit.

5. A control system comprising a motor having a plurality of phase winding groups for obtaining two pole numbers, a plurality of reactive devices severally having cores and a plurality of sets of coils wound thereon, the respective sets of one kind of coils being successively connected in circuit with said phase winding groups, a direct-current generator driven by said motor, means comprising a plurality of switches for selectively connecting said generator to the respective sets of the other kind of coils for governing the successive energization of said phase winding groups, and time-element means energized from said generator for selectively excluding the respective reactive devices from circuit.

6. A control system comprising a motor having a plurality of sets of phase windings respectively corresponding to different operating speeds of the motor, a plurality of reactive devices severally having cores and a plurality of oppositely wound coils thereon, the respective sets of coils being connected in circuit with said phase windings, an additional coil mounted on each core, a direct-current generator driven by said motor, means comprising a plurality of switches for selectively connecting said generator to said additional coils for governing the energization

of said phase windings, and time-element means energized from said generator for selectively excluding the respective reactive devices from circuit.

7. A control system comprising a plurality of phase windings of a motor, a plurality of mechanically and magnetically independent reactive devices connected in circuit with the respective windings, a source of direct current, a plurality of switches, and means for selectively governing said switches to apply direct current from said source to the respective reactive devices, whereby the energization of said windings is successively obtained.

8. A control system comprising a plurality of phase winding groups of a motor for obtaining two pole numbers, a plurality of independent reactive devices severally having cores and a plurality of sets of coils wound thereon, the respective sets of one kind of coils being successively connected in circuit with said phase winding groups, a plurality of switches, a source of direct current, and means for selectively governing said switches to apply direct current from said source to the respective sets of the other kind of coils, whereby the energization of said winding groups is successively obtained.

9. A control system comprising a plurality of phase winding groups of a motor for obtaining two pole numbers, an alternating-current circuit for energizing said windings to operate the motor, a plurality of independent reactive devices severally having cores and a plurality of oppositely wound coils mounted thereon, and the sets of such coils being successively connected in circuit with said phase winding groups, an additional coil mounted on each core, a source of direct current, a plurality of switches, and means for selectively governing said switches to apply direct current from said source to the sets of said additional coils, whereby the energization of said winding groups is successively obtained.

10. A control system comprising a motor having a plurality of phase windings corresponding to different operating speeds thereof, an alternating-current circuit for energizing said windings to operate the motor, a plurality of reactive devices connected in circuit with the respective windings, a plurality of switches, a source of direct current, and means for selectively governing said switches to apply direct current from said source to the corresponding reactive devices, whereby the energization of said windings is successively obtained.

11. A control system comprising a plurality of phase windings of a motor, a plurality of mechanically and magnetically independent reactive devices severally having cores and a plurality of sets of coils wound thereon, one of the respective sets of coils being connected in circuit with said phase windings, a plurality of switches, a source of direct current, means for selectively governing said switches to apply direct current from said source to another set of coils, whereby the energization of said windings is successively obtained, and means responsive to the speed of said motor for successively governing the inclusion or exclusion of certain coils of the respective reactive devices.

12. A control system comprising a motor having a plurality of phase winding groups for obtaining two pole numbers, an alternating-current circuit for energizing said windings to operate the motor, a plurality of reactive devices severally having cores and a plurality of sets of coils wound thereon, the respective sets of one kind of coils being successively connected in circuit with said phase winding groups, a plurality of switches, a source of direct current, means for selectively governing said switches to apply direct current from said source to the respective sets of the other kind of coils, whereby the energization of said winding group is successively obtained, a generator driven by said motor, and means responsive to the voltage of said generator for successively governing the short-circuit or removal thereof of certain coils of the respective reactive devices.

In testimony whereof, I have hereunto subscribed my name this 4th day of September, 1926.

RAY P. HIGBEE.