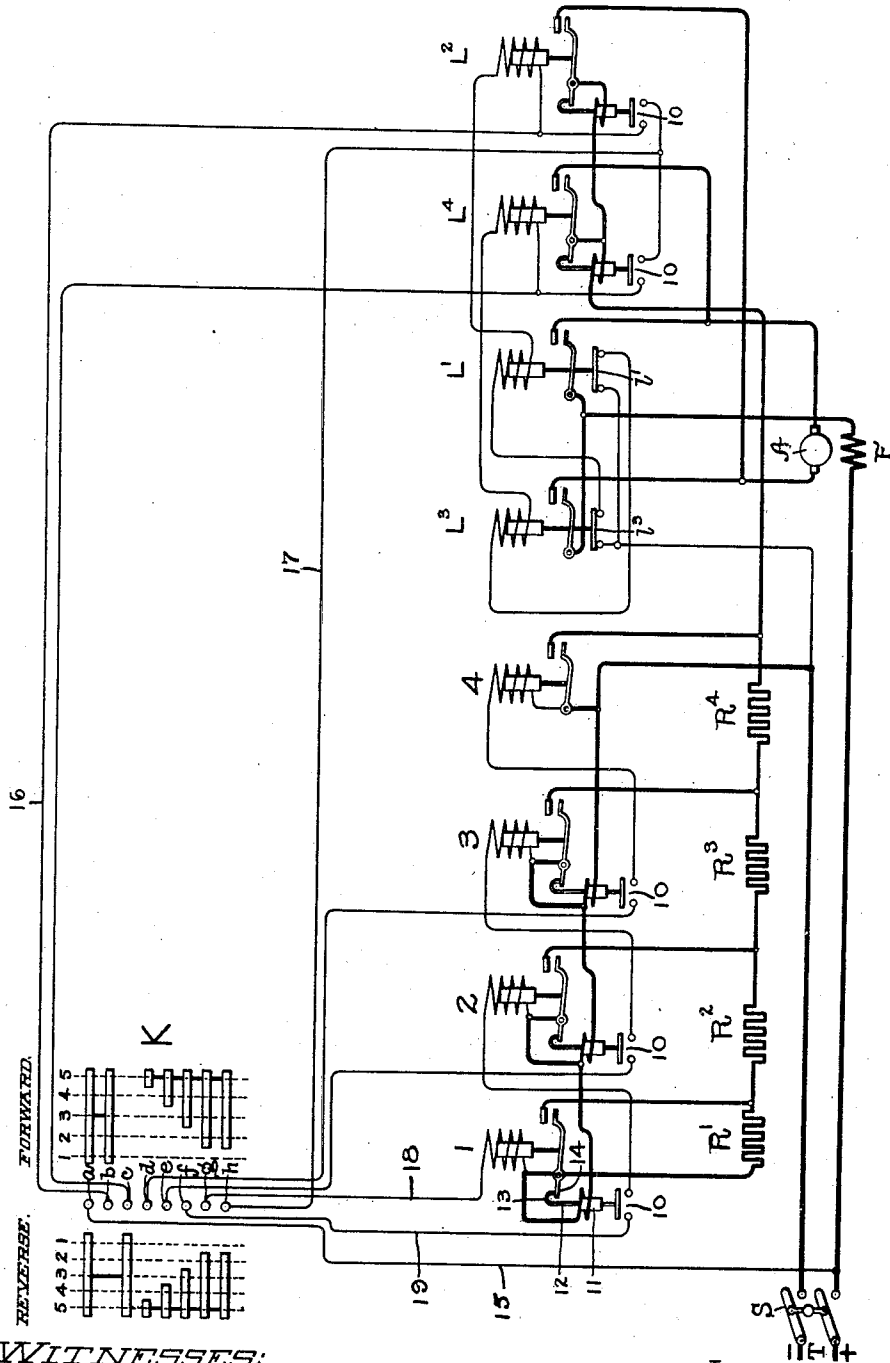


H. E. WHITE & E. R. CARICHOFF.
 CONTROL OF ELECTRICALLY OPERATED SWITCHES.
 APPLICATION FILED FEB. 27, 1909.

969,585.

Patented Sept. 6, 1910.



UNITED STATES PATENT OFFICE.

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SIGNORS TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

CONTROL OF ELECTRICALLY-OPERATED SWITCHES.

969,585.

Specification of Letters Patent.

Patented Sept. 6, 1910.

Application filed February 27, 1909. Serial No. 480,483.

To all whom it may concern:

Be it known that we, HAROLD E. WHITE and EUGENE R. CARICHOFF, citizens of the United States, residing at Schenectady, in the county of Schenectady and State of New York, have invented certain new and useful Improvements in Control of Electrically-Operated Switches, of which the following is a specification.

Our invention relates to the operation and control of electrically-controlled switches and particularly to the operation successively in a certain order of a plurality of such switches. It is especially useful in connection with systems of motor control in which a plurality of electrically-controlled switches or contactors are arranged to operate in succession to increase step-by-step the voltage applied to the motor. Arrangements of this kind are employed in starters for electric motors and have been so arranged that, by closing a single master-switch, contactors are caused to operate automatically in succession to cut out section by section resistance interposed in the motor circuit on starting, or, in some other way, to increase step-by-step the voltage applied to the motor. Similar arrangements have also been used in systems of motor control in which the master-switch has a plurality of "on" positions and serves to regulate the operation of the series of contactors, the arrangement being such that the master-switch may either directly control the operation of the contactors one at a time or may cause a number or all of them to operate automatically in succession. In such systems of motor control it is desirable that a certain time interval, the length of which depends upon the conditions of service, should elapse between the operation of succeeding contactors. It is also often desirable that the rate of successive operation of the contactors depend upon the current in the motor circuit, that is, that the operation of a succeeding contactor be prevented if the closing of the preceding contactor has resulted in producing a current in the motor circuit in excess of a certain safe value. Various arrangements have been used for giving this so-called "time and current limit" to the action of a series of switches used for the above described purposes, one of the best known being the system in which a "notching relay" is arranged to interrupt the

actuating circuit for the series of switches after each switch has operated and to maintain said circuit interrupted as long as the current in the motor circuits exceeds a certain value.

It is a general object of our invention to provide a new and improved system of control for a plurality of electrically controlled switches or contactors intended for operation in succession under the control of the varying conditions in the power circuit in which said contactors effect certain connections.

Our invention comprises an arrangement in which a plurality of contactors, intended for operation in succession, are each controlled by an auxiliary switch which coöperates with a preceding contactor and which is positively held open while said contactor is open, an electromagnet being provided for each auxiliary switch which is energized from the power circuit to be controlled and which controls the closing of said auxiliary switch after its coöperating contactor has closed.

In the particular embodiment of our invention hereinafter described, we use, in connection with a plurality of contactors intended for operation in succession to effect certain connections in a power circuit, auxiliary switches each of which coöperates with a contactor and serves to control the succeeding contactor, a connection being provided between each contactor and its coöperating auxiliary switch, whereby when the former is open the latter is positively held open and when the former is closed the latter is permitted to close, magnets, all of which are energized upon the completion of the power circuit being arranged to control the closing of each auxiliary switch, and the connections being such that each contactor in closing besides effecting the desired connection in the power circuit also shunts the magnet of the auxiliary switch which controls said contactor.

In the drawing we have shown diagrammatically our invention as applied to a simple system of control for a direct current motor, but this is merely illustrative and, as will be obvious to those skilled in this art, it may equally well be applied to other forms of dynamo-electric machinery and to other types of control; or, in fact, employed in any connection where it is desired to

regulate the conditions in a power circuit by means of a plurality of switches operating in succession.

Referring to the drawing, a source of current is indicated at T, with which the power and control circuits of the system are connected through a switch S. The armature of the motor to be controlled is indicated at A and its field at F, the motor in this case being a series motor, although other types of motor might equally well have been shown. Suitable electrically controlled switches or contactors L^1 , L^2 and L^3 , L^4 are shown as arranged to connect the motor to the source for either direction of rotation. A starting or control resistance is shown as made up of sections R^1 , R^2 , R^3 and R^4 which may be short-circuited by suitable electrically-operated switches or contactors 1, 2, 3 and 4, respectively. A master-switch K is shown developed, in the usual conventional manner, and as of type in which a drum, provided with suitable segments, co-operates in both directions from "off" position with a set of fingers a , b , c , d , e , f , g and h and serves to regulate the operation of the contactors for both directions of rotation of the motor. Contactors L^1 and L^3 are provided with interlocking switches L^1 and L^3 of any well-known form, shown in the usual conventional way, which are closed when the contactors L^1 and L^3 are open and are opened by the closing of the latter. Switches L^2 , L^4 , 1, 2 and 3 are each provided with an attachment which consists of an auxiliary or interlocking switch 10, to the movable element of which is secured a core 11 which is arranged for movement in a magnetic field produced by a conductor or coil arranged in coöperative relation to the core and carrying motor current. The movable member of each auxiliary switch 10 and its coöperating core 11 is mechanically connected in any suitable manner to the movable member of its corresponding contactors L^2 , L^4 , 1, 2 or 3 and is held in its raised position, as shown in the diagram, when its corresponding contactor is open.

In the arrangement diagrammatically illustrated, the core 11 has extending upwardly from it a rod 12 which at its upper end is bent into a hook 13, the downwardly extending end of which rests upon a heel 14 of the movable contact member of the contactors L^2 , L^4 , 1, 2 and 3. With a construction of this kind when any one of said contactors is open the core 11 of its auxiliary switch is held in its raised position and this switch is therefore open; but when a contactor closes the heel 14 moves away from the end of the hook 13 and the switch 10 is free to close unless prevented as hereinafter explained. The magnetic field structures and the magnetizing coils of the auxiliary switches 10 are so designed that

said switches will be held open, when released by the closing of their corresponding contactors, if the current in a conductor or coil which coöperates with their cores 11 is in excess of a certain value, in other words, if the current in the motor at that time exceeds a certain predetermined safe value. When, however, a core 11 has dropped, no increase in motor current thereafter will cause it to pull up.

The particular design of auxiliary switch mechanism necessary to the carrying out of the functions just mentioned will be at once apparent to those skilled in this art, it being well known that the operation of a core of magnetic material in the field of an electromagnet can be regulated by properly arranging the number of ampere turns in the magnet coil and the field structure of the magnet, particularly the air gap in the magnetic circuit which varies with the movement of the core. The characteristics and the design of electromagnetically-operated devices are now so well understood that the diagrammatic illustration of our device and the statement of its functions is sufficient to enable any one skilled in the art to build the same.

As will be evident from the following description of the mode of operation of the system, the auxiliary switches 10 which coöperate with the contactors L^2 and L^4 control the energization of the actuating circuits for the resistance controlling contactors 1, 2, 3 and 4; and the auxiliary switches 10 which coöperate with the contactors 1, 2 and 3 are located respectively in the control circuits to the actuating coils of the contactors 2, 3 and 4. The arrangement of motor and control circuits will be apparent from the diagram and from the following description of the mode of operation of the system.

The switch S being closed and the master-switch K being thrown to its first forward position, a circuit is completed from the + side of the source, through the wire 15, through the two upper fingers a and b and coöperating segments on the forward side of the master-switch to the wire 16, thence to the actuating coils of the contactors L^2 and L^4 in series, through the auxiliary switch L^3 on the contactor L^3 to the — side of the source. The contactors L^1 and L^2 will, therefore, close and a circuit will be completed from the positive side of the source through the field F of the motor, contactor L^1 , armature A, contactor L^2 , through all of the resistance R^1 , R^2 , R^3 and R^4 to the — side of the source. It is to be observed that this circuit passes through the conductors or coils which produce the magnetic fields operating upon the cores 11 of the attachments to contactors L^2 , L^4 , 1, 2 and 3 and that, even though released by the

closing of their corresponding contactors, these cores will not fall and cause the switches 10 to close if the motor current exceeds a certain value. As long as the master-switch K remains in its first "on" position no further changes in the motor circuit take place and the motor will be connected to the source with all the resistance in circuit. If the master-switch K is moved to its second forward position, the two lower fingers *g* and *h* thereof engage with their cooperating segments, and if the current in the motor circuit has fallen to such a value that the auxiliary switch 10 cooperating with the contactor L² has closed, a circuit is completed from the wire 16, through the switch 10 on the contactor L², through wire 17, through the two lower fingers *g* and *h* and their segments on the master-switch to the wire 18, and thence through the actuating coil of the contactor 1 to the — side of the line through the conductor which cooperates with the cores 11 of the attachments to the contactors 1, 2 and 3. The contactor 1 will, therefore, close and will short circuit the section of resistance R¹. As long as the master-switch K remains in its second position no further operation of the contactors will occur. If, however, the master-switch is thrown to its third forward position, the finger *f* will engage with its cooperating segment and the wire 19, leading to the auxiliary switch 10 of the contactor 1, will be energized as was wire 18 and, if the current in the motor circuit has dropped below a certain predetermined value and the auxiliary switch 10 cooperating with contactor 1 has therefore closed, a circuit will be completed through the actuating coil of the contactor 2 which will close, short-circuiting the section of resistance R².

From the foregoing it will be clear that the motor may be connected to the source and the resistance cut out section-by-section by moving the master-switch K through its various "on" positions, and that during this operation if the motor current exceeds a certain value the successive operation of the resistance controlling contactors 1, 2, 3 and 4 will be retarded.

It is, of course obvious that, if desired, the master-switch K may be thrown at once to its fifth or full "on" position whereupon the operation of the contactors will take place automatically under the same limitations in the rate of closing as in the mode of operation above referred to.

We have not deemed it necessary to illustrate in this application any particularly mechanical construction of contactor and auxiliary switch attachment therefor, since it will be obvious to those skilled in the art that our invention may be embodied in many different constructions. The contactors may be

of any suitable and well known type as for example that which, together with a particular construction of auxiliary switch attachment for the contactors, is shown in a co-pending application in the name of Harold E. White, Ser. No. 480,481, filed February 27, 1909, in which application are also set forth certain improvements in systems of control for electrically controlled switches of the same general nature as that shown in the present application.

While we have shown our invention as incorporated in a system of motor control having switches or contactors which are electromagnetically operated, we realize that it may equally well be used in connection with systems in which the switches are operated pneumatically. It is, therefore, our intention to cover such systems in this application and wherever we have used the expressions "electrically controlled switch" or "contactor" we mean to include both those which are operated electromagnetically and those which are operated electro-pneumatically, these two systems being now well known to those familiar with this art. Furthermore, while we have shown our invention as embodied in a system in which the magnet coils of the auxiliary switch attachments are traversed by the entire motor or power current, we do not wish to be understood as limiting it to this arrangement, since, of course, these magnetizing coils may be energized from the motor or power circuit in many different ways as is well known to those skilled in the art.

It will be obvious to those skilled in this art that our invention may be embodied in a great variety of forms, and it is our intention to cover in the following claims all such embodiments as come within the scope of our invention.

What we claim as new and desire to secure by Letters Patent of the United States, is,—

1. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, actuating magnets for said contactors, auxiliary switches cooperating with certain of said contactors, each arranged to control the operation of a succeeding contactor, means for positively holding each auxiliary switch open while its cooperating contactor is open, and electrical means independent of said actuating magnets for controlling the closing of said auxiliary switches.

2. In combination with a power circuit a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, actuating magnets for said contactors, auxiliary switches cooperating with certain of said contactors, each arranged to control the operation of a succeeding contactor, means for holding

each auxiliary switch open while its cooperating contactor is open, and a magnet independent of said actuating magnets cooperating with each auxiliary switch and energized from the power circuit for controlling the closing of said auxiliary switch.

3. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, actuating magnets for said contactors, auxiliary switches cooperating with certain of said contactors, each arranged to control the operation of a succeeding contactor, means for holding each auxiliary switch open while its cooperating contactor is open, a magnet cooperating with each auxiliary switch and energized from the power circuit for controlling the closing of said auxiliary switch, and connections whereby each of said contactors in closing shunts the magnet of its controlling auxiliary switch.

4. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, auxiliary switches cooperating with certain of said contactors, each arranged to control the operation of a succeeding contactor, a connection between each of said contactors and its auxiliary switch whereby when the former is open the latter is positively held open and when the former is closed the latter is permitted to close, a magnet cooperating with each auxiliary switch and energized from the power circuit for controlling the closing of said auxiliary switch, and connections whereby each of said contactors in closing shunts the magnet of its controlling auxiliary switch.

5. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, actuating magnets for said contactors, auxiliary switches cooperating with certain of said contactors each arranged to control the operation of a succeeding contactor, means for holding each auxiliary switch open while its cooperating contactor is open, a magnet cooperating with each auxiliary switch and energized from the power circuit for controlling the closing of said auxiliary switch, and connections whereby each contactor in closing both effects the desired connection in the power circuit and shunts the electromagnet cooperating with the auxiliary switch which controls the control circuit for that contactor.

6. In combination with a power circuit, a plurality of switches intended for operation in succession to effect certain connections in said power circuit, auxiliary switches cooperating with certain of said first mentioned switches, each arranged to control

the operation of a succeeding switch, a connection between each of said first mentioned switches and its auxiliary switch whereby when the former is open the latter is positively held open and when the former is closed the latter is permitted to close, and means energized from the power circuit for controlling the closing of said auxiliary switches.

7. In combination with a power circuit, a plurality of electrically controlled switches intended for operation in succession to effect certain connections in said power circuit, control circuits for said switches, auxiliary switches cooperating with certain of said electrically controlled switches and each arranged to control the control circuit of a succeeding electrically controlled switch, a connection between each electrically controlled switch and its auxiliary switch whereby when the former is open the latter is positively held open and when the former is closed the latter is permitted to close, and means responsive to current in the power circuit for controlling the closing of said auxiliary switches.

8. In combination with a power circuit, a plurality of switches intended for operation in succession to effect certain connections in said power circuit, auxiliary switches cooperating with certain of said first mentioned switches, each arranged to control the operation of a succeeding switch, a mechanical connection between each of said first mentioned switches and its auxiliary switch whereby when the former is open the latter is positively held open and when the former is closed the latter is permitted to close, and means energized from the power circuit for controlling the closing of said auxiliary switches.

9. In combination with a power circuit, a plurality of electrically controlled switches intended for operation in succession to effect certain connections in said power circuit, control circuits for said switches, auxiliary switches cooperating with certain of said electrically controlled switches and each arranged to control the control circuit of a succeeding electrically controlled switch, a mechanical connection between each electrically controlled switch and its auxiliary switch whereby when the former is open the latter is positively held open and when the former is closed the latter is permitted to close, and means responsive to current in the power circuit for controlling the closing of said auxiliary switches.

10. In combination with a power circuit, a plurality of electrically controlled switches intended for operation in succession to effect certain connections in said power circuit, control circuits for said switches, auxiliary switches cooperating with certain of said electrically controlled switches and each ar-

5 ranged to control the control circuit of a succeeding electrically controlled switch, a mechanical connection between each electrically controlled switch and its auxiliary switch whereby when the former is open the latter is positively held open and when the former is closed the latter is permitted to close, and electromagnetically operated means energized from the power circuit for controlling the closing of said auxiliary switches.

11. In combination with a power circuit, a plurality of electrically controlled switches intended for operation in succession to effect certain connections in said power circuit, control circuits for said switches, auxiliary switches cooperating with certain of said electrically controlled switches and each arranged to control the control circuit of a succeeding electrically controlled switch, a mechanical connection between each electrically controlled switch and its auxiliary switch whereby when the former is open the latter is positively held open and when the former is closed the latter is permitted to close, and electro-magnets energized from the power circuit for controlling the closing of said auxiliary switches.

12. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, control circuits for said contactors, auxiliary switches each cooperating with a contactor and arranged to control the control circuit of a succeeding contactor, a mechanical connection between each contactor and its auxiliary switch whereby when the former is open the latter is positively held open and when the former is closed the latter is permitted to close, and an electromagnet the energization of which depends upon the current in the power circuit arranged to prevent the closing of said auxiliary switch if the current in the power circuit exceeds a certain value.

13. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, control circuits for said contactors, auxiliary switches having fixed and movable members cooperating with certain of said contactors and each arranged to control the control circuit of a succeeding contactor, a mechanical connection between each contactor and its auxiliary switch whereby when the former is open the latter is positively held open and when the former is closed the latter is permitted to close, an armature of magnetic material connected to the movable member of said auxiliary switch, and a coil energized from said power circuit and arranged to magnetically influence said armature and thereby control the closing of the auxiliary switch.

14. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, control circuits for said contactors, auxiliary switches having fixed and movable members cooperating with certain of said contactors and each arranged to control the control circuit of a succeeding contactor, a mechanical connection between each contactor and its auxiliary switch whereby when the former is open the latter is positively held open and when the former is closed the latter is permitted to close, an armature of magnetic material connected to the movable member of said auxiliary switch, and a coil energized from said power circuit and arranged to magnetically influence said armature and maintain said auxiliary switch open if the current in the power circuit exceeds a certain value.

15. In combination, a contactor, a relay, and a mechanical connection between said contactor and said relay whereby when said contactor is open the contacts of the relay are held open and when said contactor is closed said relay is operatively independent.

16. In combination, a contactor having a movable member, a relay having a movable member, and a mechanical connection between the movable member of the contactor and the movable member of the relay whereby when the former is in one position the latter is held in one position and when the former is in its other position said mechanical connection is ineffective.

17. In combination, a contactor having a pivoted member, a relay having a longitudinally movable member, and a mechanical connection between said pivoted member and said longitudinally movable member whereby when the former is in one position the latter is positively held in one position and when the former is in its other position the latter is movable independently of the former.

18. The combination with a contactor having a fixed contact member, a movable contact member, and an actuating coil for moving said movable contact member into engagement with said fixed contact member, of an auxiliary switch attachment comprising a fixed contact member, a movable contact member, a mechanical connection between the movable contact member of said contactor and the movable contact member of said auxiliary switch attachment whereby when said contactor is open the contacts of said auxiliary switch attachment are held open and when said contactor is closed the contacts of said auxiliary switch attachment are permitted to close, and a magnet coil cooperating with the movable contact member of said auxiliary switch attachment.

19. The combination with a contactor hav-

ing a fixed contact member, a movable contact member, an actuating coil for moving said movable contact member into engagement with said fixed contact member, of an
 5 auxiliary switch attachment comprising a fixed contact member, a movable contact member, a mechanical connection between the movable contact member of said contactor and the movable contact member
 10 of said auxiliary switch attachment whereby when said contactor is open the contacts of said auxiliary switch attachment are held open and when said contactor is closed the contacts of said auxiliary switch attachment
 15 are permitted to close, and a magnet coil for controlling the closing of the contacts of the auxiliary switch attachment.

20 20. The combination with a contactor having a fixed contact member, a movable contact member, and an actuating coil for moving said movable contact member into engagement with said fixed contact member, of an auxiliary switch attachment comprising

a fixed contact member, a movable contact member, a mechanical connection between
 25 the movable contact member of said contactor and the movable contact member of said auxiliary switch attachment whereby when said contactor is open the contacts of said auxiliary switch attachment are held
 30 open and when said contactor is closed the contacts of said auxiliary switch attachment are permitted to close, and a magnet coil connected in the same circuit with the contacts of the contactor and cooperating
 35 with the movable contact member of said auxiliary switch attachment.

In witness whereof, we have hereunto set our hands this 26th day of February, 1909.

HAROLD E. WHITE.
 EUGENE R. CARICHOFF.

Witnesses:

BENJAMIN B. HULL,
 HELEN ORFORD.