Oct. 3, 1933. H. C. NYCUM ET AL 1,928,701

REGULATING EQUIPMENT

Filed Feb. 19, 1932

Fig. 1.

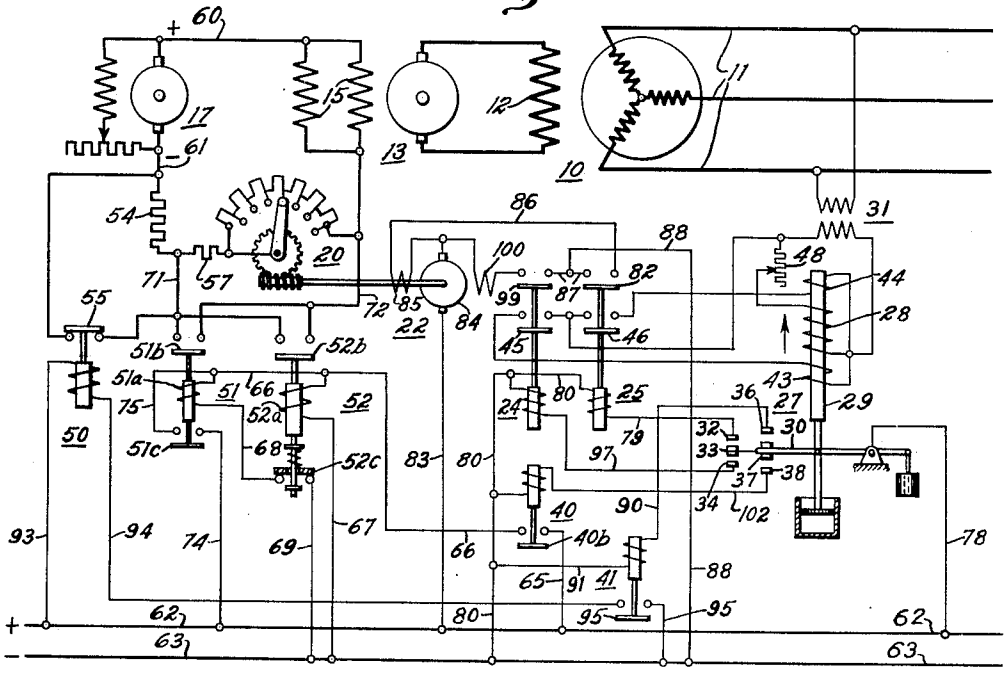


Fig. 2.

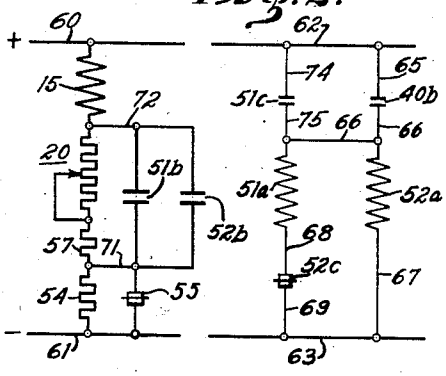


Fig. 3.

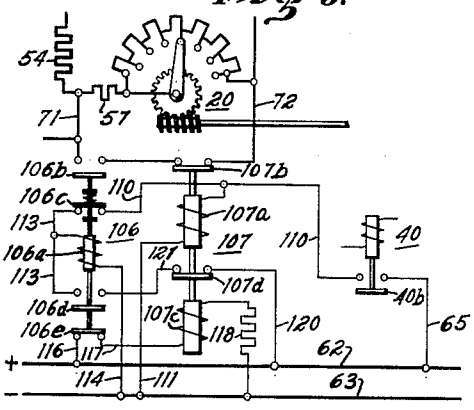
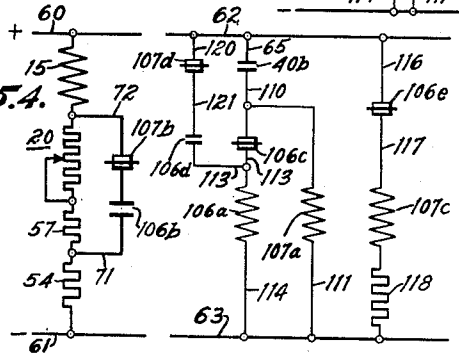


Fig. 4.



WITNESSES:
R. D. Williams
C. F. Bryant

INVENTORS.
John H. Ashbaugh and
Homer C. Nycum.
BY
Franklin E. Hardy
ATTORNEY

Patented Oct. 3, 1933 1,928,701

UNITED STATES PATENT OFFICE

1,928,701

REGULATING EQUIPMENT

Homer C. Nycum, Wilkinsburg, Pa., and John H. Ashbaugh, Longmeadow, Mass., assignors to Westinghouse Electric and Manufacturing Company, a corporation of Pennsylvania

Application February 19, 1932. Serial No. 594,008

9 Claims. (Cl. 171—119)

Our invention relates to electrical regulators and has particular relation to generator-voltage regulators of the quick-response type which utilize means for rapidly short circuiting resistance in the excitation-control circuit of the regulated machine.

The rate of response of generator-voltage regulators of the rheostatic type, in which changes in voltage of the generator causes variations in the generator excitation by suitably actuating a motor-operated rheostat, may be greatly accelerated by providing means whereby sections of a field-circuit resistor are momentarily removed from, or inserted in, the field-winding circuit, upon the occurrence of predetermined large changes in generator voltage. To control the effectiveness of these resistor sections, contactors or relays are employed to bridge them in a manner that a section that is normally short circuited may be introduced into the circuit when the voltage suddenly rises, to rapidly reduce the generator excitation, while a second section, which may include the motor-operated rheostat of the regulating system, is short circuited only upon the occurrence of a large drop in voltage, to rapidly increase the excitation and thus quickly restore the voltage to normal.

As is known, in many applications of generator voltage regulators rapidity of response is of paramount importance, for example, when the question of power-system stability is involved. In such regulating systems, therefore, it is essential that the resistor short-circuiting operations be made as rapidly as possible, especially upon the occurrence of sudden drops in voltage, for power system stability is found to closely depend upon the speed with which the generator voltage is returned to normal following such sudden decreases. It is to the provision of means for increasing the rapidity of these short-circuiting operations that this invention is directed.

Generally stated, therefore, an object of our invention is to provide means for quickening the speed of response of a regulating system of the type under consideration.

More specifically stated, an object of our invention is to provide, in a regulating system of the type described, means whereby a section of excitation-control-circuit resistance may be short circuited in the minimum time following a voltage-raising impulse.

It is known that the size of a circuit controlling device is determined by the current interrupting requirement rather than by the circuit closing duty. Consequently, in a given load-carrying circuit, a heavier contactor or relay will be required to open the circuit than is required to close it, the difference in contactor size resulting from the fact that the arcing incident to current interruption is not present during circuit closure.

It is further known that the inherent speed of operation of a contactor or relay decreases rapidly as the size or capacity of the device is raised. Hence, to obtain the quickest response in the control of a circuit, it is necessary to use as small a contactor as the requirements will permit.

It will be apparent that the same set of conditions applies to the establishing and interrupting of a short circuit around a resistance which is connected in a current-carrying circuit of the type to be found in the generator-voltage regulator systems under consideration.

We have discovered that, if one contactor be caused to establish the short circuit around the excitation-control-circuit resistance and a second contactor be utilized to interrupt this short circuit after the voltage conditions have been properly restored, the short-circuiting operation may be considerably quickened, for, in accordance with the considerations already pointed out, the first of these contactors may be of a light-duty, quick-acting type while the second may be of the usual heavier-duty, slower-acting type necessitated by the short-circuit-interrupting requirements. It will thus be evident that by the employment of such contactors in the practice of our invention, the speed of regulator response may be greatly increased over that which is possible by the employment of a single contactor for short circuiting the resistor.

Our invention will best be understood from the following description of specific embodiments thereof, when taken in conjunction with the accompanying drawing, in which

Figure 1 is a diagrammatic view of apparatus and circuits representing one embodiment of our invention when applied to a generator-voltage regulator of a well known exciter-rheostatic type.

Fig. 2 is a schematic diagram showing in simplified form the connections and control circuits for two separate resistor-bridging contactors utilized in the system of Fig. 1.

Fig. 3 is a diagrammatic representation of a portion of the regulating system of Fig. 1 in which a modification of the two-contactor resistor-bridging scheme is illustrated, and

Fig. 4 is a simplified schematic diagram of the excitation and contactor-control circuits shown in the system of Fig. 3.

Referring to the drawing, and particularly to Fig. 1 thereof, the regulating system there illustrated is disposed to control the voltage of an alternating-current generator 10, comprising an armature winding connected to the circuit conductors 11, and an exciting-field winding 12 energized from an exciter-generator 13. The exciter-generator 13 is provided with a field winding 15, shown as being of the parallel path type to reduce inductive lag, which may be energized from any suitable source of substantially constant direct-current potential, such as an auxiliary exciter 17.

To control the voltage of the regulated generator 10, a motor-operated rheostat 20 is connected in circuit with the exciter field winding 15 to control the field current and hence the voltage impressed by the exciter 13 upon the field winding 12 of the generator 10. The rheostat 20 is operated by a suitable motor 22, the energization of which is controlled by the operation of relays 24 and 25, respectively, to operate in the voltage-raising, or the voltage-lowering direction.

The motor-control relays 24 and 25 are controlled by means of a contact-making voltmeter or primary relay 27 that is responsive to the voltage across the circuit conductors 11. As shown, the primary relay 27 comprises a main winding 28 that is energized from a potential transformer 31 in accordance with the generator voltage. An increase in the generator voltage increases the upwardly acting magnetic pull upon the armature member 29 and causes the contact-carrying member 30 to be moved upwardly, while a decrease in generator voltage similarly allows the member 30 to move downwardly.

The primary relay is provided with two separate sets of contacts, a small-change-responsive set comprising members 32, 33 and 34, and a large-change-responsive set comprising members 36, 37 and 38. The small-change-responsive set of contacts will be seen to control the rheostat-motor control relays 24 and 25, while the large-change-responsive set controls, by means of a pair of auxiliary relays 40 and 41, a group of contactors that are disposed to short circuit sections of a resistor in the field-winding circuit of the exciter 13.

The primary relay 27 is shown as being also provided with anti-hunting windings 43 and 44 that are energized upon the actuation of motor-control relays 24 and 25, respectively, to their circuit closing positions through the contact members 45 and 46, carried by these relays. An adjustable resistor 48 is also illustrated in the energizing circuit of the main winding 28 of the relay 27 for the purpose of adjusting the value of voltage which the regulating system will maintain at the terminals of generator 10.

In order that the regulating system responds quickly to correct for large variations in voltage from the desired value, provision is made for short circuiting from, and for inserting in, the field control circuit relatively large blocks of resistance. This structure includes the set of large-change-responsive contacts 36—37—38 of the primary relay 27, and auxiliary relays 40 and 41 already mentioned, and, contactors 50, 51 and 52 controlled by these relays.

The contactor 50, for example, when in its circuit closing position, as illustrated, short circuits a resistor 54. Likewise, the contactors 51 and 52 are connected to short circuit the field rheostat 20 and a resistor 57, when required, when either is moved to its circuiting closing position.

It will be seen that, in the system of Fig. 1, a large increase in the generator voltage, causes engagement of the contact members 36 and 37, thus operating the auxiliary relay 41 to its circuit closing position, and the contactor 50 to its circuit opening position to interrupt the circuit in shunt relation to the resistor 54, and thereby effect a sudden decrease in generator excitation. Similarly, an excessive decrease in generator voltage causes operation of the auxiliary relay 40 and the contactors 51 and 52 to short-circuit the resistor 57 and the rheostat 20 and thereby effect a rapid increase in the generator excitation.

It has already been indicated that in the practice of our invention, we replace the usual single short-circuiting contactor by a pair of contactors having widely different capacities and operating speed characteristics. In the system of Fig. 1, these contactors are represented at 51 and 52, the contactor 51 being of a low-capacity quick-acting type connected to close a short circuit upon engagement of the regulator contacts 37 and 38, while the contactor 52 is of the usual heavier-duty slower-acting type required to interrupt the short circuit current upon separation of the contacts 37 and 38.

As illustrated, the contactor 51 comprises a winding 51*a* which, when energized, moves the contact members 51*b* and 51*c* upwardly to their circuit closing positions. The main contact member 51*b* will thus establish a short circuit around the rheostat 20 and the resistor 57, while the auxiliary contact member 51*c* acts in the control circuit of the contactor in a manner to be explained.

Contactor 52 is illustrated as comprising an actuating winding 52*a* which, when energized, biases the contact member 52*b* upwardly, to its circuit closing position, and an auxiliary contact member 52*c* to its circuit opening position. The main contact member 52*b* is connected in parallel circuit relation to the main contact member 51*b* of contactor 51, so that, when closed, it also provides a short circuit around the rheostat 20 and the resistor 57. The auxiliary member 52*c*, which acts in the contactor control circuits in a manner to be explained, remains closed throughout the major portion of contact travel, it being adjusted to open before the limit of upward travel of the contactor armature has been reached.

The connections of contactors 51 and 52 are illustrated in simplified form in the schematic diagram in Fig. 2 in order that they may be more clearly understood. In Fig. 2, the positive and negative conductors of the excitation source 17 are designated by the horizontal lines 60 and 61 at the top and bottom of the diagram, while similarly positioned lines 62 and 63 designate the positive and negative supply conductors of the control circuit source similarly designated in Fig. 1. In Fig. 2, the contact members of the auxiliary relay 40 are designated by 40*b* and the several contact members of each of the contactors 51 and 52 are designated by the same markings as in Fig. 1.

The relay 40 through the contact members 40*b*, completes an energizing circuit for the actuating windings of both contactors 51 and 52. In the system of Figs. 1 and 2, the circuit for the relay 52 may be traced from the positive-supply conductor 62 through conductor 65, contact members 40*b* of relay 40, conductor 66, the operating winding 52*a* of relay 52, and conductor 67, back to

the negative supply conductor 63. The energizing circuit for the relay 51 is completed from the conductor 66, through winding 51*a*, conductor 68, the normally closed contact members 52*c* of relay 52, and conductor 69 to negative supply conductor 63.

When both contactors are thus energized, the contactor 51, being of lighter construction than contactor 52, closes first and establishes the desired short circuit through contact member 51*b*, and conductors 71 and 72 around the rheostat 20 and the resistor 57. The contactor 51 also closes a holding circuit through contact member 51*c* that maintains its winding energized independently of the contact member 40*b*. This holding circuit extends from the positive supply conductor 62, through conductor 74, contact member 51*c* and conductor 75 through the contactor windings, and thence to the negative supply conductor 63.

The contactor 52, being slower in operation than the contactor 51 does not close until after the holding circuit for the contactor 51 has been completed. When the closing operation of contactor 52 is practically completed, the auxiliary contact 52*c* is moved to its open circuit position and thereby interrupts the energizing circuit for the contactor 51. This allows the contactor 51 to reopen after the contactor 52 has been closed to complete, through its main member 52*b*, the short circuit around the rheostat 20 and the resistor 57.

The energizing circuit for the winding 52*a* of the contactor 52 is now completed by means of relay 40 only, so that the opening of contact members 40*b* will interrupt this circuit and thereby allow the contactor 52 to move to its open position. The subsequent opening of the contactor 52 interrupts the short circuit about the rheostat 20 and the resistor 57 and closes the contact member 52*c*, thus preparing a circuit through which the winding of the relay 51 may be energized upon the reclosure of the contact members 40*b* of relay 40.

It is thus seen that, in the system of Fig. 1, engagement of the regulator contact members 37 and 38 causes the light duty contactor 51 to establish the short circuit around the excitation control circuit resistance. The heavy duty contactor 52 then closes, to also complete a short circuit and in so doing allows the light duty contactor to open. From this moment, the heavy duty contactor remains closed until the regulator contact members 37 and 38 separate, at which time it opens, and interrupts the short circuit around the excitation control circuit resistance.

A brief description of the operation of the complete regulating system shown in Fig. 1 will now be considered. It has already been pointed out that the primary relay 27 is provided with two sets of contact members, the first of which are brought into engagement in response to small changes in the regulating voltages while the second set engage only in response to predeterminedly large voltage changes. Thus, for example, an increase in the voltage of the generator 10 first effects the engagement of the contact members 33 and 32 thereby completing an energizing circuit for the relay 25 that extends from the positive supply conductor 62 through conductor 78, contact-carrying arm 30 and contact members 33 and 32 of the primary relay 27, conductor 79, the winding of relay 25, and conductor 80 back to negative-control conductor 63.

Thus energized, the relay 25 is actuated to close circuits through its contact members, completing through the member 82 an energizing circuit for the rheostat-operating motor 22 that extends from the positive-supply conductor 62, through conductor 83, the armature and field windings 84 and 85 of the motor 22, conductor 86, the contact members 82 of relay 25 and conductors 87 and 88 back to the negative supply conductor 63.

Thus energized, the motor 22 rotates to operate the rheostat 20 in a direction to increase the resistance in the field winding circuit, thus causing the voltage of the generator 10 to be reduced.

If the increase in generator voltage to be corrected is sufficiently large, the primary relay 27, in addition to closing the contact members 32 and 33, will also bring the contact member 37 into engagement with the contact member 36 and establish an energizing circuit for the auxiliary relay 41 that extends from the positive supply conductor 62 through conductor 78, contact members 37 and 36 of relay 27, conductor 90, the winding of relay 41 and conductors 91 and 80 back to the negative supply conductor 63.

The relay 41, when actuated to its circuit closing position, completes an energizing circuit for the short-circuit removing contactor 50 that extends from the positive supply conductor 62, through conductor 93, the winding of contactor 50, conductor 94, contact members 95 of relay 41, and conductor 95 back to negative supply conductor 63.

Thus energized, the contactor 50 actuates its contact member 55 to the open circuit position, and by thus interrupting the short circuit around the resistor 54 inserts this resistor into the excitation control circuit. This action very rapidly reduces the excitation of the regulated generator.

When the voltage is corrected to such extent that the contact members 36 and 37 are separated, the relay 41 opens to deenergize the winding of the contactor 50 and thereby permits it to re-establish the short circuit around the resistor 54. Further correction in the regulated voltage is then accomplished in a well known manner by the automatic operation of the rheostat 20.

Similarly, in the event that the voltage of the generator 10 decreases below its desired value, the contact member 33 of the primary relay 27 will be moved into engagement with contact member 34 thereby completing an energizing circuit for the relay 24 which extends from the positive supply conductor 62 through conductor 78, contact members 33 and 34 of the primary relay 27, conductor 97, the winding of relay 24 and conductor 80 back to the negative supply conductor 63.

Thus energized, the relay 24 moves to its circuit closing position completing, through contact member 99, an energizing circuit for the motor 22 that extends from the positive supply conductor 62 through the conductor 83, the armature and field windings 84 and 100 of the motor, contact members 99 of relay 24, and conductors 87 and 88 to the negative supply conductor 63. Thus energized, the motor 22 operates the rheostat 20 in a direction to decrease its resistance and to decrease the generator voltage.

In the event that the decrease in the generator voltage to be corrected is large, the primary relay 27, in addition to closing the contact members 33 and 34, will also move the contact member 37 into engagement with the contact member 38, thereby completing an energizing circuit for the

auxiliary relay 40 that extends from the positive supply conductor 62 through conductor 78, contact members 37 and 38 of the primary relay, conductor 102, the winding of the relay 40, and conductor 80 to the negative supply conductor 63.

Thus energized, the relay 40 actuates the contact member 40*b* to complete the energizing circuits hereinbefore traced for contactors 51 and 52. Since the manner in which these contactors operate to short circuit the rheostat 20 and the resistor 57 in minimum time has been completely described above, a repetition of this explanation will not be made here.

The short circuit last mentioned will be maintained until the regulated voltage has been raised to such extent that the contact members 37 and 38 of the primary relay 27 disengage, at which time the relay 40 is deenergized and the contact member 40*b* interrupts the energizing circuit for the contactor 52 allowing this contactor to open and remove the short circuit in the manner already explained. From this point, further correction in the regulated voltage is effected through the operation of the rheostat 20 in the usual manner.

Combinations of a light duty and a heavy duty contactor to secure faster action in the control of a circuit in shunt relation to a resistor in an electric circuit other than the particular one shown and described in connection with Fig. 1 may be made. Thus, a second preferred embodiment of our invention providing such a combination is shown in Figs. 3 and 4.

In Fig. 3, only those portions of the regulating system illustrated in Fig. 1, directly associated with the two contactors under consideration have been represented, while in Fig. 4, the control circuits illustrated in Fig. 3 are shown in simplified schematic form to better indicate their operation.

In this embodiment, the light and heavy duty contactors, represented at 106 and 107, respectively, have their main contact members 106*b* and 107*b* connected in series-circuit relation instead of in parallel circuit relation, as in the embodiment of Figs. 1 and 2. As illustrated, the light duty contactor 106 comprises, in addition to the normally open main contact member 106*b*, an actuating winding 106*a*, and three auxiliary contact members 106*c*, 106*d* and 106*e*.

The heavier-duty contactor 107 comprises, in addition to the normally-closed contact member 107*b*, two separate actuating windings 107*a* and 107*c* and an auxiliary contact member 107*d*. The energization of the windings, 107*a* or 107*c*, causes the contactor 107 to move to its illustrated or circuit closing position.

In the operation of the system illustrated in Figs. 3 and 4, the heavy duty contactor 107 is normally maintained in its energized position, as shown, while the light duty contactor 106 is normally in its deenergized position.

The contactor 107 is maintained in this closed position by energizing the winding 107*c* through a circuit that extends from the positive supply conductor 62 through conductor 116, auxiliary contact member 106*e* of the contactor 106, conductor 117, the winding 107*c* and resistor 118 to the negative supply conductor 63.

The initiation of a voltage-raising impulse, in effecting the closure of the contact member 40*b* of the auxiliary relay 40, completes an energizing circuit for the contactors that extends from the positive supply conductor 62 through the conductor 65, contact member 40*b*, conductor 110, the winding 107*a* of relay 107 and conductor 111 to the negative supply conductor 63, and also from the conductor 110 through the normally-closed contact member 106*c* of the relay 106, conductor 113, the winding 106*a* of contactor 106, and conductor 114 to the negative supply conductor 63.

Thus energized, the contactor 106 moves its contact members to their circuit closing positions, completing, through the contact member 106*b*, the desired short circuit around the rheostat 20 and the resistor 57 and establishing, through the contact member 106*d*, a holding-in circuit that extends from the positive supply conductor 62 through the conductor 120, auxiliary contact member 107*d* of the contactor 107, conductor 121, contact member 106*d* of the contactor 106, conductor 113, the winding 106*a* of the contactor 106, and conductor 114 to the negative supply conductor 63.

The actuating winding 107*a* of the contactor 107 is now energized, and the contactor is maintained in its closed position independently of the opening of the energizing circuit for the winding 107*c*, by the action of the contact member 106*e*. Thus, both of the contactors 106 and 107 are maintained closed so long as the voltage-raising impulse persists.

A discontinuance of the impulse causes an interruption of the contact member 40*b* and thus deenergizes the actuating winding 107*a* of the contactor 107. The contactor 107 is thus allowed to move to its circuit opening position to interrupt the shunt circuit around the rheostat 20 and the resistor 57 through main contact member 107*b*. This operation of the contactor 107 also, by means of the auxiliary contact member 107*d*, deenergizes the actuating winding 106*a* of contactor 106 and thereby permits the contactor 106 to open.

It will be recognized that the light duty contactor 106 can open, however, only after the heavy duty contactor 107 has interrupted the short circuit about the excitation control resistance. In opening, contactor 106 reestablishes, through the contact member 106*e*, the energizing circuit for actuating the winding 107*c* of the heavy duty contactor 107, and thus causes this contactor to reclose to be ready for another operation of the type just described in detail.

It will be apparent that still further modifications of the control circuit and contactor arrangements are possible in attaining the higher-speed short-circuit operation feature already described.

Although we have shown and described certain specific embodiments of our invention, we are fully aware that other modifications thereof are possible. Our invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. In a regulating system, a dynamo-electric machine, an excitation control circuit for said machine, a resistor in said circuit, a light-duty contactor for short-circuiting said resistor, a heavy-duty contactor for interrupting said short circuit, and means responsive to predetermined voltage conditions of said machine for controlling said contactors.

2. Regulating apparatus for an electrical generator having a field winding, an excitation control circuit for said field winding including a resistor, regulator means for controlling said circuit in accordance with an electrical condition of said generator, a quick-acting contactor con-

trolled to short circuit said resistor upon a predetermined operation of said control regulator means, and a slower-acting contactor controlled to open said short circuit upon a second predetermined operation of said regulator means.

3. In a regulating system comprising a current-carrying circuit, a resistor in said circuit, two contactors and a control circuit therefor, the first of said contactors being effective to close a circuit in shunt relation to said resistor upon the closing of said control circuit, and the second of said contactors being disposed to interrupt said shunt circuit upon the interruption of said control impulse.

4. In combination, an electrical generator, an excitation control circuit for the generator, a resistor connected in said circuit, means for producing a control impulse when the voltage of said generator decreases below a predetermined value, a contactor disposed to establish a shunt circuit around said resistance upon the initiation of a control impulse, and a second contactor disposed to interrupt said short circuit upon the discontinuance of the control impulse.

5. In combination, an electrical generator, an excitation control circuit for the generator, a resistor connected in said circuit, means for producing a control impulse when the voltage of said generator decreases below a predetermined value, a contactor for establishing a shunt circuit around said resistance upon the initiation of a control impulse, and a second contactor for interrupting said shunt circuit upon the discontinuance of the control impulse, said first-named contactor being of a light-duty, quick-acting type, and said second-named contactor being of heavier-duty slower-acting type.

6. In a regulating system, a controlled circuit, a pair of contactors so connected that the closing of either completes said circuit, the first of said contactors being faster in its operation than the second, a control circuit for the contactors, means effective upon the completion of said control circuit for causing both contactors to close, means for releasing said first contactor upon the closure of the second contactor, and means for retaining said second contactor in its circuit closing position until said control circuit is interrupted.

7. In a regulating system, a controlled circuit, a pair of contactors so connected that the closure of either completes said circuit, the first of said contactors being faster in its operation than the second, an actuating winding for each contactor, a control circuit for energizing said contactor actuating windings of both contactors for causing both contactors to close, means actuated upon the closure of the second contactor for deenergizing the actuating winding of the first contactor and allowing it to open, means for maintaining the actuating winding of the second contactor energized so long as the control circuit persists, and means for causing the second contactor to open upon an interruption of said control circuit.

8. In a regulating system, a circuit, a pair of contactors so connected that the closure of both is required to complete said circuit, the first of said contactors being faster in its operation than the second, a control circuit for actuating the contactors, means for normally maintaining said second contactor in its circuit closing position, means effective upon the closure of said control circuit for causing said first contactor to be actuated to its circuit closing position, means effective upon the interruption of said control circuit for releasing said second contactor, means actuated upon the opening of said second contactor for releasing the first contactor, and means actuated upon the opening of the first contactor for causing the closing of the second contactor.

9. In a regulating system, a circuit, a pair of contactors so connected that the closure of both is required to complete said circuit, the first of said contactors being faster in its operation than the second, said first contactor being provided with an actuating winding, said second contactor being provided with two independent actuating windings, a source of control impulses for said contactors, means whereby one winding of said second contactor is energized when the first contactor is in its open circuit position to maintain the second contactor closed, means whereby the initiation of a control impulse energizes the actuating winding of the first contactor and the second winding of the second contactor and thereby effects closure of the first contactor, means whereby the interruption of said control impulse deenergizes only the actuating winding of the second contactor and allows it to open, and means whereby the opening of said second contactor denergizes the winding of the first contactor allowing it to open, the opening of the first contactor re-energizing the first winding of the second contactor thereby causing it to reclose.

HOMER C. NYCUM.
JOHN H. ASHBAUGH.