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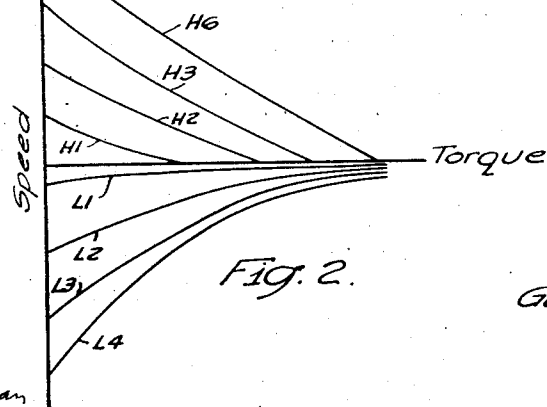
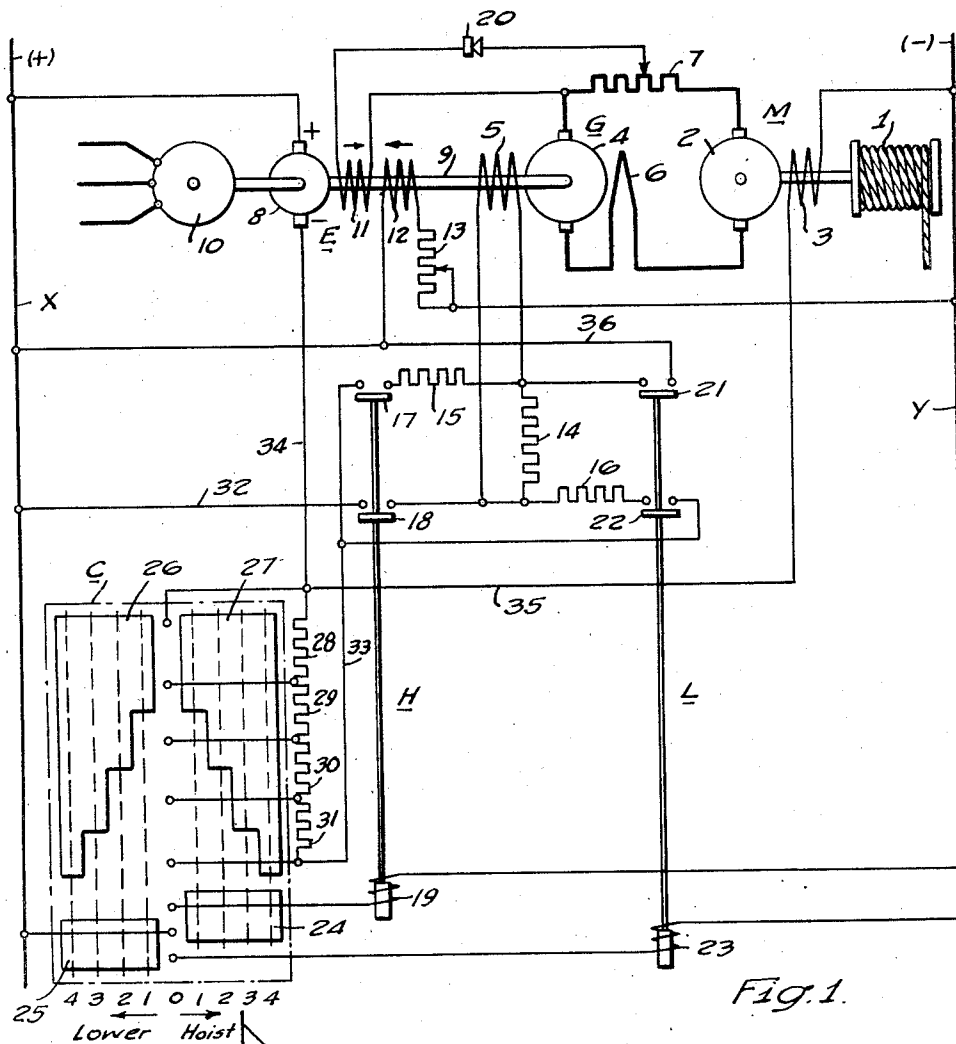
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2,456,950

ELECTRIC HOIST CONTROL SYSTEM

Filed Dec. 27, 1947

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 3.

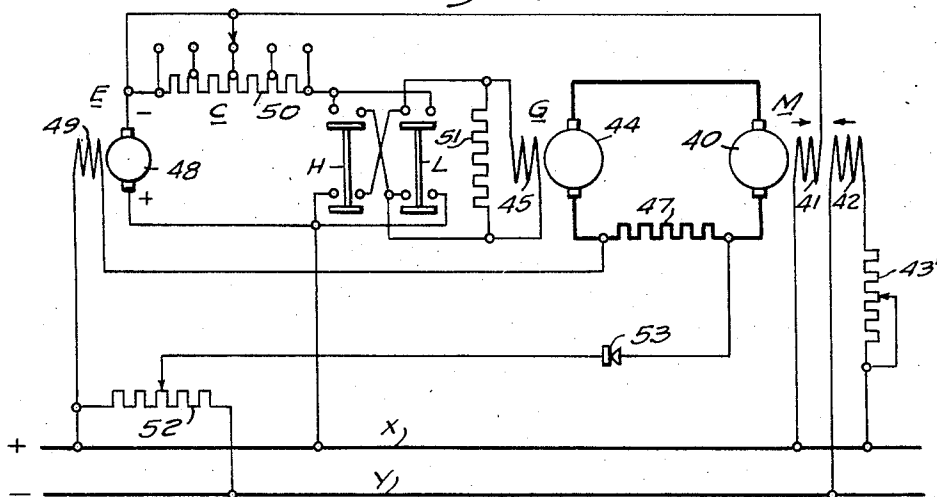
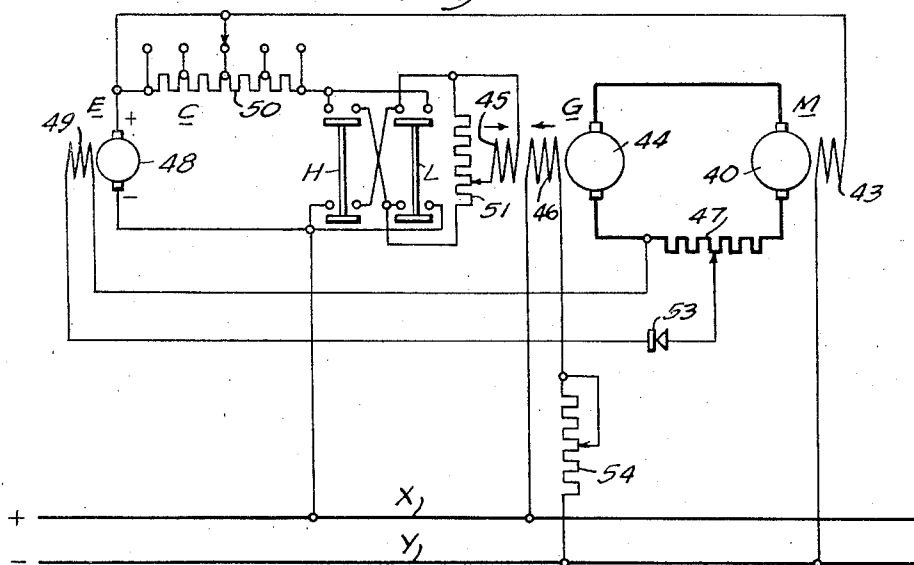


Fig. 4.



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2,456,950

ELECTRIC HOIST CONTROL SYSTEM

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Application December 27, 1947, Serial No. 794,165

6 Claims. (Cl. 318—154)

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My invention relates to electric control systems for hoisting equipment, such as used on cranes, elevators, lift-bridges, lifting or winch machinery for marine purposes, mine hoists and the like.

Such hoisting equipment must satisfy various operating conditions which, for special applications, may involve an appreciable number of diversified requirements. A hoist drive for cranes, for instance, may have to satisfy the following requirements.

When hoisting at lowest speed, the speed should be very low at minimum or no load and the stalled torque should be relatively high. The maximum hoisting speed at no load should not exceed a predetermined value; and in the last-point hoisting position of the master controller, the stalled torque should remain below an adjusted overload limit.

When lowering, a proper positioning of the master controller should cause the motor either to produce drive-down torque or to retard the load by up-torque, depending upon whether or not the load is overhauling. The maximum lowering speed at no load should be a desired predetermined value, and the speed when lowering under load for any selected positioning of the master controller, should be the smaller the higher the load. It is also desired that the control system, when hoisting maximum load, remains capable of providing sufficient braking torque for securing a reliable lowering of the same load. On the other hand, the control system should not cause stalling during lowering performance.

The system should secure a reasonably safe performance even if the adjustment of the master controller is changed more rapidly than desired, and should brake and stop the motor in the event of power failure.

In order to satisfy, within a single hoist control system, many or all of these requirements, the known systems must be given a rather complicated design composed of a large number of circuit elements or circuit sections and involving a large number of contactors and relays. Another known system provides the desired characteristics with the aid of an exciter generator of special design which has two individually excited magnetic flux paths with crossed flux axes. The output voltage of such a cross-flux exciter has always the same polarity regardless of the polarity of excitation applied to the control field winding.

In contrast thereto, it is an object of my invention to devise hoist control systems that permit achieving many or even all above-mentioned de-

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siderata with the aid of a comparatively very simple control system which involves a minimum of relay and other auxiliary equipment, and which does not require using cross-flux excited or other special dynamos thus affording a less costly design and simple maintenance requirements.

According to one feature of my invention, I provide a Ward-Leonard type drive whose generator field and motor field are varied in inverse relation to each other by an exciter generator of normal voltage characteristic, i. e. whose flux has symmetrical distribution and varies in the same manner in all field poles and whose output voltage has a polarity determined by that of the exciter control field as is the case in conventionally excited direct-current generators; and I interconnect the motor, generator and exciter in the manner apparent from the following description of the embodiments shown in the drawing.

Figure 1 represents the circuit diagram of a crane hoist drive capable of satisfying all above-mentioned requirements;

Fig. 2 is an explanatory coordinate diagram of speed-torque characteristics obtainable with a system according to Fig. 1; and

Figs. 3 and 4 show circuit diagrams of two other embodiments, respectively.

According to Figure 1, the hoist drum 1 of a crane is connected to the armature 2 of a hoist motor M whose field winding is denoted by 3. Armature 2 is connected in a loop circuit with the armature 4 of a main generator G. Generator G has a separately excited main field winding 5 and an auxiliary series field winding 6. A rheostat 7 is series-connected in the loop circuit. Excitation for field winding 5 is provided by a regulating generator or exciter E, whose armature 8 is mounted on the shaft 9 of generator armature 4, the shaft being driven by an auxiliary motor 10 at substantially constant speed. It may be preferable, however, to provide a separate constant-speed motor for driving the exciter E independent of the generator G. The exciter E has two field windings 11 and 12 which operate in differential relation to each other. The field winding 11 (pilot field winding) is connected across a tapped-off portion of the rheostat 7 and hence is excited in proportion to the load current flowing in the loop circuit. A valve or rectifier may be provided at 20. The field winding 12 (pattern field winding) receives excitation in series with an adjusting rheostat 13 from the buses X and Y of a suitable source of substantially constant direct-current voltage.

Field winding 5 of the main generator G is connected across a resistor 14 which is associated with resistors 15 and 16. The resistance arrangement is controlled by a "hoist" contactor H and a "lower" contactor L. Contactor H has two contacts 17 and 18 controlled by a coil 19, and contactor L has two contacts 21 and 22 under control by a coil 23.

A master controller C with an "off" position, four sequential "hoist" positions, and four sequential "lower" positions, is equipped with contact segments 24 and 25 for controlling the respective circuits of contactor coils 19 and 23. Two other segments 26 and 27 serve to control a group of series-connected resistors denoted by 28, 29, 30 and 31. The master controller is shown in developed form, as customary. A number of leads appertaining to the motor control system are denoted by 32 through 36 and will be referred to in the description of the operation given in a later place. Safety limit switches and other auxiliary devices, including a magnetically released brake, may be used as customary but are not shown in the drawing because they do not form part of the invention proper.

In the above-described system, the motor M forms part of the variable voltage or Ward-Leonard system in which the controlling field excitation for the main generator G is provided by the exciter generator E in a circuit which includes the operator controllable resistors 28, 29, 30 and 31 in series connection. The voltage generated by the exciter depends on the differential value of the control excitation provided by the field windings 11 and 12. The excitation of the field winding 12 remains constant at an adjusted value during the operation of the system. Since the field winding 11 is excited proportionally to the armature current of the Ward-Leonard system, the pattern field of the winding 12 is unopposed under no-load conditions of the Ward-Leonard system. The rheostat 13 is so adjusted that under these conditions the voltage generated in the exciter armature 8 has the desired maximum value. The rheostat 7 is adjusted so that, at maximum desirable overload of the hoist motor M, the ampere turns of the pilot field winding 11 equal the ampere turns of the pattern field winding 12 so that the armature voltage of the exciter E is zero.

Since under no-load conditions the field excitation of the exciter E is constant, the voltage effective across the main generator field winding 5 then depends only upon the total resistance value of the resistor group 28 to 31. Hence, the speed of the hoist motor M under no-load conditions is determined by the selected position of the master controller C.

The motor field winding 3 is connected across the constant voltage mains X and Y in series-opposed connection with the exciter armature 8 so that the exciting voltage for field winding 3 is equal to the difference between the constant voltage of mains X and Y and the variable exciter voltage. The field circuit is designed so that with maximum exciter voltage the motor M will operate at twice full field speed. At the exciter voltage obtained with full load on the hoist motor M, the motor field winding 3 is at full field value, and at maximum overload the motor field is stronger than full field to provide maximum torque and slowest operating speed.

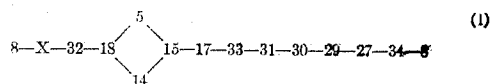
When hoisting a load, the exciter voltage is a function of the load, and the circuit of the Ward-Leonard system is adjusted so that the

motor M will stall when the desired maximum load is exceeded. When lowering a load, the load will cause the motor M to regenerate so that the load current is in the same direction as when hoisting. The exciter voltage is then again a function of the hoist motor load.

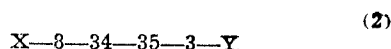
A family of speed torque characteristics for hoisting operation in the four hoist positions of the master controller is shown in Fig. 2 and denoted by H1, H2, H3 and H4, respectively. A corresponding family of characteristics for lowering operations is represented by curves L1, L2, L3 and L4 in Fig. 2. The shape of these curves can be altered within limits by changing the design of the circuit elements, for instance by using an exciter generator E with a differently shaped magnetic saturation characteristic.

A detailed description of hoisting and lowering operations follow. In the "off" position of the master controller C, with mains X and Y energized and the motor generator set G-E running at the proper speed, motor M remains at rest because the armature voltage of main generator G is zero since the main generator field winding 5 is not excited.

When the master controller is placed in first "hoist" position, contactor H picks up and closes contacts 17 and 18. Resistor 14 and the parallel-connected field winding 5 are now energized in the circuit:



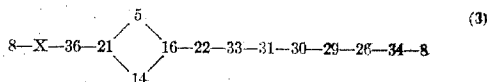
The voltage generated in armature 8 of the exciter E is now effective across resistor 14 and field winding 5 through the series resistors 28, 30 and 31. Motor field winding 3 is now connected in the circuit:



The motor now operates in the hoisting direction at low speed, for instance in accordance with the characteristic H1 in Fig. 2.

When the master controller C is moved to subsequent hoist positions, the field circuit (1) of the main generator remains the same except that the resistors 29, 30 and 31 are progressively shorted out of the circuit. Hence, the voltage across resistor 14 and field winding 5 is progressively increased for producing a higher voltage of the main generator G. The field circuit (2) for motor M remains the same. The motor now operates substantially in accordance with the hoist characteristics H2, H3 or H4 (Fig. 2) depending upon the selected position of the master controller.

When setting the master controller to first position lowering, contactor L picks up and connects the resistor 14 with field winding 5 across the exciter armature 8 in the circuit:



This generator field circuit is similar to circuit (1) except that the polarity of connection for field winding 5 is reversed and that the resistor 15 is replaced by the resistor 16 which is differently rated to adjust a reduced field excitation for generator G as desirable for lowering operation. As mentioned above, the resistance calibration is now such that the motor operates regeneratively under underhauling load so that

the load responsive control of the exciter generator E leads to the desired lowering characteristics, such as those exemplified by curves L1, L2, L3 and L4 in Fig. 2.

The embodiments illustrated in Figs. 3 and 4 are represented by simplified diagrams in which a master controller C is merely shown as a step-wise adjustable rheostat while the contactors H and L are indicated only by the appertaining contacts, it being assumed that the two contactors are controlled by the master controller in substantially the same manner as in the system shown in Fig. 1 and described in the foregoing.

In Fig. 3, the armature of the motor to be controlled is denoted by 40. The motor has two mutually differential field windings 41 and 42. Field winding 42 is connected across the positive bus X and the negative bus Y of a suitable source of direct current of substantially constant voltage. Field winding 42 provides main excitation for the motor and its voltage is adjusted by a resistor 43' to provide the full rated motor field when the excitation of field winding 41 is zero. Hence, field winding 41 merely provides a subtractive effect which, when in full force, reduces the resultant field excitation to a predetermined minimum value. The armature of the generator G energizing the motor armature is denoted by 44, and the appertaining main field winding by 45. The common armature circuit of motor and generator includes a series resistor 47. The exciter E whose armature is denoted by 48 is equipped with a single field winding 49. Exciter armature 48 is connected to the main generator field winding 45 in series with the adjustable resistor 50 of the master controller C and in parallel with a resistor 51. The polarity of connection is controlled by the hoist and lowering contactors H and L. The control field winding 49 of exciter E is connected in the output branch of a differential control circuit which has two pairs of input terminals. One pair of terminals is attached to the buses X and Y in order to provide a normally constant control voltage across the tapped-off portion of a voltage-dividing rheostat 52. The other pair of terminals is attached across the resistor 47 in order to provide a variable control voltage upon the current flowing in the common armature circuit of motor and generator. The differential value of the two control voltages is effective across the control field winding 49. A valve or rectifier 53 is inserted between the resistor 47 and the control field winding 49.

When the armature current of motor M is zero, the constant control voltage from rheostat 52 is alone effective to excite the control field winding 49. Consequently, the exciter now receives maximum field excitation and generates maximum voltage across its armature 48. This voltage is applied across the field winding 41 of motor M. Consequently, field winding 41 has maximum opposing effect relative to the main field winding 42 of the motor, and the resultant motor field has a minimum value. At the same time, the exciter voltage is applied to the field winding 45 of generator G so that the generator field excitation for any selected adjustment of the master controller C is a maximum. On the other hand, with a high current flowing in the armature circuit of motor and generator, the control voltage across resistor 47 has a correspondingly high value which acts differentially with respect to the constant control voltage from rheostat 52 so that the excitation of field wind-

ing 49 is reduced. The voltage generated by the exciter armature 48 is also reduced so that the motor field winding 41 receives less excitation. As a result, the resultant field excitation of motor M is increased. At the same time, the excitation of generator field winding 45 is reduced. Consequently, the motor field and generator field are varied by the exciter E in inverse relation to one another. In this respect, the performance of the system resembles that of Fig. 1 so that the same functions and advantages are obtained.

In the embodiment of Fig. 4, the motor M has a field winding 43 excited from the constant voltage buses X and Y and also from the armature 48 of the exciter E. Similar to the embodiment of Fig. 1, the exciter armature 48 is series-connected between the motor field winding 43 and the buses X, Y. However, in contrast to Fig. 1, the polarity of connection of the exciter in Fig. 4 is such that the exciter voltage acts in a cumulative or boosting sense relative to the constant voltage across the buses. That is, the voltage applied to the motor field winding 43 is the sum of the exciter and bus voltages. The armature 40 of motor M is energized from the armature 44 of the generator G in series with a resistor 47 across which the control field winding 49 of the exciter E is attached through a valve or rectifier 53. Generator G has two field windings 45 and 46 which act in opposition to each other. Field winding 45 is connected across a resistor 51 and in series with the resistor 50 of the master controller C from the exciter armature 48 under control by contactors H and L. Field winding 46 receives constant excitation from buses X and Y through a rheostat 54.

When in the control system according to Fig. 4 the current in the armature circuit of motor and generator is zero, the field excitation of the exciter E and the output voltage of the exciter are also zero. Then, the constant excitation from buses X and Y is alone effective in the field winding 43 of motor M in order to provide a minimum field of a desired value. At the same time, the excitation of generator field winding 45 is zero so that the field winding 46 is alone effective to provide the generator with maximum field excitation of a desired value adjusted by the rheostat 54. On the other hand, when the current in the armature circuit of the motor has a high value, the exciter receives high field excitation and generates a correspondingly high exciter voltage. This voltage increases the excitation of motor field winding 43. At the same time, the excitation of generator field winding 45 has a finite value in opposition to field winding 46 so that the resultant generator field is reduced. It will again be recognized that despite differences in design, the motor field and generator field are controlled by the exciter in inverse relation to each other and in substantially the same manner as in the embodiment of Fig. 1 so that a similar performance is achieved.

Referring to all three illustrated embodiments, it should be noted that the rectifier or valve in the control field circuit of the exciter may be omitted if the invention is used for hoists that operate only under overhauling load conditions when lowering. As mentioned above, the direction of current flow in the motor armature circuit during overhauling load, i. e. when motor M is regenerating, is the same as during hoisting performance so that the control field winding of the exciter is excited by voltage of the same polarity even if no valve or rectifier is inserted. If the

hoist is called upon to lower a load under drive-down torque, and if it is desired to control the speed torque characteristic of the drive-down performance in a manner similar to that desired for hoisting operations, a rectifier must be inserted in order to prevent the control field of the exciter from reversing its polarity.

Speed-torque characteristics of the type exemplified by Fig. 2 and obtained in systems according to the invention, are predicated upon operating the exciter E within a properly chosen range of its saturation characteristic. When the resultant control excitation of the exciter has its rated maximum value, the operating point of the exciter should lie within the saturated portion beyond the substantially linear section of the magnetic characteristic, the particular point to be selected in accordance with a desired shape or curvature of the speed-torque characteristics. The proper selection of the operating point at full control field excitation is made by accordingly rating the ampere-turns of the field windings or the applied field voltages or the resistance rating of the field rheostats.

If desired, the inverse field regulation of motor and generator can be made dependent upon the occurrence of a motor armature current above a predetermined minimum value. To this end, a voltage limiting device may be inserted in the control field circuit of the exciter. As a matter of fact, the above-mentioned valves or rectifiers (20 in Fig. 1, 53 in Figs. 3 and 4) function also as such limiting devices. That is, since these rectifiers conduct current only when the voltage across their respective electrodes exceeds a threshold value, an appreciable excitation of the exciter control field occurs only when the current in the motor armature circuit exceeds a finite minimum value. Another possibility afforded by my invention of modifying the control effect at armature currents below a given minimum value, consists in the use of an exciter whose field poles are provided with saturable magnetic shunt paths as disclosed, for instance, in the copending application of J. G. Ivy, Serial No. 532,870, assigned to the assignee of the present invention. Such exciters may be used in any of the illustrated embodiments of my invention instead of the exciter E without change in the circuit connections shown in the drawing and described in the foregoing. Exciters with saturably shunted field poles suppress the generation of an exciter voltage at low control field excitation until the excitation, and the current which causes the excitation, exceed a predetermined value.

The above-mentioned modifications will suffice to show that my invention is capable of being altered in various respects, and it will be obvious to those skilled in the art that the invention can be embodied by circuit designs other than those specifically disclosed, without departing from the essential features of the invention as set forth in the claims annexed hereto.

I claim as my invention:

1. A hoist control system, comprising a direct-current hoist motor having an armature and field means, a main generator having an armature circuit connected with said motor armature to provide variable voltage therefor and having field means for controlling said voltage, an exciter generator of symmetrical field distribution and field-controlled output polarity having an exciter armature connected to said main generator field means and to said motor field means, resistance means and appertaining selective master control

means connected between said exciter armature and said main generator field means for selectively varying the proportion of the exciter voltage applied to said field means of said main generator and motor respectively, a resistor series-connected in said armature circuit, a control circuit connecting said exciter field means across said resistor for controlling said exciter generator in dependence upon the current flowing in said armature circuit, a rectifier disposed in said control circuit for maintaining the exciter output voltage at a given polarity irrespective of the flow direction of said current, direct-current supply means of substantially constant voltage connected to said motor field means and having the polarity of connection required to cause an increase in resultant excitation of said motor field means with increase of said current, circuit means connecting said current supply means with the field means of one of said generators and having the polarity of connection required for causing a decrease in resultant excitation of said main generator field means with increase of said current.

2. A hoist control system, comprising a direct-current hoist motor having an armature and field means, a main generator having an armature circuit connected with said motor armature to provide variable voltage therefor and having a main field winding for controlling said voltage, an exciter connected to said main field winding to provide excitation therefor and having a pattern field winding and a pilot field winding disposed in differential relation to each other to produce a single resultant flux, a resistor series-connected in said armature circuit, said pilot field winding being connected across said resistor to be controlled in accordance with variations of the current flowing in said armature circuit, current supply means of substantially constant voltage connected to said pattern field winding for providing normally constant excitation therefor, resistance means disposed between said exciter and said generator field winding, selective master control means connected with said resistance means for controlling them to selectively vary the excitation of said generator field winding, said exciter and said current supply means being connected in mutually differential relation to said motor field means.

3. A hoist control system, comprising a direct-current hoist motor having an armature and field means, a main generator having an armature circuit connected with said motor armature to provide variable voltage therefor and having a field winding for controlling said voltage, a regulating exciter connected to said generator field winding to provide excitation therefor and having a pattern field winding and a pilot field winding opposing each other, current supply means of substantially constant voltage connected to said pattern field winding for providing normally constant excitation therefor, resistance means series-connected in said armature circuit and attached across said pilot field winding to control said pilot field winding in accordance with the current flowing in said armature circuit, said resistance means having a resistance value rated so that said pilot field winding and said pattern field winding balance each other at a desired minimum overload value of said current, resistance means series-connected between said exciter and said generator field winding, selective master control means connected with said resistance means for controlling them to selectively vary the excitation of said generator field winding, said exciter and

said current supply means being connected in mutually differential relation to said motor field means.

4. A motor control system, comprising a direct-current motor having an armature and a separately excited field winding, a main generator having an armature circuit connected with said motor armature to provide variable voltage therefor and having a field winding for controlling said voltage, a regulating exciter connected to said generator field winding to provide excitation therefor and having a pattern field winding and a pilot field winding opposing each other, current supply means of substantially constant voltage connected to said pattern field winding for providing normally constant excitation therefor, a resistor series-connected in said armature circuit and attached across said pilot field winding to control said pilot field winding in accordance with the current flowing in said armature circuit, said resistor having a resistance value rated so that said pilot field winding and said pattern field winding balance each other at a desired minimum overload value of said current, resistance means series-connected between said exciter and said generator field winding, selective master control means connected with said resistance means for controlling them to selectively vary the excitation of said generator field winding, said exciter and said current supply means being connected in series-opposition to said motor field winding for differentially exciting said latter winding, and said motor field winding having ampere-turns rated to provide full motor field excitation when the voltage of said exciter substantially corresponds to rated full-load current in said armature circuit.

5. A motor control system, comprising a direct-current motor having an armature and field means, a main generator having an armature circuit connected with said motor armature to provide variable voltage therefor and having a main field winding for controlling said voltage, an exciter connected to said main field winding to provide excitation therefor and having a control field winding, current supply means of substantially

constant voltage, a differential control circuit having two pairs of input terminals and a differential output branch, one of said pairs of terminals being attached to said armature circuit to provide a variable control voltage in dependence upon the current flowing in said armature circuit, said other pair of terminals being attached to said current supply means to provide a normally constant control voltage, and said output branch including said control field winding for exciting it in accordance with the differential value of said two control voltages, resistance means disposed between said exciter and said generator field winding, selective master control means connected with said resistance means for controlling them to selectively vary the excitation of said generator field winding, said exciter and said current supply means being connected in mutually differential relation to said motor field means so that said exciter varies the excitation of said motor field means and of said main field winding in inverse relation to each other.

6. A motor control system, comprising a direct-current hoist motor having an armature and field means, a main generator having an armature circuit connected with said motor armature to provide variable voltage therefor and having two mutually differential field windings for jointly controlling said voltage, an exciter having an armature connected to one of said generator field windings to provide excitation therefor and having a control field winding connected to said armature circuit for varying said excitation in dependence upon the current flowing in said armature circuit, current supply means of substantially constant voltage connected to said other generator field winding, said exciter armature and said current supply means being connected to said motor field means in cumulative relation to each other relative to the resultant excitation of said motor field means.

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No references cited.