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ELEVATOR CONTROL SYSTEM

Filed April 12, 1928

Fig. 1.

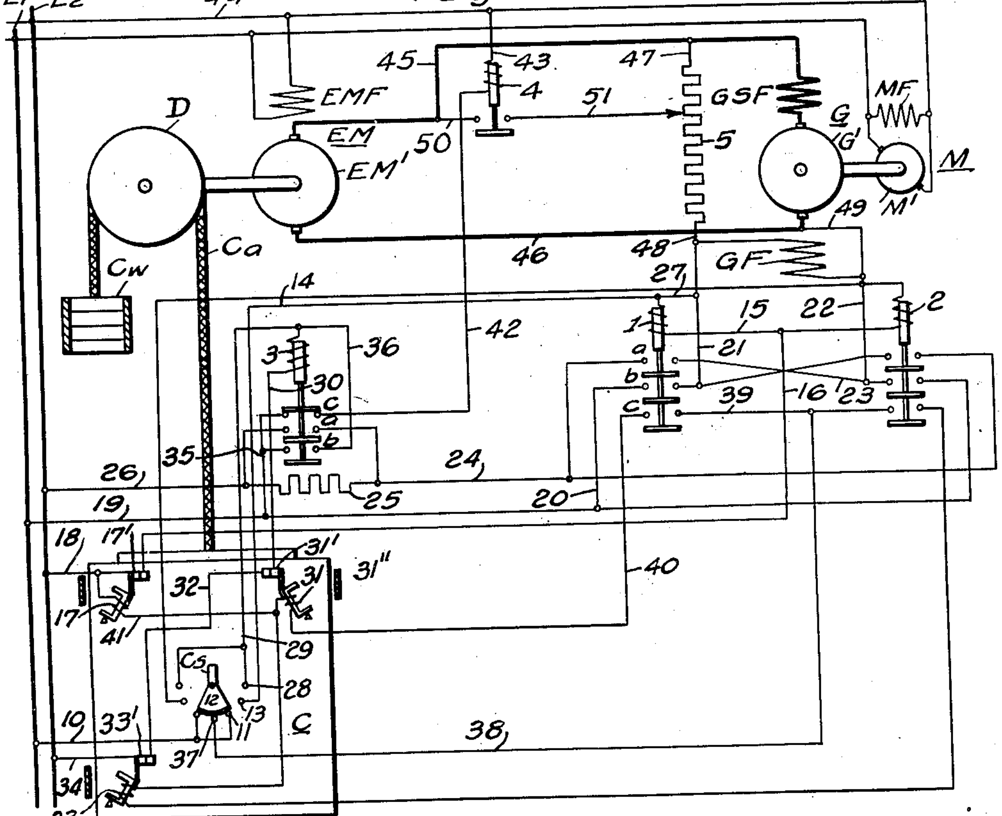
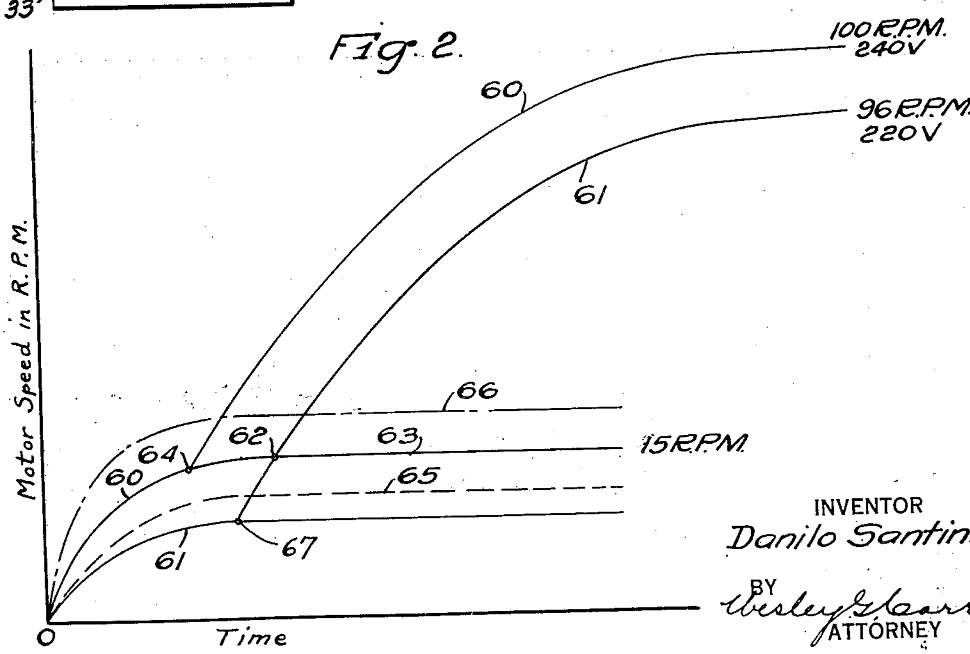



Fig. 2.

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# UNITED STATES PATENT OFFICE

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## ELEVATOR CONTROL SYSTEM

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My invention relates to motor-control systems and has particular relation to control systems, elevator hoists, and the like.

An object of my invention is to provide a control system for elevators operated by Ward-Leonard or variable-voltage drive wherein the driving generator will be self-excited.

Another object of my invention is to provide a control system for elevators of the type using variable-voltage drive wherein the generator is arranged to be self-excited in proportion to the load on the motor to thereby obtain accuracy of speed regulation of the motor at low speeds.

In modern elevator equipment, it is desirable that the elevator shall be operated at the highest practicable speed in order to reduce the running time to the lowest possible value, since the construction of tall buildings requires that the elevator shall travel long distances. With elevators operating at high speeds, the rate of acceleration and deceleration should be as rapid as possible in order to reduce unnecessary loss of time in moving the elevator. Moreover, the time required to accelerate and decelerate should be the same for all conditions of loading in order that accurate stops may be made level with the landings served by the elevator, with a minimum loss of time occasioned by over-running and under-running the floor.

Accuracy of speed regulation of the elevator motor independent of the load in the elevator car provides the attendant with a ready means for determining the position of the car with reference to the floor at which he must initiate deceleration in order to bring the car to an accurate stop level with the floor.

The solution of the problem of accuracy of speed regulation has been attempted in many ways, such as by cumulatively compounding the generator to such degree as will substantially obtain constant-speed regulation and I propose to add to such cumulative compounding a further compounding of the generator by utilizing the main or separately-excited-field winding on the generator as a device for regulating the voltage supplied to the motor in accordance with the load on the motor. The manner in which I propose to accomplish this result is to provide a connection for the generator-separately excited field winding to the elevator-motor armature in such manner that, under the condition of decelerating the motor, this winding will act as a self-excited field winding deriving a portion of its exciting current from the motor and generator-armature terminals. Hence, the degree of self-excitation will depend upon the load on the elevator car and will vary in accordance with variations in the load, and the stopping of the elevator car level with the floor may thus be accomplished with a greater degree of accuracy.

It is obvious that the landing speed of an elevator motor operating under heavy lifting-load conditions should be slightly greater than when operating under heavy overhauling-load conditions, since the time required for deceleration under lifting loads will be shorter than that for overhauling loads due to the influence of gravity on the loaded car. Hence, to make the slow-down distance, that is, the distance between the point of initiating deceleration from the landing speed and the final stopping of the car, will be the same under either overhauling or lifting loads if the effect of gravity is compensated. The utilization of self-excitation for the generator field winding is one method of accomplishing this compensation.

My invention will be described with reference to the accompanying drawings, wherein

Figure 1 illustrates an elevator-control system of the variable-voltage automatic-landing type, and

Fig. 2 is a diagrammatic view of speed-voltage curves illustrating the effect of self-excitation of the generator field winding.

Referring to the drawings, I have illustrated, in Fig. 1, an elevator car C suspended upon a cable *Ca* which passes over a hoisting drum to a counterweight *Cw*. Directly coupled to the hoisting drum D, is the armature EM′ of an elevator motor EM having its field winding EMF connected, for excitation, to a suitable source of power designated by the reference characters L1 and L2. The armature EM′ is connected in loop circuit with the armature G′ of a generator G. The generator G is of the compound-wound type having a separately-excited-field winding GF and a series field winding GSF. The generator G is driven by means of any suitable motor M, illustrated as of the shunt-wound type having an armature M′ and a shunt field winding MF.

The direction and speed at which the elevator car C is to operate is controlled by up and down-direction switches 1 and 2, respectively, and a speed switch 3. The switches are, in turn, controlled through the operation of a car switch *Cs* on the car. The actuation of direction switches 1 and 2 determines the direction of the exciting current supplied to the separately-excited-field winding GF, while the speed switch 3 determines the value of such exciting current. The separately excited field winding GF, in addition to being supplied with exciting current by means of the direction switches, has a connection to the armature EM′ of the elevator motor by means of a circuit containing a relatively high resistance (resistor 5), which normally renders the effect of such connection negligible. To render the field-winding connection to the armature circuit effective, a switch 4 is provided for shunting a portion of the resistor 5.

My system will best be understood with reference to an assumed operation. Assuming that it is desired to start car C upwardly, the car switch *Cs* may be actuated, in a counter-clockwise direction, to supply energizing current to up-direction switch 1. The circuit for up-direction switch 1 extends from line conductor L1, through conductor 10, contact members 11, 12 and 13 on car switch *Cs*, conductor 14, the coil of up-direction switch 1, conductors 15 and 16, normally closed contact members 17′ of a stopping inductor relay 17 and conductor 18, to line conductor L2. Actuation of up-direction switch 1 completes a circuit for exciting separately excited field winding GF for the generator G, which circuit extends from line conductor L1, through conductors 19 and 20, contact members *b* of up-direction switch 1, conductor 21, separately excited field winding GF, conductors 22 and 23, contact members *a* of up-direction switch 1, conductor 24, resistor 25 and conductor 26, to line conductor L2. The energization of separately excited field winding GF will cause the generator G to supply voltage to the armature EM′ of the motor EM in accordance with the value of the excitation current, as determined by resistor 25.

Up-direction switch 1 also completes a self-holding circuit for itself which extends from line conductor L1 through conductors 19 and 20, contact members *b* on up-direction switch 1, conductors 21 and 27, the coil of up-direction switch 1, conductors 15 and 16, contact members 17′ of inductor relay 17 and conductor 18 to line conductor L2. Hence, centering of the car switch thereafter will permit the elevator car to continue operating at its slow speed.

If it is desired to operate the car C at a higher speed, car switch *Cs* may be actuated to a further position, in a counter-clockwise direction, to complete a circuit for speed switch 3, which circuit extends from line conductor L1, through conductor 10, contact members 11, 12 and 28, conductor 29, the coil of speed switch 3, conductor 30, contact members 31′ of up-slow-down inductor relay 31″, conductor 32, contact members 33′ of down-slow-down inductor relay 33 and conductor 34, to line conductor L2. Speed switch 3 shunts resistor section 25 from the separately-excited field-winding circuit through actuation of contact members *a* on this switch, while actuation of contact members *b* on this switch completes a self-holding circuit for speed switch 3 extending from line conductor L1, through conductors 19 and 35, contact members *b* of speed switch 3, conductor 36, the coil of speed switch 3, conductor 30, contact members 31′ of up-slow-down inductor relay 31, conductor 32, contact members 33′ of down-slow-down inductor relay 33, and conductor 34, to line conductor L2. The elevator car C will, therefore, be driven at a speed corresponding to the full line-voltage excitation of the separately-excited field winding GF.

Variations in the load on elevator car C would normally cause variations in the speed at which the elevator motor would operate and, for this reason, the series-field winding GSF, for the generator G, is connected in the loop circuit to supply greater or lesser excitation for the generator G in accordance with the load on the car and, if properly arranged, the motor EM will operate at substantially the same speed, regardless of variations in load upon the car. However, as will be hereinafter set forth, the value of series field which may be used on the generator is limited by the value of the separately-excited field which is used.

To stop the elevator car, when operating at its high speed, the car switch *Cs* may be returned to its central or "off" position, as illustrated. Movement of the car switch *Cs* to this position energizes the operating coils of inductor relays 31 and 17, or 33 and 17, dependent upon the direction in which the car is traveling. It will be observed that up-direction switch 1 is provided with an additional contact member *c* which, when actuated, partially completes a circuit for energizing inductor relays 31 and 17, which circuit is completed by moving the car switch *Cs* to its off position. The completed circuit for relays 31 and 17 extends from line conductor L1, through conductor 10, contact members 11, 12 and 37, conductors 38 and 39, contact members $c$ on up-direction switch 1, conductor 40, the coil of inductor relay 31, conductor 41, the coil of inductor relay 17 and conductor 18, to line conductor L2. However, with the circuit just described completed, the car C will continue to operate at its highest speed until inductor relay 31 passes an inductor plate 31″ (one of which is mounted in the hatchway adjacent each of the floors past which car C moves). Movement of relay 31, now energized, past inductor plate 31 causes actuation of the relay to open its contact member 31′, thus releasing the holding circuit for speed switch 3. Speed switch 3, when deenergized, reinserts resistor section 25 in the circuit for the separately-excited field winding GF, and the elevator motor EM will be decelerated to its slow landing speed operating condition.

Speed switch 3, when deenergized, also closes, by means of its contact members $c$, a circuit for relay 4, which circuit extends from line conductor L1, through conductors 19 and 35, contact members $c$ of speed switch 3, conductor 42, the coil of relay 4 and conductors 43 and 44, to line conductor L2. Relay 4, when energized, completes a circuit for a portion of resistor 5 from the generator field winding circuit GF.

The separately excited field winding GF for generator G is normally connected to conductors 45 and 46 (constituting the loop circuit for armatures G′ and EM′, respectively,) by way of conductor 47, resistor 5, conductor 48, field winding GF and conductor 49. Relay 4, therefore, when actuated, shunts resistor section 5 by way of conductors 50 and 51.

It will be understood by those skilled in the art of dynamo-electric machinery that the effective voltage supplied to elevator motor armature EM′ will correspond to the excitation voltage impressed upon the separately excited field winding GF of the generator G minus, however, the voltage required to overcome the resistance in the loop circuit, that is, the sum of the resistances of the conductors and the internal resistances of the generator and the motor armatures, respectively. The voltage drop in the loop circuit is dependent upon the load in amperes which passes through this circuit. Hence, for any given load, the voltage drop in the circuit will be constant for all values of voltage supplied to field winding GF.

Referring to Fig. 2, I have graphically illustrated a speed-time curve indicating the impressed voltage and the effective voltage to illustrate the point that the voltage drop in the loop circuit is not noticeable at high speeds but becomes important as the speed of the motor is reduced. Curve 60 illustrates the speed curve which would be obtained if all of the excitation voltage were effective. That is, at zero volts the speed of the motor is zero, at 240 volts the speed of the motor is, for example, 100 R. P. M. However, due to the drop in potential in the loop circuit, the speed actually obtained is approximately 96 R. P. M., a difference of 4 R. P. M. However, at low speeds, a landing speed, for example, of 15 R. P. M. is obtained, a voltage drop, equivalent to 4 R. P. M., is almost one-third of the desired speed of the car. If, however, at this low speed, additional excitation be supplied to the generator, the variation in speed due to voltage drop in the loop circuit will be compensated.

As will be observed from an inspection of Fig. 1, the point in the cycle of operations of the car C at which relay 4 will be deenergized, is that point at which the speed of the car is increased from low landing speed to high speed. Hence, until this time, a portion of the current in the loop circuit will pass through the generator-separately-excited field winding GF, causing excitation of this winding in addition to the excitation supplied from the separate source of power.

Referring to Fig. 2, 61 illustrates the actual speed of the car at given load due to the loss in the loop circuit. The portion of the curve between the origin and point 63 represents the rate at which the car will accelerate from zero speed to the speed determined by the value of the generator field as limited by resistor 25, with no additional or compensating excitation. Such speed is indicated at 67, or about 12 R. P. M., for example. On curve 60, the portion from the origin to the point 64 represents the rate at which the car will accelerate from zero speed to a speed determined by the resistor 25, plus the additional excitation supplied the generator when relay 4 shunts a portion of resistor 5 to divert part of the generated current through the generator field, which speed is about 15 R. P. M. Thus, it will be observed that the car speed has been raised from 12 R. P. M., which would be its normal speed, at this value of excitation, to the desired speed of 15 R. P. M. The condition just described represents the effect of a heavy lifting load, that is, the elevator car C is heavily loaded and the car is moving in an upward direction. For lighter lifting loads, normal speed values between 12 and 15 R. P. M. will be attained (see curve 65) since, at smaller values of load upon the car, a smaller voltage drop in the armature circuit will be obtained. But the voltage produced by the generator will be lower, under these conditions, due to the effect of the series field winding. Since the voltage is lower, the value of self-excitation produced will be lower and the speed of the car will be raised a proportionally smaller amount to thereby approach the desired speed of 15 R. P. M. Hence, the speed of the car will be maintained substantially constant for all loads.

On the other hand, with an overhauling-load condition, deceleration of the car C would normally be along curve 66, that is at a higher speed than desired, however, this condition causes a current to flow in the loop circuit, which current, it will be understood, is in opposition to the current normally supplied to the separately-excited field winding GF. Hence, under overhauling-load conditions, the effect of self-excitation of the generator field winding GF will be to reduce the effective voltage instead of increase it and the car C speed will be reduced to approach the desired 15 R. P. M. curve.

The value of the effect of such self-excitation may be adjusted to over-compensate for the voltage drop in the armature circuits by adjusting resistor 5 to cause the speed to be in proportion to the positive load.

The direct result of this over-compensation and the resulting variation in speed is that, where the slow-down distance is fixed by the location of inductor plates 31″, the time required for the car to traverse the distance between the inductor plate and the floor is dependent upon the speed with which the car moves. Since gravity operates always in the down direction, it assists in decelerating the car when operating under lifting load and detracts from the deceleration under overhauling loads, the variations in speed just described may be so adjusted as to compensate for the effect of gravity, and the distance required to decelerate the load will be constant.

In addition, it will be observed that, for ordinary speed regulation, the degree of compounding permissible is limited by the effective strength of the separately-excited field since the largest series field which may be used must not exert a force greater than that exerted by the separately-excited field, otherwise, under regenerative braking conditions, the field of the generator will be reversed and cause a sudden pause in the motor operation, sometimes sufficient to start the motor in the opposite direction or, at least, to cause the motor to come to a complete stop. However, if, during deceleration, the separately excited field is made additionally strong, a larger series field winding may be used, by just that degree with which the separately excited field is strengthened. An advantage of a larger series field is that acceleration may be made more rapid.

It will be observed, therefore, that, with my system of additionally exciting the separately-excited field winding, the advantages of compensation for the effect of gravity under different load conditions is obtained, as well as the advantage of permitting the use of a stronger series field on the generator of the driving equipment.

It is to be understood that the apparatus just described is illustrative only and that I do not desire to be limited to the specific devices shown, except insofar as they are specified in the appended claims.

I claim as my invention—

1. In an elevator-control system, a motor, a generator, having a separately excited field winding, for supplying voltage to said motor, means for controlling the excitation of said generator to start and stop said motor and to control the speed thereof, and means for connecting said field winding to said generator for self-excitation in addition to said separate excitation when said control means is actuated to reduce the speed of said motor.

2. In an elevator-control system, an elevator motor, a generator for supplying voltage thereto, including an armature and a separately excited field winding, means for controlling the direction and value of excitation of said field winding to control the direction and speed of movement of said motor, a circuit including a high resistance normally connecting said field winding to said armature for self-excitation, and means for reducing the resistance in said circuit when said control means is actuated to reduce the speed of said motor.

3. In an elevator-control system, an elevator motor, a generator for supplying voltage thereto, including an armature and a separately excited field winding, means for controlling the direction and value of excitation of said field winding to control the direction and speed of movement of said motor, a normally ineffective circuit connecting said field winding to said armature for self-excitation in addition to said separate excitation, and means operable by actuation of said control means to reduce the speed of said motor for rendering said circuit effective.

4. In an elevator-control system, an elevator motor, a generator for supplying voltage thereto, including an armature and a separately excited field winding, means for controlling the direction and value of excitation of said field winding to control the direction and speed of movement of said motor, a circuit connecting said field winding and said armature for self-excitation and including such values of resistance as will prevent effective self-excitation of said field winding, and means operable by actuation of said control means to reduce the speed of said motor for excluding a portion at least of said resistor from said circuit.

5. In an elevator-control system, an elevator, a motor, a generator for supplying voltage thereto, including a separately excited field winding and an armature, means for controlling the separate excitation of said generator to operate said car at a plurality

of speeds, means operable in correspondence with movements of said elevator for automatically actuating said controlling means to decelerate and stop said motor, and means operable by actuation of said last-named means for connecting said field winding to said armature for self-excitation in addition to said separate excitation.

6. In an elevator-control system, an elevator, a motor, a generator for supplying voltage thereto, including a separately excited field winding and an armature, means for controlling the separate excitation of said generator to operate said car at a plurality of speeds, means operable in correspondence with movements of said elevator for automatically actuating said controlling means to decelerate and stop said motor, and means operable by actuation of said last-named means for connecting said field winding to said armature for self-excitation in addition to said separate excitation, and means for determining the value of such self-excitation.

7. In an elevator-control system, an elevator, a motor therefor, a generator for supplying voltage to said motor, including a separately excited field winding and an armature, means for controlling the separate excitation of said field winding to operate said motor at zero speed, a landing speed and at least one higher speed, means operable in correspondence with movements of said elevator for actuating said controlling means to decelerate and stop said elevator, and means operable by actuation of said controlling means to decelerate said elevator to said landing speed for connecting said field winding to said armature for self-excitation in addition to said separate excitation.

8. In an elevator-control system, an elevator motor, a generator for supplying voltage thereto having an armature, a separately excited field winding and a series field winding, said field windings being so designed as to obtain at least constant-speed regulation of said motor independent of load, means for controlling the separate excitation of said separately excited field winding to control the speed of said motor and means operable by actuation of said control means to stop said motor for connecting said separately excited field winding to said armature for self-excitation in addition to said separate excitation, whereby a greater series field strength may be used in proportion to the value of such self-excitation.

9. In an elevator-control system, a motor, a generator for supplying voltage thereto including an armature and a separately excited field winding, means for controlling the separate excitation of said field winding to start to accelerate and decelerate said motor and means operable during deceleration of said motor for connecting said field winding to said armature for self-excitation in addition to said separate excitation in accordance with the positive load on said motor, and means for so determining the value of such self-excitation as to compensate for the effect of gravity on variable loads on said elevator.

10. In a motor-control system, a motor, a generator for supplying voltage to said motor, a separately excited field winding for said generator and a source of excitation therefor, means for controlling the excitation of said generator to control the speed of said motor, means to supply an additional additive component of excitation for said generator comprising means for subjecting said winding to a voltage proportional to the voltage of said generator, and means responsive to the actuation of said control means to reduce the speed of said motor for rendering said additional means effective.

11. In a motor-control system, a motor, a generator for supplying voltage to said motor, a source of excitation for said generator, means for controlling the value of said source to cause said motor to operate at a plurality of speeds, means for cumulatively compounding said generator to maintain the speed of said motor at a value determined by said control means, means for supplying an additional cumulative component of excitation for said generator, and means operably responsive to the actuation of said control means to cause said motor to operate at a relatively low speed for rendering said additional means effective.

12. In a motor-control system, a motor, a generator for supplying voltage to said motor, a separately excited field winding for said generator and a source of excitation therefor, means for controlling the value of said source to cause said motor to operate at a plurality of speeds, means for cumulatively compounding said generator to maintain the speed of said motor at a value determined by said control means, and means for supplying an additional cumulative component of excitation to said generator when said motor is operating at relatively low speeds comprising means to subject said winding to a voltage proportional to the voltage of said generator.

13. In a motor-control system, a motor, a generator for supplying voltage to said motor, a separately excited field winding for said generator and a source of excitation therefor, means for controlling the value of said source to cause said motor to operate at a plurality of speeds, means for cumulatively compounding said generator to maintain the speed of said motor at a value determined by said control means, means for supplying an additional cumulative component of excitation to said generator comprising means to subject said winding to a voltage proportional to the voltage of said generator, and

means operably responsive to the operation of said control means to cause said motor to operate at a relatively slow speed for rendering said additional means effective.

14. In a motor-control system, a motor, a generator for supplying voltage to said motor, a separately excited field winding for said generator and a source of excitation therefor, means for controlling the value of said source to cause said motor to operate at a plurality of speeds, means for cumulatively compounding said generator to maintain the speed of said motor at a value determined by said control means, means for supplying an additional cumulative component of excitation to said generator comprising means to subject said winding to a voltage proportional to the voltage of said generator, and means operably responsive to the operation of said control means to cause said motor to operate at a relatively slow speed for increasing the proportion of the voltage of said generator to which said winding is subjected.

In testimony whereof, I have hereunto subscribed my name this 11th day of April, 1928.

DANILO SANTINI.