R. E. HELLMUND.

SYSTEM OF CONTROL.

APPLICATION FILED OCT. 16, 1918.

1,343,211. Patented June 15, 1920.

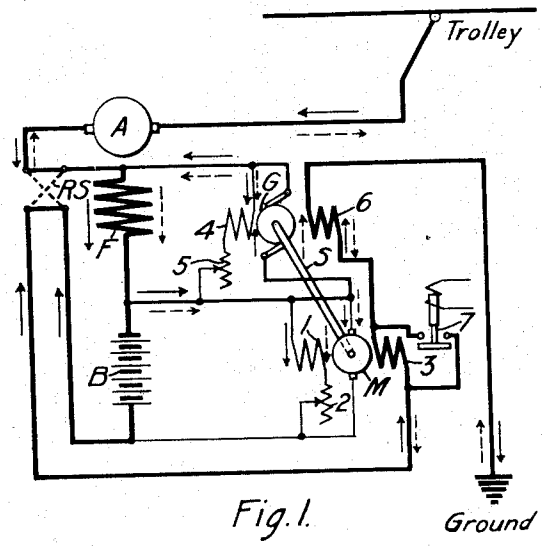

Fig. 1.

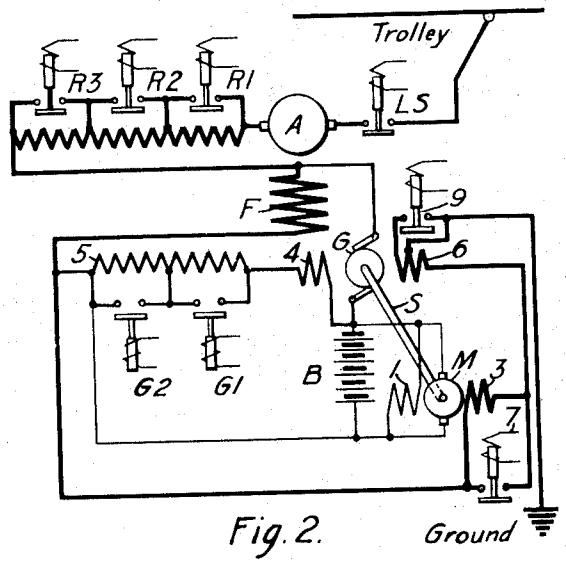

Fig. 2.

Switches	LS	R1	R2	R3	G1	G2	9
a	○				○	○	
b	○	○			○	○	
c	○	○	○		○	○	
d	○	○	○	○	○	○	
e	○	○	○	○	○		
f	○	○	○	○			
g	○	○	○	○			○

Position

Fig. 3.

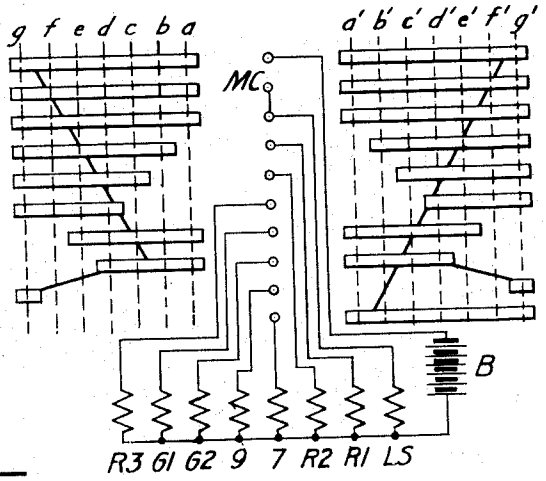

Fig. 4.

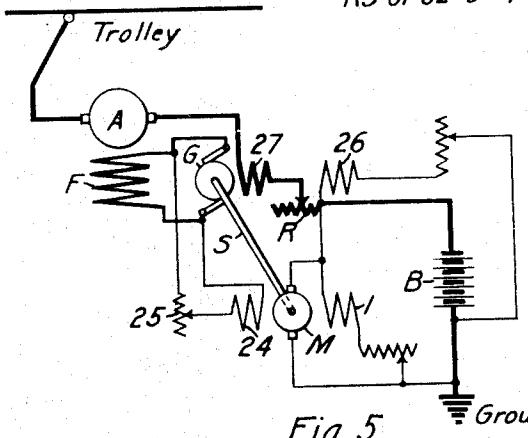

Fig. 5.

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SYSTEM OF CONTROL.

1,343,211. Specification of Letters Patent. Patented June 15, 1920.

Original application filed October 24, 1916, Serial No. 127,381. Divided and this application filed October 16, 1918. Serial No. 258,443.

To all whom it may concern:

Be it known that I, RUDOLF E. HELLMUND, a citizen of the German Empire, and a resident of Swissvale, in the county of Allegheny and State of Pennsylvania, have invented a new and useful Improvement in Systems of Control, of which the following is a specification, this application being a division of application Serial No. 127,381, filed October 24, 1916, patented Oct. 28, 1919, No. 1,320,053.

My invention relates to systems of control for dynamo-electric machines, and it has special relation to the regenerative control of electric motors that are adapted for use in propelling electric railway vehicles and the like.

One object of my invention is to provide simple, durable and reliable means for effecting regenerative operation of the momentum-driven armatures of motors of the above-indicated character, whereby a certain proportion of the energy absorbed during the propelling period is returned to the supply circuit, to reduce operating expenses, and whereby various other well-known operating advantages are secured.

Another object of my invention is to provide a system of regenerative control which shall embody means for automatically compensating for the unavoidable voltage fluctuations in the supply-circuit voltage, whereby a substantially constant regenerated current is maintained during such fluctuations.

More specifically stated, an object of my invention is to provide a motor-generator set or dynamotor of relatively small capacity for variably energizing the main series field magnet winding of the propelling motor or motors during regenerative operation. The set may be driven either from the regenerative circuit or from a suitable external source of energy.

Viewed from another angle, it is an object of my invention to provide a regenerative system employing substantially constant main-field winding excitation that is essentially independent of the supply circuit voltage, but is dependent upon the regenerated current for purposes to be set forth.

The various novel circuit arrangements and connections employed in my invention may best be understood by reference to the accompanying drawings, in which Figures 1, 2 and 5 are diagrammatic views of the main circuit connections of various control systems embodying my invention; Fig. 3 is a chart, of well-known form, indicating the sequence of operation of the various motor-controlling switches shown in Fig. 2; and Fig. 4 is a diagrammatic view of an auxiliary control system for operating the system of Fig. 2 in accordance with the chart, Fig. 3.

Like reference characters designate like parts in all of the figures.

Referring to Fig. 1 of the drawings, the system here shown comprises a supply circuit that includes a supply conductor marked "Trolley" and a return circuit conductor marked "Ground"; a dynamo-electric machine, such as a direct-current railway motor, for example, having an armature A and a series-type field winding F; and an auxiliary motor-generator set comprising a motor M that is supplied with propelling energy from a suitable source, such as a battery B, and a generator or exciter G, that is suitably mechanically connected to the motor M, as by a shaft S.

The motor M is provided with a shunt field magnet winding 1, the strength of which may be varied by a suitable resistor 2, and a series-type field winding 3, that is connected in series-circuit relation with the armature A. The generator G has a shunt field winding 4 and a variable resistor 5, and is connected to energize the field winding F of the propelling motor, thereby imparting a compounding characteristic thereto during regeneration. A series-type field winding 6 for the generator G is also connected in series relation with the main armature A, and is suitably differentially-wound with respect to the shunt field winding 4, thus acting in opposition thereto.

In Fig. 1, the circuits of the motor M and the generator G are interconnected and a reversing switch RS is conveniently interposed between the armature A and the circuits that include the field winding F and the entire motor-generator set. The series field winding 3 of the motor M may be wholly or partially short-circuited by one or more switches 7 for purposes of control.

The general operation of the system of Fig. 1 is as follows: During motor accelera-

tion, the current traverses the system as indicated by the solid arrows, and the reversing switch RS occupies the solid line position. For regenerative operation, the electrical relation of the series-connected field winding F is reversed with respect to the armature A, by throwing the reversing switch RS to the dotted-line position. It will be understood that the particular system for accelerating the motor is not material to my present invention, and that any suitable system may be employed.

Assuming the system to be connected as shown and that the armature A is driven by the momentum of the associated vehicle at a speed suitable for regeneration to the supply circuit, the operation of the system, relative to compensation for supply-circuit voltage fluctuations, may be described as follows: If the supply-circuit voltage decreases, the regenerated current will correspondingly increase because of the relatively great difference between the momentum-driven machine voltage and the voltage of the supply circuit. The field flux of the shunt motor M will, consequently, be strengthened through the increased energization of the series field winding 3, thereby decreasing the speed of the motor-generator set, in accordance with well-known principles. The output of the generator G, that is to say, the excitation of the main machine field winding F, is correspondingly decreased, thereby tending to maintain a substantially constant value of regenerated current. Furthermore, the temporary increase of regenerated current, in addition to the slowing-down effect on the motor-generator set, also serves to decrease the effective field flux of the generator G by reason of the differential action of the series and shunt field windings thereof. The excitation of the series field winding F is thus again decreased, with the desired effect of maintaining a substantially constant regenerated current. Modifications of the system illustrated, by omitting certain of the field windings of the motor-generator set, may be employed in some instances, dependent upon operating conditions.

Fig. 2 illustrates a system that is adapted for "field control" and regenerative control, and is dependent upon the differential action between a battery and a small exciter that is driven by a motor. The system comprises a suitable supply circuit as previously described; the armature A: series field winding F; a motor-generator set similar to that shown in Fig. 1; a main circuit resistor, the sections of which are adapted to be respectively short-circuited by switches R1, R2 and R3; line switch LS; the switch 7 for short-circuiting the series field winding 3; a switch 9 for short-circuiting a portion of the series field winding 6; and a plurality of switches G1 and G2 for short-circuiting sections of the auxiliary generator field-circuit resistor 5.

Assuming that the motor-generator set operates at a substantially constant speed, the relative voltages of the battery and the motor-generator set may, for instance, be chosen in such manner that, when the shunt field winding 4 of the generator G is alone active, that is to say, with no load on the main motor, the voltage of the generator armature is equal and opposite to the battery voltage, and, therefore, the main motor has zero field excitation. However, when the main motor is operative and is consuming current from the supply circuit, the generator series field winding 6 is designed to oppose or counteract the shunt field winding 4, thereby decreasing the generator voltage to a value that is less than the voltage of the battery, whereupon the battery will energize the main series field winding F, the energization varying directly with the main motor load.

If desirable, the shunt and series field windings of the small motor M may be differentially wound to cause an increased motor speed with increased main motor load, thus changing the operating characteristics of the main motor, as will be understood.

As indicated by the sequence chart of Fig. 3, and in the auxiliary control system of a familiar type that is illustrated in Fig. 4, the main motor is accelerated by initially short-circuiting the main circuit resistor, and subsequently weakening the field flux of the generator G by opening switches G1 and G2. The short-circuiting of a portion of the series field winding 6, by the closure of the switch 9, further weakens this field flux, to cause an additional increase in main motor speed.

During regeneration, the same motor-controlling steps may be made, the series field winding 3 of the small motor M being preferably permanently short-circuited by the closure of the switch 7, as indicated in Fig. 4.

Referring now to Fig. 5, the system shown comprises the supply-circuit conductors respectively marked "Trolley" and "Ground," the main motor armature A and field winding F, an auxiliary motor-generator set including a motor M and a generator G, a battery B, and a main circuit accelerating resistor R. The motor M is supplied with energy from the battery B and is provided with a variable shunt field winding 1, and a second field winding 24 that is connected in series circuit with a variable resistor 25 across the main field winding F. The generator G has its armature connected to excite the field winding F, and is provided with a variable field winding 26, which is

connected across the battery B, and a second field winding 27 that is connected in series circuit with the main armature A.

The regenerative operation of the system may be briefly described as follows: Regulation of the regenerated current may be effected by suitable manipulation of the resistor R or the resistor 25, to vary the field current of the generator G or of the motor M, respectively, or by variation of the current in the field winding 1 or the field winding 26, as will be understood. For a given direction of rotation of the main motor, the excitation of the field winding 24 will remain constant in direction, by reason of its association with the main field winding F, and thus cannot have a negative compounding effect upon the small motor, to cause an undesirably high speed thereof.

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. In a system of control, the combination with a supply circuit and a main dynamo-electric machine having an armature and a field winding, of a plurality of auxiliary mechanically-connected armature windings respectively acting as driving means and as an exciter for said main field winding, and an energy-accumulating device connected in series circuit relation with said main armature and field winding between the supply circuit conductors and adapted to energize said driving armature, the latter having field windings respectively energized by the device and the main-machine current.

2. In a system of control, the combination with a supply circuit and a main dynamo-electric machine having an armature and a field winding, of a plurality of auxiliary mechanically-connected armature windings respectively acting as driving means and as an exciter for said main field winding, and means connected in series-circuit relation with the main armature and field winding between the supply-circuit conductors for supplying energy to said driving armature, the latter having field windings respectively energized by the last-named means and the main-machine current.

3. In a system of regenerative control, the combination with a supply circuit and a main dynamo-electric machine having an armature and a field winding, of a plurality of auxiliary mechanically-connected armature windings respectively acting as driving means and as an exciter for said main field winding, low-voltage means connected in series relation with the main armature between the supply-circuit conductors for supplying energy to said driving armature, and means for causing the exciter voltage to vary in the opposing direction to changes of regenerated current.

4. In a system of control, the combination with a supply circuit, and a momentum-driven armature of a dynamo-electric machine having a series field-magnet windings, of an auxiliary generating dynamo-electric machine connected to energize said field winding, an independent source of energy, a driving motor for said auxiliary machine receiving energy from said source and having a field-magnet winding connected in parallel-circuit relation with said series field winding, and means for varying the amount of energy delivered to the series field winding from the auxiliary machine to vary the regenerated current.

5. In a system of control, the combination with a supply circuit and a main dynamo-electric machine having an armature and a field winding, of a plurality of auxiliary mechanically-connected armature windings respectively acting as driving means and as an exciter for said main field winding, and a plurality of field windings for the auxiliary armatures respectively energized in accordance with the main-field-winding voltage and the main-armature current.

6. In a system of control, the combination with a supply circuit and a main dynamo-electric machine having an armature and a field winding, of a plurality of auxiliary mechanically-connected armature windings respectively acting as driving means and as an exciter for said main field winding, an energy-accumulating device connected in series relation with the main armature for supplying energy to said driving armature, field windings for the respective auxiliary armatures energized from said device, and other field windings for the auxiliary armatures respectively energized in accordance with the main-field-winding voltage and the main-armature current.

In testimony whereof, I have hereunto subscribed my name this 30th day of Sept., 1918.

RUDOLF E. HELLMUND.