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Oct. 9, 1928.

1,686,684

L. I. DAVIS

CONTROL SYSTEM FOR ELEVATORS

Filed Oct. 29, 1925 2 Sheets-Sheet 1

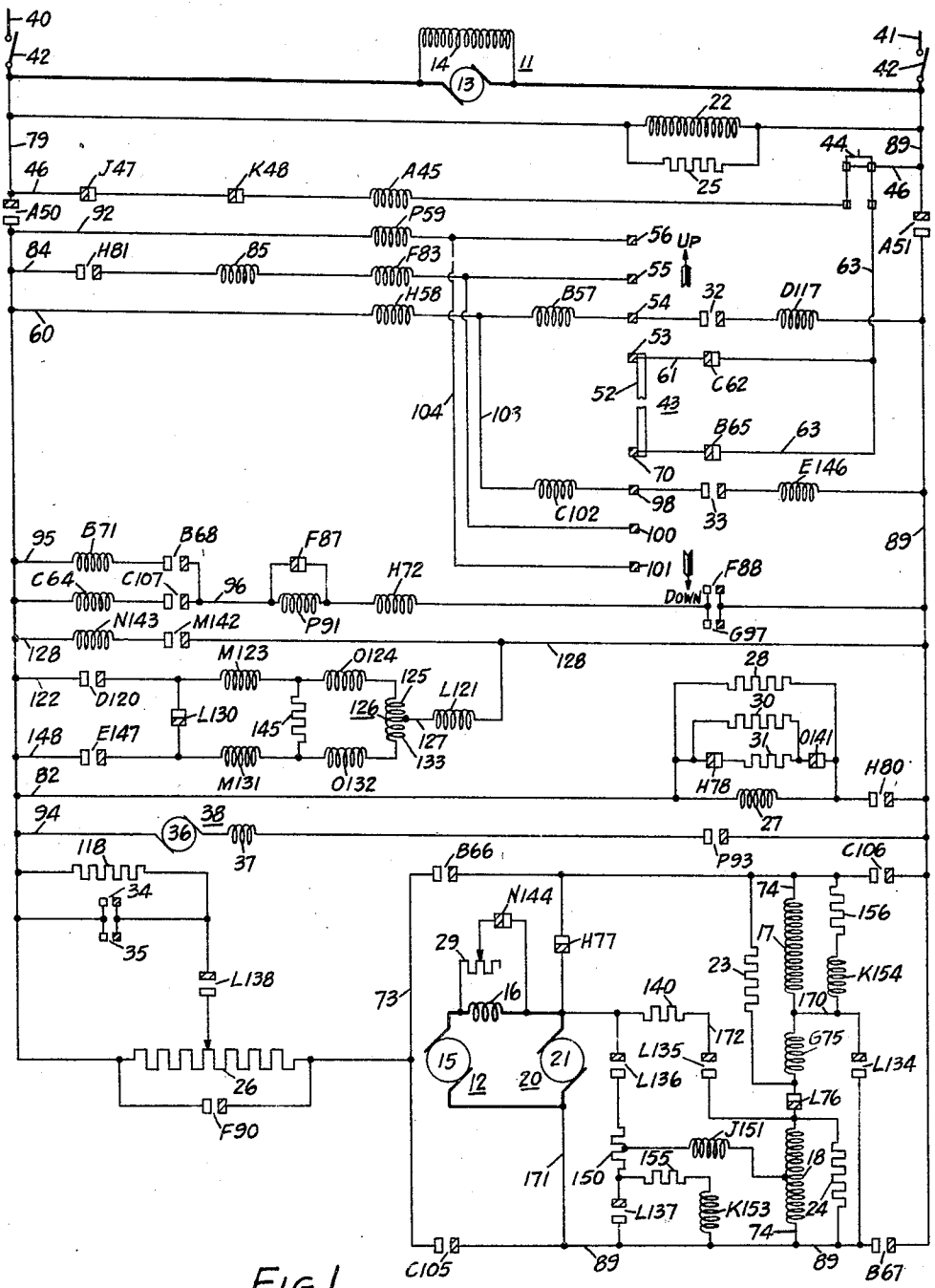


FIG. 1

Lee I. Davis Inventor

By his Attorney Hall & Bradley

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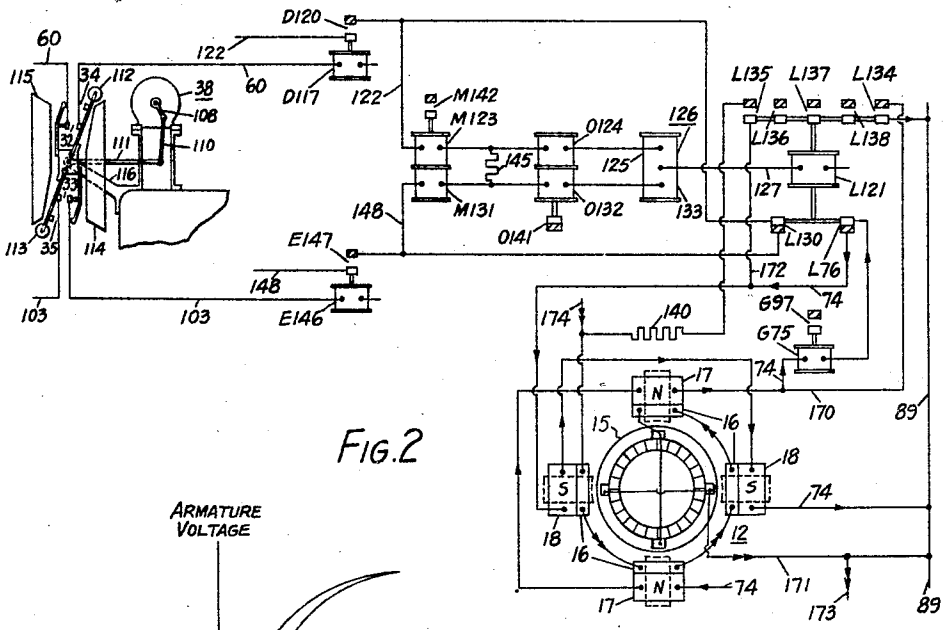


FIG. 2

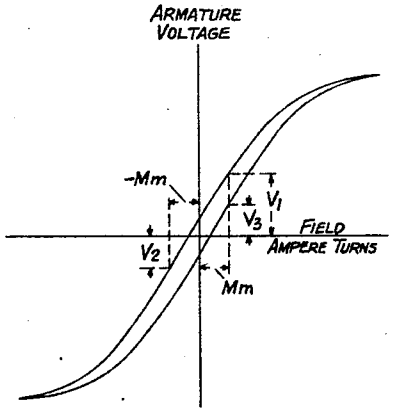


FIG. 3

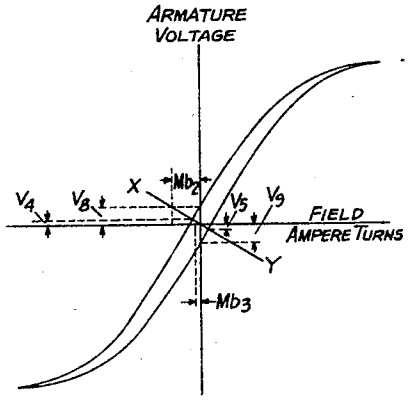


FIG. 4

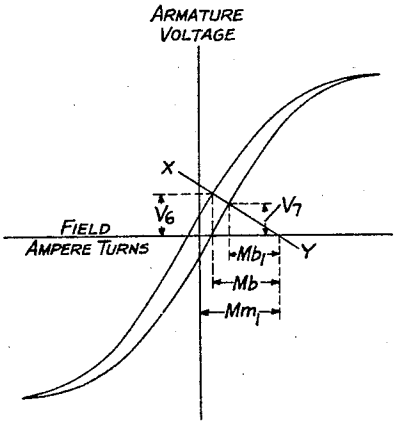


FIG. 5

Lee I. Davis Inventor

By his Attorney Walter S. Bradley

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Patented Oct. 9, 1928. 1,686,684

UNITED STATES PATENT OFFICE.

LEE I. DAVIS, OF NEW YORK, N. Y., ASSIGNOR TO OTIS ELEVATOR COMPANY, OF JERSEY CITY, NEW JERSEY, A CORPORATION OF NEW JERSEY.

CONTROL SYSTEM FOR ELEVATORS.

Application filed October 29, 1925. Serial No. 65,612.

The invention relates to control systems, and particularly to control systems for elevators.

In elevator control systems where the elevator motor is supplied with current by a variable voltage generator, the generator is required to operate over a wide range of E. M. F. values varying from a maximum in one direction to a maximum in the other. Where self-leveling apparatus is employed, the generator is required to operate at low values of E. M. F. in bringing the car to a level with a desired landing. Due to the residual flux of the generator field, the E. M. F. values obtained for a given value of field current during the leveling operation vary considerably, depending on the previous magnetic state of the machine and whether the car is approaching the landing or returning to the landing after an overrun. Such variations in E. M. F. values cause undesirable variations in the operation of the car during the leveling period.

One feature of the invention is to cause more uniform operation of the elevator car during the leveling period by minimizing the effects of the residual flux of the generator.

Another feature resides in controlling the strength of the generator field due to its series field winding during the leveling period in such manner as to bring the elevator car quickly and positively to the landing regardless of whether it has underrun or overrun the landing.

Other features and advantages will become apparent from the following description, taken in connection with the accompanying drawings wherein one embodiment of the invention is illustrated and in which:

Figure 1 is a diagram of an elevator control system;

Figure 2 is a fragmental schematic view of a portion of the elevator system, illustrating the manner in which the generator field windings are controlled during the leveling operation; and

Figures 3, 4 and 5 are hysteresis curves employed to illustrate the invention.

No attempt is made in Figure 1 to show the coils and contacts of the various electromagnetic switches in their associated positions, a "straight" diagram being employed wherein the coils and contacts of the various switches are separated in such manner as to render the circuits involved relatively simple. Also the parts of other switches and apparatus are separated in the interest of simplifying the diagram. For a clearer understanding of the invention, the stationary contacts of the switches are illustrated in cross section. It is to be understood that the system illustrated is chosen merely for convenience of description and that, although described in conjunction with a car switch controlled system, the invention is equally applicable to other types of elevator systems such as push button control systems and to other systems employing a work motor supplied with current from the generator of a motor generator set.

The motor generator set comprises a driving motor 11, illustrated for convenience of description as of the direct current type, and a variable voltage direct current generator 12. The armature of the driving motor is designated 13 and its field winding 14. The armature of the generator is designated 15, its series field winding 16, its separately excited field winding being divided into two portions 17 and 18. The elevator motor is designated as a whole by the numeral 20, its armature being designated 21 and its field winding 22. An adjustable resistance 29 is arranged in shunt to the generator series field winding. Discharge resistances 23 and 24 are provided for the portions 17 and 18 respectively of the generator separately excited field winding. Discharge resistance 25 is provided for the elevator motor field winding. A resistance 26 is provided for controlling the strength of the generator field and therefore the voltage applied to the elevator motor armature. 27 is the release coil for the elevator motor electromagnetic brake. This coil is provided with discharge resistances 28, 30 and 31 for controlling the application of the brake under different conditions of operation. 32 and 33 are the up slow speed contacts and the down slow speed contacts respectively of the leveling switch, the up and down fast speed leveling switch contacts being designated 34 and 35 respectively. 36 is the armature and 37 is the field winding of the motor 38 for moving the rollers of the leveling switch into position to clear the leveling cams. 40 and 41 are the direct current supply mains. 42 is a double pole knife switch for connecting the system to the supply mains. In order to suit the type of diagram employed, the blades of this switch are shown separated. The car switch is designated as a whole by the numeral 43.

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44 is the safety switch in the car. The various safety, limit, stop and emergency switches and door and gate contacts are omitted in order to simplify the description.

The electromagnetic switches have been designated as follows:

A—potential switch,
B—up direction switch,
C—down direction switch,
D—up slow speed leveling relay,
E—down slow speed leveling relay,
F—accelerating switch,
G—maintaining relay,
H—brake switch,
J—protective relay,
K—auxiliary protective relay,
L—slow down switch,
M—series field relay,
N—series field switch,
O—hard brake switch,
P—leveling switch motor relay,

Throughout the description which follows, these letters, in addition to the usual reference numerals, will be applied to the parts of the above enumerated switches. For example, contacts B 66 are contacts on the up direction switch, while actuating coil A 45 is the coil that operates the potential switch. The electromagnetic switches are shown in their deenergized positions.

Upon the closing of the knife switch 42, the driving motor 11, elevator motor field winding 22 and potential switch actuating coil A 45 are energized, the circuit for coil A 45 being by way of line 46 including protective relay contacts J 47, auxiliary protective relay contacts K 48 and safety switch 44. The driving motor starts in operation, bringing the generator 12 up to full speed. Starting means for the driving motor are omitted to simplify the description. The potential switch, upon operation, causes the engagement of contacts A 50 and A 51 preparing the circuit for the generator separately excited field winding, the electromagnetic brake release coil and the control circuits. The condition of the circuits so far described might be termed normal.

Assume that the system is designed for an installation of several floors and that the car is at rest at the first floor landing. In order to start the car in the up direction, the operator moves the car switch into position where its contact bar 52 bridges contacts 53, 54, 55 and 56. Upon the contact bar 52 engaging contact 54, a circuit is completed for the actuating coil B 57 of the up direction switch and the actuating coil H 58 of the brake switch. This circuit may be traced from the left-hand blade of switch 42, by way of line 79 through contacts A 50, by way of line 60 through coils H 58 and B 57, contacts 54 and 53 of the car switch, by way of line 61 through contacts C 62, line 63, switch 44, line 46, by way of line 89, to the right-hand blade of switch 42. The engagement of the contact bar and contact 55 prepares a circuit for the actuating coil F 83 of the accelerating switch. The engagement of the contact bar and contact 56 completes a circuit for the actuating coil P 59 of the leveling switch motor relay. This circuit may be traced from the left-hand blade of switch 42, by way of line 79 through contact A 50, by way of line 92 through coil P 59, contacts 56 and 53 of the car switch, to the right-hand blade of switch 42 as above traced.

It is preferred to provide the direction switches with a mechanical interlock to prevent their simultaneous operation. Such an interlock may be of the form of a walking beam pivotally mounted for engaging catches on the armatures of the direction switches. Upon operation of the up direction switch in response to the energization of its actuating coil B 57, contacts B 65 separate and contacts B 66, B 67 and B 68 engage. The separation of contacts B 65 breaks the circuit leading from the car switch down feed contact 70, contacts B 65 and the corresponding down direction switch contacts C 62 serving as electrical interlocks. The engagement of contacts B 68 prepares the circuit for the up direction switch holding coil B 71 and the brake switch holding coil H 72. The engagement of contacts B 66 and B 67 completes a circuit for the generator separately excited field winding. This circuit may be traced from the left-hand blade of switch 42, by way of line 79 through contacts A 50 and resistance 26, by way of line 73 through contacts B 66, by way of line 74 through field winding portion 17, actuating coil G 75 of the maintaining relay, slow-down switch contacts L 76, field winding portion 18, by way of line 89 through contacts B 67 and contacts A 51, to the right-hand blade of switch 42. Relay G does not operate at this time as insufficient current is supplied to its actuating coil.

The brake switch H operates simultaneously with the direction switch B. Switch H, upon operation, causes the separation of contacts H 77 and H 78 and the engagement of contacts H 80 and H 81. The separation of contacts H 77 disconnects the generator separately excited field winding from the generator armature. The purpose of contacts H 77 will be seen from later description. The separation of contacts H 78 disconnects resistance 31 from across the brake release coil 27. Resistance 31 being of low ohmic value, its disconnection before contacts H 80 engage prevents excess power consumption from mains 40 and 41. The engagement of contacts H 80 completes the circuit for the brake release coil 27. This circuit may be traced from the left-hand blade of switch 42, by way of line 79 through contacts A 50, by way of

line 82 through coil 27 and contacts H 80, by way of line 89 through contacts A 51, to the right-hand blade of switch 42. The engagement of contacts H 81 completes the circuit for the accelerating switch actuating coil F 83. This circuit may be traced from the left-hand blade of switch 42, by way of line 79 through contacts A 50, by way of line 84 through contacts H 81, reactance 85 and coil F 83, contacts 55 and 53 of the car switch, by way of line 61 through contacts C 62, line 63, switch 44, line 46, line 89, to the right-hand blade of switch 42.

The leveling switch motor relay, upon operation, causes the engagement of contacts P 93, completing the circuit for the leveling switch motor 38. This circuit may be traced from the left-hand blade of switch 42, by way of line 79 through contacts A 50, by way of line 94 through armature 36 and field winding 37 of motor 38 and contacts P 93, by way of line 89 through contacts A 51, to the right-hand blade of switch 42. The leveling switch motor acts to move the leveling switch operating rollers so as to clear the leveling cams during movement of the car. This operation will be explained later.

The brake release coil 27 being energized and current being supplied from the generator armature 15 to the elevator motor armature 21, due to the generator field winding portions 17 and 18 being energized, the elevator motor starts. The field winding portion 18 as now connected assists the field winding portion 17.

The accelerating switch F does not operate immediately the circuit for its actuating coil F 83 is completed, its action being delayed by the reactance 85. Upon operation, switch F causes the separation of contacts F 87 and the engagement of contacts F 88 and F 90. The separation of contacts F 87 removes the short-circuit around the holding coil P 91 of the leveling switch motor relay. The engagement of contacts F 88 completes the circuit for holding coils B 71, P 91 and H 72. This circuit may be traced from the left-hand blade of switch 42, by way of line 79 through contacts A 50, by way of line 95 through coil B 71 and contacts B 68, by way of line 96 through coils P 91 and H 72 and contacts F 88, by way of line 89 through contacts A 51, to the right-hand blade of switch 42. The purpose of the energization of these holding coils will be seen from later description. The engagement of contacts F 90 short-circuits resistance 26, increasing the voltage applied to generator field winding portions 17 and 18. Thus the generator voltage is brought up to its full value and the motor comes up to full speed. Also sufficient current is now supplied to the coil G 75 to cause the operation of the maintaining relay. Thus contacts G 97 engage, by-passing accelerating switch contacts F 88. It is to be understood that several accelerating switches may be employed to short-circuit successively sections of resistance 26; all but one, illustrated as short-circuiting the whole of the resistance, being omitted in order to simplify the description.

The starting of the car in the down direction is accomplished in a similar manner and will be only briefly described. The operator moves the car switch into position where its contact bar 52 bridges contacts 70, 98, 100 and 101. Upon the engagement of the contact bar and contact 98, a circuit is completed for the down direction switch actuating coil C 102 and coil H 58 which circuit may be traced from the left-hand blade of switch 42, through coil H 58, as previously traced, by way of line 103 through coil C 102, car switch contacts 98 and 70, by way of line 63 through contacts B 65, to the right-hand blade of switch 42 as previously traced. The engagement of the contact bar and contact 100 prepares a circuit for coil F 83 and the engagement of the contact bar and contact 101 completes a circuit for the coil P 59 by way of line 104. The down direction switch, upon operation, causes the separation of contacts C 62 and the engagement of contacts C 105, C 106 and C 107, these contacts corresponding with up direction switch contacts B 65, B 66, B 67 and B 68 respectively. The holding coil of the down direction switch is designated C 64. The circuit for coil F 83 is completed by contacts H 81 as before. Further than this, the operation of starting the car in the down direction is the same as described for starting it in the up direction.

Assume that the car is running in the up direction and that the operator centers the car switch between the second and third floors in order to stop at the third floor landing. Upon the disengagement of the contact bar 52 and contact 56, the circuit for the leveling switch motor relay actuating coil P 59 is broken. The relay remains in operated condition, however, due to its holding coil P 91. The disengagement of contact 55 and the contact bar breaks the circuit for the accelerating switch actuating coil F 83. The accelerating switch, therefore, drops out, causing the separation of contacts F 88 and F 90 and the engagement of contacts F 87. The separation of contacts F 88 is simply in preparation for the next starting operation. the circuit for coils B 71, P 91 and H 72 being maintained by contacts G 97. The separation of contacts F 90 removes the short-circuit for resistance 26, decreasing the strength of the generator field winding portions 17 and 18. Thus the generator E. M. F. is decreased and the speed of the elevator motor is reduced. Discharge resistances 23 and 24 act to smooth out the retardation. The engagement of contacts F 87 short-circuits the holding coil P 91 of the leveling switch motor

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relay. The disengagement of contact 54 and contact bar 52 breaks the circuit for actuating coils B 57 and H 58. The up direction switch and brake switch are maintained in operated condition, however, by their holding coils B 71 and H 72 respectively.

The leveling switch motor relay P, dropping out upon the short-circuiting of coil P 91, causes the separation of contacts P 93 to deenergize the leveling switch motor 38. In this manner the operating rollers of the leveling switch are extended for engagement by the leveling cams. Referring briefly to Figure 2, the leveling switch motor is operatively connected to the leveling switch by means of an arm 108 on the motor shaft, a connecting link 110 and a lever 111. In the starting operation, the motor 38 being energized, arm 108 rotates, acting through link 110 and lever 111 to move the leveling switch as a whole about a pivot. In this manner the leveling switch operating rollers 112 and 113 are moved into position where they do not engage the leveling cams 114 and 115 during motion of the car, a stop being provided to determine the extent of the movement. It is to be understood that leveling cams are provided for each floor. The leveling switch is pivoted on a braket 116 secured to the car frame. In the stopping operation, upon the deenergization of the leveling switch motor, a spring (not shown) moves the lever 111 and therefore the leveling switch back into the first described position with the rollers 112 and 113 extended for engagement by the leveling cams. Each pair of leveling contacts 32, 33, 34 and 35 comprises a stationary contact and a movable contact operated by the engagement of its corresponding roller and leveling cam. The fast speed contacts 34 and 35 are arranged to separate before their corresponding slow speed contacts 32 and 33 in the leveling operation. Springs (not shown) are provided for causing the separation of the contacts of the pairs as the leveling operation is effected and stops are provided for determining the extent of movement of the rollers as they ride off the leveling cams.

It will be assumed that the up leveling switch operating roller 112 moves onto the vertical surface of up leveling cam 114 before relay G drops out. The engagement of up slow speed leveling contacts 32 completes a circuit for actuating coils H 58 and B 57 and up slow speed leveling relay actuating coil D 117. This circuit may be traced from the left-hand blade of switch 42, by way of line 79 through contacts A 50, by way of line 60 through coil H 58, coil B 57, contacts 32 and coil D 117, by way of line 89 through contacts A 51, to the right-hand blade of switch 42. The engagement of fast speed leveling contacts 34 by-passes resistance 118, the purpose of which will be explained below. The energization of coils H 58 and B 57 has no particular effect at this time as the up direction switch and brake switch are being maintained in operated condition by coils B 71 and H 72. Relay G, however, drops out as soon as the current flowing through its actuating coil drops to a predetermined value, the current being sustained by the action of field winding portion 17 and discharge resistance 23. As a result, contacts G 97 separate, deenergizing holding coils B 71 and H 72. The up direction switch and brake switch are then maintained operated by coils B 57 and H 58. Had the slow speed leveling contacts not been in engagement when the relay G dropped out, their subsequent engagement as roller 112 rode onto the vertical surface of the cam would cause the energization of coils H 58 and B 57.

As set forth above, actuating coil D 117 of the up slow speed leveling relay was energized upon the engagement of slow speed leveling contacts 32. This relay, upon operation, causes the engagement of contacts D 120, completing the circuit for coil L 121. This circuit may be traced from the left-hand blade of switch 42, by way of line 79 through contacts A 50, by way of line 122 through contacts D 120, up series field relay actuating coil M 123, up hard brake switch actuating coil O 124 and a portion 125 of reactance 126, by way of line 127 through coil L 121, line 128, by way of line 89 through contacts A 51, to the right-hand blade of switch 42. The circuit comprising contacts L 130, down series field relay actuating coil M 131, down hard brake switch actuating coil O 132 and the other portion 133 of reactance 126 are in parallel with coils M 123 and O 124 and reactance portion 125. The polarities of the coils of relay M and switch O and of the portions of the reactance 126 is such that the ampere turns in coils M 131 and O 132 and reactance portion 133 neutralize the ampere turns in coils M 123 and O 124 and reactance portion 125 respectively so that the resultant magnetizing force for the magnetic circuits of the relay, switch and reactance is zero. Thus neither relay M nor switch O operates. The slow-down switch L, however, operates immediately, causing the separation of contacts L 76 and L 130 and the engagement of contacts L 134, L 135, L 136, L 137 and L 138. The separation of contacts L 76 disconnects field winding portions 17 and 18, field winding portion 17 being connected to the mains 40 and 41 by the engagement of contacts L 134 and field winding portion 18 being connected to the generator armature through resistance 140 by the engagement of contacts L 135. The polarity of the latter connection is such that the current supplied to the field winding portion 18 flows in such direction as to create a magnetizing force which opposes the magnetizing force due to

field winding portion 17. The effect of field winding portion 18 is reduced by resistance 140. The engagement of contacts L 138 completes a short-circuit through fast speed leveling switch contacts 34 for an adjustable portion of resistance 26. These connections cause the elevator motor to run at a desired leveling speed as will be explained later in more detail. Resistances 23 and 24 act to smooth out the changes in generator E. M. F. due to these operations. The purpose of the engagement of contacts L 136 and L 137 will be explained later. It is to be noted that the separation of contacts L 76 also breaks the circuit for coil G 75. Thus had the current in coil G 75 not dropped to a sufficiently low value to permit relay G to drop out, as might result from the late centering of the car switch, the disengagement of contacts L 76 in response to the engagement of up slow speed leveling contacts 32 insures the separation of contacts G 97 and the consequent deenergization of holding coils B 71 and H 72.

The separation of contacts L 130 breaks the parallel circuit around coils M 123 and O 124 and reactance portion 126. Upon the separation of contacts L 130, the reactance reduces the current supplied to coils M 123 and O 124 to a valve below that required to operate relay M and switch O and thereafter prevents the rapid building up of the current, thus slightly delaying the operation of the relay and switch. Switch O may be adjusted so that it operates almost immediately the current again starts to build up. Switch O, upon operation, causes the separation of contacts O 141 to break the circuit for resistance 30 in parallel with the brake release coil 27. Relay M, upon operation, causes the engagement of contacts M 142 to complete the circuit for the series field switch actuating coil N 143. This circuit may be traced from the left-hand blade of switch 42, by way of line 79 through contacts A 50, by way of line 128 through coil N 143 and contacts M 142, by way of line 89 through contacts A 51, to the right-hand blade of switch 42. Switch N, upon operation, causes the separation of contacts N 144, breaking the circuit including resistance 29 in shunt to the generator series field winding 16. The generator series field coils are so wound that, without the parallel resistance 29, they would have too great an effect for proper operation of the car. The desired compounding is obtained by employing the low resistance shunt. Upon separation of contacts N 144, the strength of the series field is increased for the leveling operation so as to aid in obtaining the desired stopping operation. The short delay in the action of relay M, and therefore the switch N, upon the initiation of the leveling operation, is desirable in order that the current in the generator armature-elevator motor armature circuit may adjust itself to such a value that proper series field strength during the leveling operation may be obtained.

As the car nears the third floor landing, roller 112 rides off the vertical surface onto the oblique surface of cam 114. This results in the separation of up fast speed leveling contacts 34, removing the short-circuit around resistance 118. The generator E. M. F., therefore, is again lowered and the elevator motor runs at its slowest speed.

Shortly before the car reaches an exact level with the landing, the roller 112 rides off the oblique surface of cam 114, thereby separating the slow speed leveling contacts 32. The circuit for coils H 58, B 57 and D 117 is thus broken. Switch B drops out causing the separation of contacts B 68, B 67 and B 66 and the reengagement of contacts B 65. The reengagement of contacts B 65 and the separation of contacts B 68 are in preparation for the next starting operation. Contacts B 66 and B 67 will be referred to later. Up slow speed leveling relay D drops out, causing the separation of contacts D 120. Thus the circuit is broken for coils M 123, O 124 and L 121. Relay M and switch L drop out immediately but switch O is delayed in its action by the effect of reactance 126 and discharge resistance 145. It is to be noted that the discharge current for coil O 124 and the reactance passes through down coil O 132 in such direction as to cause coil O 132 to assist coil O 124 in maintaining switch O in operated condition. Relay M, upon dropping out, causes the separation of contacts M 142, deenergizing series field switch actuating coil N 143. Switch N drops out to reconnect resistance 29 across the generator series field. Switch L, upon dropping out, causes the separation of contacts L 134, L 135, L 136, L 137 and L 138 and the engagement of contacts L 76 and L 130. The separation of contacts L 136, L 137 and L 138 and the engagement of contacts L 130 are in preparation for the next starting operation. Contacts L 134, L 135 and L 76 will be referred to later. Switch H drops out along with switch B and relay D, causing the separation of contacts H 81 and H 80 and the engagement of contacts H 78 and H 77. The separation of contacts H 81 is in preparation for the next starting operation. The separation of contacts H 80 breaks the circuit for the brake release coil 27, effecting the application of the brake. The engagement of contacts H 78 during this operation has no particular function.

The engagement of contacts H 77 along with the separation of contacts B 66 and B 67 of the up direction switch and the separation of contacts L 134 and L 135 and the engagement of contacts L 76 of the slow-down switch disconnects field winding portion 17 from mains 40—41 and connects both field winding portions 17 and 18 to the generator

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armature. The polarity of the latter connection is such that the generator sends current through the whole field winding in such direction as to oppose the flux which produces the generator E. M. F., thus tending to destroy the residual flux of the generator field. Thus, the brake being applied and the generator separately excited field winding being disconnected from mains 40—41, the car is brought to rest level with the third floor landing Since the engagement of contacts O 141 is delayed, a hard application of the brake is obtained, assuring a positive stop at the landing.

In the event of an overrun, the operation of the switches is modified. Assuming in the above example that the car overruns the third floor to the extent of causing the engagement of down slow speed leveling contacts 33, a circuit is completed for coils H 58 and C 102 and actuating coil E 146 of the down slow speed leveling relay. This circuit may be traced through coil H 58 as previously traced, by way of line 103 through coil C 102, contacts 33 and coil E 146, by way of line 89 through contacts A 51, to the right-hand blade of switch 42. The relay E, upon operation, causes the engagement of contacts E 147, completing a circuit for down coils M 131 and O 132 and coil L 121. This circuit may be traced from the left-hand blade of switch 42, by way of line 79 through contacts A 50, by way of line 148 through contacts E 147, coils M 131 and O 132 and reactance portion 133, by way of line 127 through coil L 121, to the right-hand blade of switch 42 as previously traced. Due to the fact that contacts L 130 are in engagement, up coils M 123 and O 124 are connected in parallel with down coils M 131 and O 132. Thus, as previously explained, the switch L operates immediately, causing the separation of contacts L 130 and L 76 and the engagement of contacts L 134, L 135, L 136, L 137 and L 138. Since contacts H 77 are separated and contacts C 105 and C 106 are in engagement due to the energization of coils H 58 and C 102 respectively, the separation of contacts L 76 and the engagement of contacts L 134 and L 135 cause the connection of field winding portion 17 to mains 40—41 and the connection of field winding portion 18 to the generator armature. As will be seen from later description, such connections of the field winding portions cause the generation of an E. M. F. which causes the elevator motor to be returned to the floor in the down direction and which E. M. F. is of a value very near to that generated with the car approaching the floor in the up direction. Variations in the generator E. M. F. for the leveling operations cause variations in the operation of the elevator motor. By causing the generation of more uniform voltages for leveling, as by the above arrangement, such variations in the leveling operation are substantially eliminated.

Relay M and switch O do not operate immediately upon the engagement of contacts E 147 and the separation of contacts L 130. When approaching the floor in the up direction, the current flowing through reactance portion 125 caused a flux to be built up in the reactance in one direction. Upon the separation of contacts D 120, the current in the reactance and coil O 124 discharged into resistance 145 tending to maintain the flux built up and, as previously explained, switch O in operated condition. Upon the engagement of contacts E 147 and the separation of contacts L 130 on the overrun, the current supplied to coils M 131 and O 132 must reverse the flux in the reactance, thus taking a longer time to build up to a value sufficient to cause the operation of relay M and switch O. Thus contacts N 144, depending for their separation upon the operation of relay M, remain closed temporarily to insure that the current in the generator armature-motor armature circuit has fallen to a low value. Since the current in the series field winding may be flowing in a direction such as to cause the generation of an E. M. F. which is of proper polarity for operating the car in the down direction, immediate increase in the strength of the series field might result in an overrun in the down direction. As the car returns to the floor. it is stopped by the separation of slow speed leveling contacts 33 in a manner similar to that described for approaching the floor.

If the overrun is great enough to cause the engagement of the down fast speed leveling contacts 35 as well as the down slow speed leveling contacts 33, resistance 118 is short-circuited, increasing the generator voltage and causing the elevator motor to run at its fast leveling speed. Further than this, the operation on an overrun is as above described.

It is to be understood that the operator may control both the acceleration and retardation of the car by moving the car switch in steps. Should the operator suddenly move the car switch from one position into the other, for example from up into down position, injury to the system is prevented by contacts B 65 which remain separated until the up direction switch drops out.

In variable voltage control systems of the type wherein the elevator motor is supplied with current from the generator of a motor generator set, the generator is required to operate over a wide range of E. M. F. values, varying from a maximum in one direction to a maximum in the other. When operating at low values of E. M. F., the armature voltage obtained for a given field current may vary over a wide range due to the varying effects of residual flux. This effect is very marked under leveling operating conditions where

low values of generated E. M. F. are employed. Such low values of E. M. F. are usually obtained by permitting only a small amount of current to flow through the generator separately excited field winding so as to produce low values of flux. Thus the residual flux present forms a large percentage of the total flux and therefore affects the operation of the system very markedly. In order that the effects of residual flux may be clearly seen, reference may be had to the assume hysteresis curve shown in Figure 3. This figure illustrates the conditions when a small current is supplied to the separately excited field winding of a separately excited generator, as during leveling operation. It will be seen that, for a certain current value, represented by the magnetizing force Mm, the E. M. F. of the generator may be any value between V_1 and V_2 depending on the previous magnetic state of the machine and whether the car is approaching the floor from one direction or is returning to the floor in this direction after an overrun from the opposite direction. V_2 represents the minimum value of the generator E. M. F. for a magnetizing force $-Mm$ of equal but opposite value to magnetizing force Mm. Obviously, such large E. M. F. variations might result in undesirable variations in operation under leveling conditions. These variations cannot be satisfactorily corrected by adjusting the amount of resistance in series with the separately excited field winding. For example, if the amount of resistance were decreased in order to raise the value of V_2, the value of V_1 also would be raised, resulting in an increasing tendency to run past the floor. Similarly, if the amount of resistance were increased in order to lower the value of V_1, the value of V_3 also would be lowered, with the possibility of V_3 being of too low a value to return the car to the floor after an overrun. Thus, if the values of V_1 and V_3 can be made nearly equal for leveling operating conditions, the system may be adjusted so as to obtain more uniform operation. This desired result may be attained by connecting field winding portion 18 to the generator armature and energizing field winding portion 17.

For convenience of explaining the action of the portions 17 and 18 of the field winding, assume that the generator has been in operation with the portions connected across the mains in such manner as to assist each other and that, as a final step in reducing the generator E. M. F., both portions are disconnected from the mains and that portion 18 is connected to the generator armature and portion 17 left unenergized, the polarity of the connection between the generator armature and portion 18 being such that the generator sends current therethrough in a direction to oppose the flux which produces the generator E. M. F. The final values of the generator E. M. F. under such conditions are illustrated in Figure 4. In this figure, the line X—Y is the resistance line of the field and shows the relation between the voltage applied to the field winding and the number of ampere turns produced thereby. With the hysteresis curve, as before, in the first and third angles, the line X—Y for winding portion 18, in accordance with the polarity of connection assumed, is in the second and fourth angles. If both winding portions had been left disconnected, the generator E. M. F. would have assumed a value V_3 or V_5 depending on the previous polarity of the machine. These values would be due to the residual flux of the generator field. For convenience of further explanation, assume that the previous polarity of the generator corresponded with the polarity indicated by E. M. F. value V_3 at the time that winding portion 17 was disconnected and winding portion 18 was connected to the armature. It is to be understood that the value of the generator E. M. F. at the instant of the change of connections would be determined by the time constant of the field and therefore might be greater than V_3. Assuming, however, that the generator E. M. F. was at a value V_3 at the instant of change, this E. M. F. applied to winding portion 18 would tend to cause this portion to exert a magnetizing force of a value Mb_2. Such magnetizing force, however, opposing the flux which produced the armature E. M. F., would cause a decrease in the value of the E. M. F., generated. A decreased E. M. F. would simply mean a decrease again in the value of the opposing magnetizing force. As a result, a state of equilibrium would be reached where any tendency for a decrease in armature E. M. F. would result in a decrease in opposing magnetizing force with the consequent increase in armature E. M. F., i. e., once the armature E. M. F. is reduced to a value V_4, a decrease in value would mean that the opposing magnetizing force would tend to assume a value Mb_3, for example, which would tend to increase the value of the armature E. M. F. The value V_5 represents the armature E. M. F. with the state of equilibrium obtained after a previous armature E. M. F. of the other polarity.

According to the preferred arrangement, however, as previously explained, field winding portion 17 is energized from the mains when portion 18 is connected to the generator armature. With the winding portions connected in this manner, conditions become as illustrated in Figure 5. In this figure, Mm_1 represents the magnetizing force created by winding portion 17 with the car moving in one direction while Mb represents the magnetizing force created by winding portion 18 for the state of equilibrium with the car ap-

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proaching the floor in this direction and Mb_1 represents the magnetizing force created by winding portion 18 for the state of equilibrium when the car is being returned to the floor in this direction after an overrun from the opposite direction. Graphically, the effect of the magnetizing force Mm_1 of winding portion 17 is to shift the resistance line X—Y for winding portion 18 to the right. When the car is approaching the floor in this direction, therefore, the final value of the armature E. M. F. is that due to the difference in the magnetizing forces of the winding portions, i. e., Mm_1—Mb, and is represented as V_6. When the car is returning to the floor in this direction after an overrun from the other direction, the final value of the armature E. M. F. is that due to the difference in the magnetizing forces of the winding portions, i. e., Mm_1—Mb_1, and is represented as V_7. The armature E. M. F., therefore, lies between the values V_6 and V_7, which values, relatively speaking, are very nearly equal. Thus the possible range of variation is much smaller than when an undivided separately excited field winding is used as explained in connection with Figure 3. The increase in field current to obtain the desired magnetizing force Mm_1 of the winding portion 17 for the voltages V_6 and V_7 is effected by the engagement of contacts L 138 in the system described. Any tendency for an increase in the armature E. M. F. under the above described conditions would result in an increase in the magnetizing force of the winding portion 18 and thus a decrease in the net magnetizing force, and vice versa.

It is preferred to utilize the field winding portion 18 to assist the field winding 17 during car switch operation as described above. The arrangement of the field winding may be as indicated in Figure 2. Here the field coils for the north poles are grouped together to be used as winding portion 17 while the field coils for the south poles are grouped together to be used as winding portion 18. With the switch L in the position illustrated, these windings are connected so as to assist each other, providing alternate north and south poles. The direction of the current is indicated by arrows. The circuit for the field winding may be traced by way of line 74 through winding portion 17 constituting the N poles, through coil G 75, contacts L 76 and winding portion 18 constituting the S poles, to line 89. It is to be understood that the manner of winding is such as to obtain the desired polarity. With the winding of switch L energized by the leveling switch contacts, the switch is moved into its other position so as to disconnect winding portion 18 from the mains and to connect it to the generator armature with the proper polarity. The circuit for winding portion 17 may now be traced by way of line 74 through winding portion 17, by way of line 170 though contacts L 134, to line 89. The circuit for winding portion 18 may be traced from the lower armature terminal, line 171, a portion of line 89, by way of line 74 through winding portion 18, by way of line 172 through contacts L 135 and resistance 140, series field windings 16, to the upper armature terminal. Lines 173 and 174 indicate the connection from the generator armature to the motor armature. The direction of the current in the generator armature-motor armature circuit when the motor is lifting a load is indicated by double arrows. It is to be understood that the manner of winding for the series field is such that the field due to the series winding assists that due to the separately excited field winding portions, when the motor is lifting a load. Thus, upon the operation of switch L to cause the engagement of its contacts L 134 and L 135 and the separation of its contacts L 76, the current supplied to the field winding portion 18 is reversed. This is true regardless of whether the elevator motor is lifting or lowering a load since the polarity of the generator armature does not change upon regeneration. The engagement of contacts L 138 results in an increase in magnetizing force due to the field winding portion 17 as previously explained. Resistance 140, connected in series with the field winding portion 18 when the latter is connected to the generator armature serves to reduce the amount of current supplied to this portion and therefore the magnetizing force produced thereby, the resistance determining the slope of the line X—Y and therefore the relative values of the armature E. M. F. Thus it will be seen that, with the above described arrangement, variations in operation during leveling caused by the effect of the residual flux of the generator are substantially eliminated. It is to be understood that the above described arrangement is applicable to generators of other pole numbers, a four pole generator being chosen merely for convenience of description. Also it is to be understood that the coils of the field winding might be grouped in other relations to effect the desired result.

The series field winding 16 acts to assist the separately excited field winding portions to obtain the desired conditions during operation. Under normal car switch operation, when these winding portions assist each other, the series field winding acts in the usual manner to compensate for varying load conditions. During leveling conditions, when the elevator motor is lifting a load, the effect of the series field winding is to aid in bringing the car to the floor since the current flow in the series field winding is in such direction as to produce a magnetizing force which assists that due to field winding portion 17 and opposes that due to field winding portion 18. Conversely, when the elevator motor is lower-

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ing a load, the effect of the series field winding is to aid in causing the car to stop at the floor since the current flow in the series field winding is in such direction as to produce a magnetizing force which opposes that due to field winding portion 17 and assists that due to field winding portion 18.

Referring again to Figure 1, in order to guard against an open circuit in field winding portion 18 during leveling with the resultant increase in generator E. M. F. and therefore car speed when contacts L 138 are in engagement, the protective relay J may be employed. Along with the employment of relay J, contacts L 136 and L 137 are employed to connect resistance 150 to the generator armature. The protective relay actuating coil J 151 is connected between a point on this resistance and the mid point of field winding portion 18. A bridge circuit is thus formed and is so balanced that under normal leveling operating conditions, no current flows through coil J 151. However, if an open circuit occurs in field winding portion 18 itself or in the circuit for resistance 150, current flows through coil J 151, causing the operation of the relay. The relay, upon operation, causes the separation of contacts J 47 in the circuit for the actuating coil A 45 of the potential switch. Relay J is preferably of the latched type to maintain contacts J 47 separated, once the relay is operated, until manually reset. Switch A, upon dropping out, causes the separation of contacts A 50 and A 51. Thus the main field winding is disconnected from mains 40 and 41 and the brake is applied, bringing the motor to a stop. Since half of field winding portion 18 is in each side of the bridge circuit, any transient voltages induced in the winding balance out and do not cause the operation of the protective relay J. However, if resistance 140 in one side of the bridge circuit is large, it may be desirable to divide it into halves, putting one-half in one side of the bridge circuit and the other half in the other side. Such arrangement would result in a perfect balance and would insure that relay J would not be operated under transient voltage conditions.

If desired, the auxiliary protective relay K, preferably of the same type as relay J so as to maintain its contacts K 48 separated until manually reset once the relay has operated, may be employed to protect against an accidental open circuit for the coil J 151 and against the accidental short circuit of resistance 26 during leveling operation which would result in an excessive voltage being applied to field winding portion 17. It is to be noted that the auxiliary protective relay is provided with two coils K 153 and K 154. Under normal car switch operating conditions, coil K 153 is connected in series with coil J 151 across one-half of field winding portion 18 and coil K 154 across field winding portion 17. By means of the resistances 155 and 156, the current supplied to the coils may be adjusted so that the ampere turns of one coil neutralize those of the other. If the circuit for coil J 151 should be accidentally opened, coil K 154 alone would be energized, causing the operation of the relay K. Relay K, upon operation, causes the separation of contacts K 48 in the circuit for the potential switch actuating coil A 45. Thus the car is brought to a stop in the manner above described. During the leveling operation, coil K 153 is short-circuited by contacts L 137 so that only coil K 154 is energized. Coil K 154 is designed, however, so as to cause the operation of the auxiliary protective relay K to effect the stopping of the car when an excessive voltage, such as would result from the short-circuiting of resistance 26, is applied to the coil. The coils of relay K are wound with a larger number of turns than coil J 151 so that, under normal car switch operation, the current flowing through coils K 153 and J 151 does not cause the operation of relay J.

It is to be noted that, when the car is stopped by deenergizing the actuating coil of the potential switch or by the centering of the car switch at such time as to stop the car without the leveling zone, the switch O is not operated. Thus contacts O 141 are in engagement, leaving resistance 30 in parallel with resistance 28, and, upon the engagement of contacts H 78, resistance 31 is connected in parallel with resistances 28 and 30 and a "soft" application of the brake is obtained.

As many changes could be made in the above arrangement and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In combination, an elevator car, a motor therefor, a generator for supplying current to said motor, said generator having a field winding, means for driving said generator, a source of current for the field winding, and means for causing said motor to bring the car to a level with a desired landing regardless of whether the car overruns or underruns said landing, said last included means comprising means for disconnecting a portion of said field winding from said source and connecting it to the armature of said generator.

2. In combination, an elevator car, a motor therefor, a generator for supplying current to said motor, said generator having a field winding, means for driving said generator, a source of current for the field winding, and means for causing said motor to bring the car to a level with a desired landing regard-

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less of whether the car overruns or underruns said landing, said last included means comprising means for disconnecting a portion of the field winding from said source and connecting it to the armature of the generator in such manner as to reverse the flow of current through said portion.

3. In combination, an elevator car, a motor therefor, a generator for supplying current to said motor, said generator having a field winding, means for driving said generator, a source of current for the field winding, and means for causing said motor to bring the car to a level with a desired landing regardless of whether the car overruns or underruns said landing, said second named means comprising means for disconnecting a portion of said field winding from said source and connecting it to the armature of said generator and means for reducing the voltage applied to said portion of the field winding below that of the generator armature.

4. In combination, an elevator car, a motor therefor, a generator for supplying current to said motor, said generator having a field winding, means for driving said generator, a source of current for the field winding, a resistance, and means for causing said motor to bring the car to a level with a desired landing regardless of whether the car overruns or underruns said landing, said last included means comprising means for disconnecting a portion of said field winding from said source and connecting it in circuit with said resistance to the armature of said motor.

5. In combination, an elevator car, a motor therefor, a generator having an armature and a field winding, the generator armature supplying current to the motor armature, means for driving said generator, a source of current, means for starting the car, said means comprising means for connecting the field winding to said source, means for bringing the car to a level with a floor upon stopping, said last included means comprising means for disconnecting a portion of said winding from said source and connecting it to the generator armature.

6. In combination, an elevator car, a motor therefor, a generator for supplying current to said motor, said generator having a field winding comprising a plurality of coils, one on each field pole, means for driving said generator, a source of current, means for connecting all of said coils to said source in such manner as to cause the motor to operate the car at a certain speed, and means for causing the motor to bring the car to a level with a desired landing at a slower speed regardless of whether the car overruns or underruns said landing, said last included means comprising means for disconnecting certain of said coils from said source and connecting them to the generator armature.

7. In combination, an elevator car, a motor therefor, a generator for supplying current to said motor, said generator having a field winding comprising a plurality of coils, one on each field pole, means for driving said generator, a source of current, means for connecting the coils to said source in such manner as to excite the alternate poles for opposite polarities, and means for causing the motor to bring the car to a level with a desired landing regardless of whether the car overruns or underruns said landing, said second included means comprising means for disconnecting the coils of alternate poles from said source and connecting them to the generator armature in such manner as to reverse their excitation.

8. In combination, an elevator car, a motor therefor, a generator for supplying current to said motor, said generator having a field winding comprising a plurality of coils, one on each field pole, means for driving said generator, a source of current, means for connecting the coils to said source in such manner as to excite the alternate poles for opposite polarities, means for causing the motor to bring the car to a level with a desired landing regardless of whether the car overruns or underruns said landing, said second included means comprising means for disconnecting the coils of alternate poles from said source and connecting them to the generator armature in such manner as to reverse their excitation, and means for reducing the voltage applied to said coils of alternate poles below that of the generator armature.

9. In combination, an elevator car, a motor therefor, a generator for supplying current to the motor, said generator having a series field winding, means for driving said generator, a leveling switch, and means responsive to the operation of said leveling switch for causing a change in the strength of the generator field due to the series field winding for a given armature current after a predetermined time interval with the car approaching the floor and after a longer time interval upon returning the car to the floor after an overrun.

10. In combination, an elevator car, a motor therefor, a generator for supplying current to the motor, said generator having a series field winding, means for driving said generator, a leveling switch, means responsive to the operation of said leveling switch for causing a change in the strength of the generator field due to the series field winding for a given armature current, and means for delaying the operation of the first named means for a longer period of time in response to the operation of the leveling switch to cause the return of the car after it overruns the landing than in response to the operation of the leveling switch to cause the car to come to the landing as it approaches the landing.

11. In combination, an elevator car, a motor

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therefor, a generator for supplying current to the motor, said generator having a series field winding, means for driving said generator, a leveling switch, means responsive to the operation of said leveling switch for causing a change of ampere turns of the series field for a given armature current, and means for delaying the operation of the first named means for a longer period of time when the car overruns the landing than when it approaches the landing.

12. In combination, an elevator car, a motor therefor, a generator for supplying current to said motor, said generator having a series field winding, means for driving said generator, a resistance in parallel with said winding, means for causing the motor to bring the car to a level with a desired landing, means responsive to the operation of the first named means, for disconnecting said resistance from said field winding, and means for delaying the operation of the second included means for a certain interval of time upon the operation of the first named means as the car approaches the landing and for delaying the operation of the second included means for a longer interval of time upon the operation of the first named means to caused the motor to return the car to the landing after an overrun.

In testimony whereof, I have signed my name to this specification.

LEE I. DAVIS.