United States Patent

Mitsui et al.

[15] 3,687,235

[45] Aug. 29, 1972

[54] **CONTROL APPARATUS FOR AN ELEVATOR CAR**

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[22] Filed: **Jan. 21, 1971**

[21] Appl. No.: **108,426**

[30] **Foreign Application Priority Data**

Jan. 21, 1970 Japan 45/5060
March 2, 1970 Japan 45/17042

[52] **U.S. Cl.** ....**187/29 R,** 318/375
[51] **Int. Cl.** **B66b 1/32**
[58] **Field of Search** 187/29; 318/46, 48, 63, 87, 318/371, 377, 441, 50, 373–375

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[57] **ABSTRACT**

A control apparatus for an elevator car having an alternating current motor system comprising a high speed motor mechanically coupled with a low speed motor, wherein the high speed motor is used in accelerating and normal running and the low speed motor is excited by a direct current voltage upon separation of the high speed motor from its alternating current source to effect deceleration.

12 Claims, 7 Drawing Figures

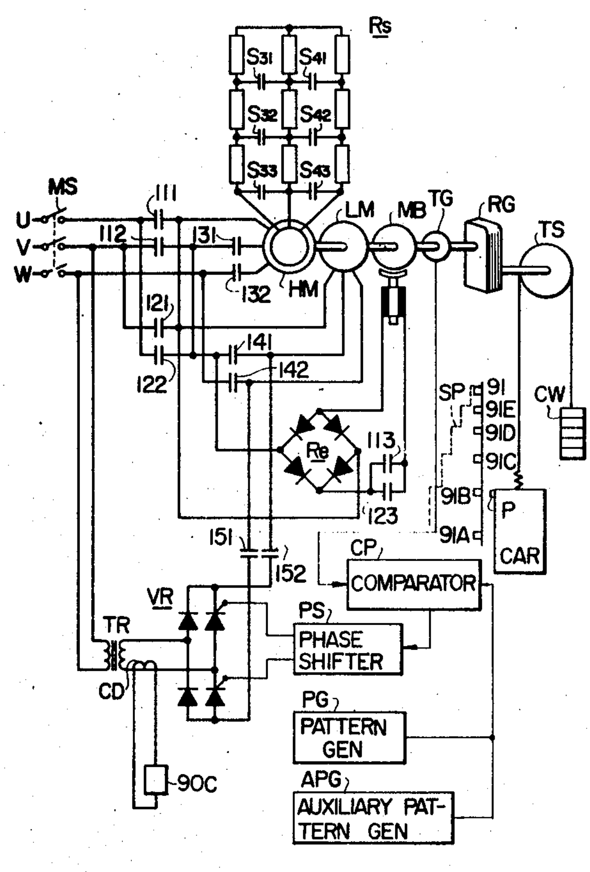

FIG. 1

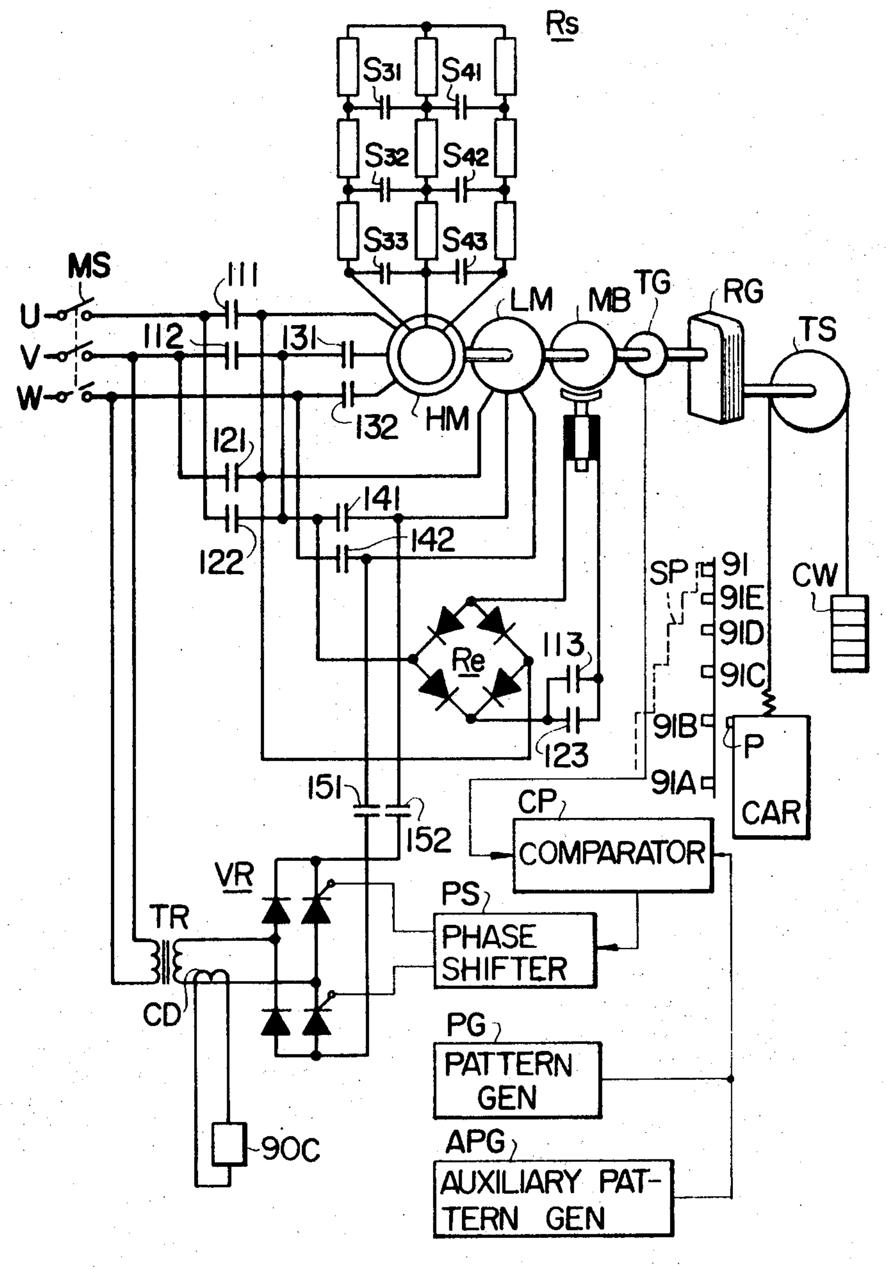

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FIG. 2

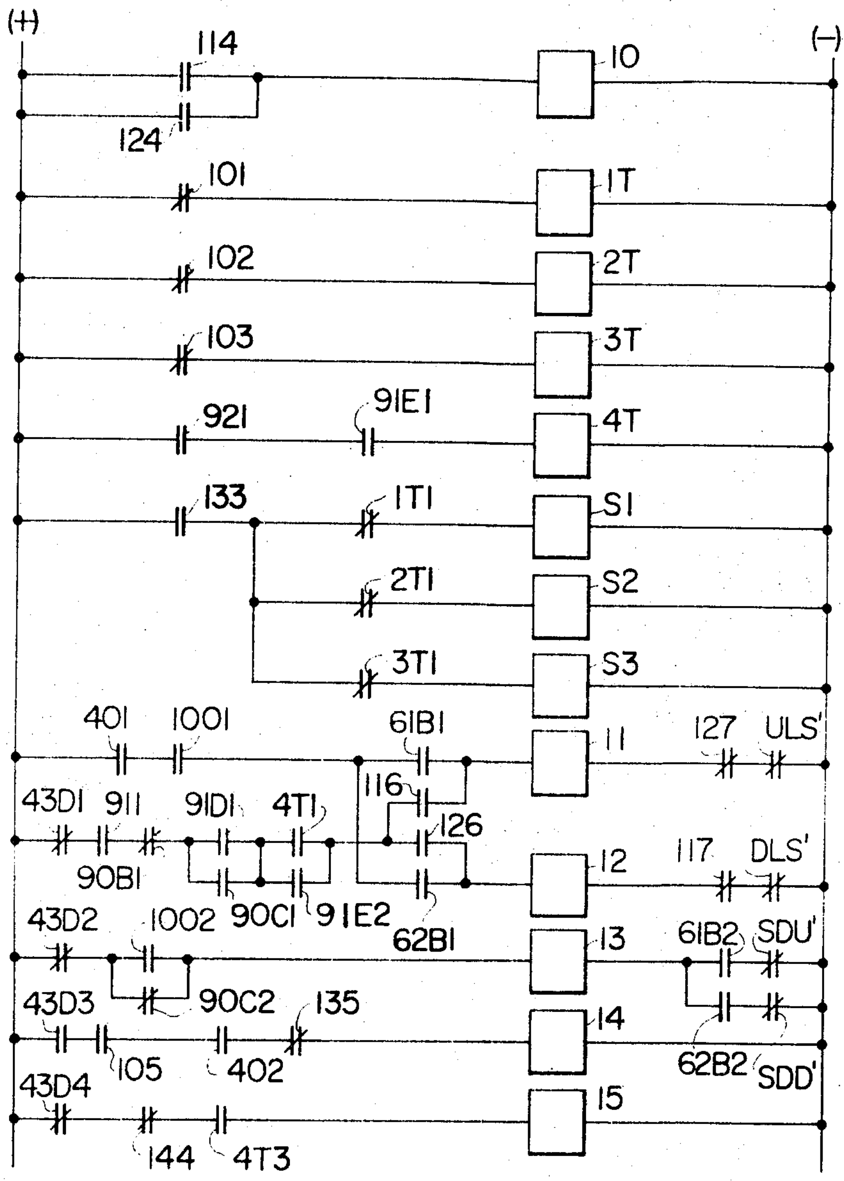

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FIG. 3a

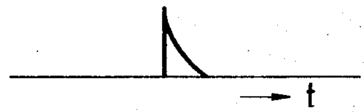


FIG. 3b

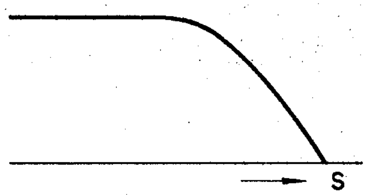


FIG. 3c

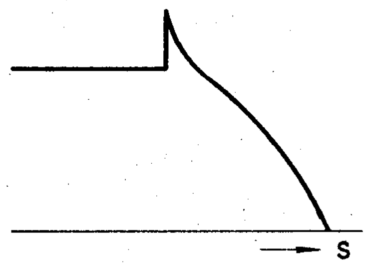
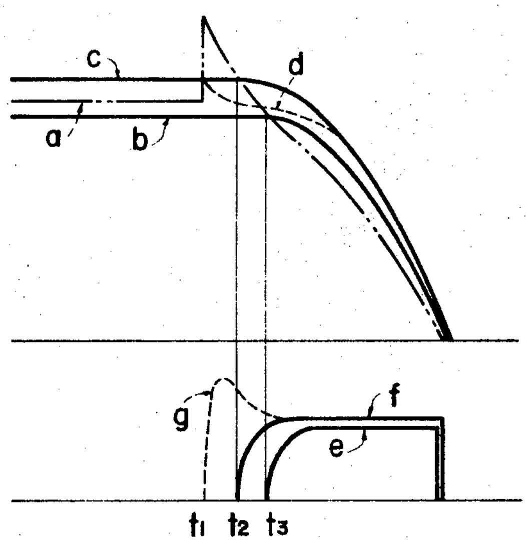


FIG. 4a

FIG. 4b



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CONTROL APPARATUS FOR AN ELEVATOR CAR

BACKGROUND OF THE INVENTION

The invention relates to improvements in a control apparatus for an elevator car having a two-speed alternating current motor system.

As is well known, conventional alternating current type elevators employ a two-speed induction motor system as the car driving means in which the speed can be changed in two stages, i.e., high speed and low speed. Such a motor system can be obtained by mechanically coupling together two kinds of induction motors which have respectively different synchronous speeds. Otherwise, a pole-change type induction motor can also be employed.

When the car reaches a brake starting point the conventional two-speed motor system is switched into low point, operation from high speed operation (during starting and acceleration) in order to perform a regenerative braking for deceleration. The brake starting point is generally selected at a physical point which is a predetermined distance before the target floor, but the brake starting point may be also selected as a point in time occuring a certain time interval after starting. After sufficient deceleration, the car is finally stopped by the operation of an electromagnetic brake.

As the conventional system uses an electromagnetic brake in order to finally stop the car at the target floor, it is necessary to decelerate the car to a predetermined low speed before the mechanical brake is operated. Conventional decelerating systems require a long time to reduce the car speed to the required low speed irrespective of load. Further, as the speed of the car is still considerably high when the electromagnetic brake acts on the car, a shock cannot be avoided at stopping.

SUMMARY OF THE INVENTION

An object of the invention is to reduce the duration of low speed operation during deceleration.

Another object of the invention is to reduce the speed of the car to substantially zero before the electromagnetic brake begins to act on the car.

Still another object of the invention is to prevent the creation of a shock such as experienced with the conventional regenerative braking systems when braking starts.

According to the main aspect of the invention, a control apparatus for an elevator car comprises a two-speed alternating current induction motor system consisting of a high speed sub-system and a low speed sub-system, in which the speed can be changed in two stages, i.e., high speed and low speed, in order to drive the car, an electromagnetic brake for braking the car, means for supplying a direct current to the low speed sub-system, and means for controlling the direct current according to the deviation between a controlled speed pattern and the actual speed of the car during deceleration.

These and other objects, features and advantages of the present invention will become more apparent from the following detailed description thereof when taken in conjunction with the accompanying drawings, and wherein:

FIG. 1 is a schematic diagram of the control circuit for the driving motor and the electromagnetic brake in accordance with the present invention;

FIG. 2 is a schematic wiring diagram of the control circuit of the car;

FIGS. 3*a*, 3*b* and 3*c* are diagrams which explain a deceleration pattern; and

FIGS. 4*a* and 4*b* show the characteristics of deceleration.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

For a general understanding of the invention, reference may be had to FIG. 1, wherein various parts of the apparatus illustrating the principles of the invention are schematically shown.

In this figure, U, V and W designate lines carrying respective phases of a three-phase alternating current source, which are connected through a main switch MS to a high speed induction motor HM and a low speed induction motor LM. Both motors are mechanically coupled to each other by the same shaft. Further, both motors may be replaced by a single pole-change type induction motor. As is well known, the pole-change type induction motor can provide a variable number of poles, for example, four poles or 24 poles. In the case of four poles, the motor rotates at a high speed and in the case of 24 poles, the motor rotates at a low speed, one-sixth of the high speed. The high speed motor HM has a group of resistors Rs which are short-circuited by step-by-step contactors S31 to S33 and S41 to S43 to control the speed of the motor.

The motor coupling shaft is provided with an electromagnetic brake MB and a tachogenerator TG, and drives a traction sheave TS through a reduction gear RG. The ends of a rope hanging on the traction sheave TS are fixed to an elevator car and a counter weight CW, respectively. A position-detecting plate P is attached to the car so that when the plate P faces segments **91A**, **91B**, **91C**, **91D**, **91E** and **91** provided at every floor in the elevator shaft in sequence, a relay connected to each segment is released to detect the position of the car and to produce a pattern for deceleration. The segment and the corresponding relay are identified by the same symbol in this case.

A single phase transformer TR is connected to the lines V and W through switch MS, the output of which is applied to a voltage regulator VR in order to supply a direct current to the low speed motor LM. The control circuit of the voltage regulator VR comprises a comparator CP, a pattern generator PG, an auxiliary pattern generator APG and a phase shifter PS. The control circuit of the voltage regulator VR controls the output voltage of the voltage regulator VR according to the deviation between the pattern speed (the combined output of the pattern generator PG and auxiliary pattern generator APG) and the actual elevator speed (the output of the tachogenerator TG). A current detector CD detects the beginning of brake efforts from the current in the secondary of transformer TR. An output of the detector CD excites a relay **90C**. A rectifier bridge Re is provided for supplying an exciting current to a coil of the electro-magnetic brake MB. The coil of the brake is excited by the output of the rectifier Re during operation of the car so that the electromagnetic brake MB is normally released.

The following description will indicate the manner of operation of contacts **111**, **112**, **121**, **122**, **131**, **132**, etc. with reference to FIG. 2.

In FIG. 2, main relays are identified as follows:

10: Operation relay (excited during the operation of the car)

1T, 2T, 3T and 4T: Time limit relays (having time delays *t*1, *t*2(*t*1), *t*3(*t*2) and *t*4, respectively)

S1, S2 and S3: Resistor short-circuiting relays

11: Upward operation relay (excited when the car operates in the upward direction)

12: Downward operation relay (excited when the car operates in the downward direction)

13: High speed operation relay (excited for operating the high speed motor HM)

14: Low speed operation relay (excited for operating the low speed motor LM)

15: Direct current excitation relay (for supplying a direct current to the low speed motor LM)

Contacts shown in FIG. 1 belong to the above-mentioned relays respectively; for example, contacts 101, 102 and 103 belong to the relay 10. Namely, the reference number of the contact expresses the number of the relay (first two numerals) and the contact number thereof (last numeral). Similarly, only the last numeral of a reference number of a symbol for the contacts shown in FIG. 2 designates the number of the contacts and the remaining part designates the number of the relay.

Other relays in addition to the above-mentioned relays will be explained in the following in connection with the explanation of the operation of the invention.

Suppose that a call takes place from an upper floor when the car is at the base floor. The car requires an upward operation in this case. An upward operation selecting relay 61B (62B is a downward operation selecting relay—both relays are not shown) is excited by the call request in the conventional manner so that contacts 61B1 and 61B2 are closed. A door-shutting relay 100 (not shown) is simultaneously excited to shut the door and to close the contacts 1001 and 1002.

The relay 13 is thus excited through the circuit from battery (+) to contact 43D2, through contacts 1002 or 90C2, relay 13, contact 61B2, and contact SDU to battery (−), so that the contacts 131 and 132 in FIG. 1 are closed. Reference symbols 43D2 and SDU′ are normally closed contacts of a low speed motor operating relay 43D and a safety switch for upward operation relay SDU, respectively (both not shown). As the low speed motor is not yet under operation, the relay 43D is not excited, and further as the car does not start yet, the switch SDU also does not operate.

When the door is entirely shut, a door closure confirming relay 40 is excited to close the contacts 401, and 402. The relay 11 is excited through the circuit battery (+) to contact 401, contact 1001, contact 61B1, relay 11, contact 127 and contact ULS′ to battery (−) closing contacts 111 and 112 in FIG. 1 so that the high speed motor HM is connected to the three-phase alternating current source. Then, the contact 127 of the relay 12 and the contact ULS′ of an upper limit switch ULS are not to open. As the low speed motor operating relay 43D is not excited and the relays 91, 91D and 91E are held operative, contacts 43D1, 911, 91D1 and 91E1 are closed. Therefore, when the relay 11 is excited to close the contact 116, the relay 11 is self-held thereafter.

As the relay 11 is excited to close the contact 114, the relay 10 is excited to open contacts 101, 102 and 103. After a time delay tI from opening of the contact 101 the relay IT is released to close the contact IT1. As the relay 13 is excited thereby and the contact 113 thereof is closed, the relay SI is excited to close the contacts S31 and S41. The motor HM is accelerated only by one step. After time delays *t*2 and *t*3, the relays 2T and 3T are released respectively in a like manner. The contacts S32, S42 and S33, S43 are sequentially closed so that the motor HM is further accelerated. When all the resistors in section Re are short-circuited, the motor HM continues to rotate at the maximum speed.

The car moves toward the target floor. When the car passes a deceleration starting point, a deceleration starting relay 92 (not shown) is excited to close a contact 921. Since the contact 91E1 is closed as aforementioned, the relay 4T is excited upon closure of the contact 921. When the relay 92 is excited, the relay 100 is released to open the contacts 1001 and 1002 by a circuit not shown. Contacts 4T1 and 4T3 are closed. The relay 15 is excited to close the contacts 151 and 152 in FIG. 1 upon closure of the contact 4T3.

Further, after the car passes the deceleration starting point, a speed pattern corresponding to position is produced as shown by the dotted line SP in FIG. 1. A smoothed pattern obtained by integrating the dotted line SP is generally used as the speed pattern. A pattern generator PG and an auxiliary pattern generator APG produce the aforementioned pattern in response to the outputs of the relays 91A to 91E. A deviation is obtained by comparing the speed pattern with the actual speed from the tachogenerator TG through the comparator CP. The voltage regulator VR controls the output voltage through a phase shifter PS according to the deviation. The motor LM is supplied with a direct current thereby so that a dynamic brake effect may be carried out. This braking current is detected by the detector CD as an alternating current. The output of the detector CD excites the relay 90C so that the contact 90C1 closes and the contact 90C2 opens. The opening of the contact 90C2 releases the relay 13 to open the contacts 131 and 132 in FIG. 1. Therefore, the motor HM is separated from the alternating current source after detecting the deceleration starting point. The car is reduced in speed by the dynamic brake as abovementioned.

When the plate P provided on the car faces the segment 91D during the deceleration, the relay connected to the segment 91D is released to open the contact 91D1. It will be appreciated that the self-holding of the relay 11 is maintained by the circuit battery (+), contact 43D1, contact 911, contact 90B1, contact 90C1, contacts 4T1 or 91E2, contact 116, relay 11, contact 127, contact ULS′ to battery (−). When the car is further decelerated and the plate P faces the segment 91E, the relay connected to the segment 91E is released to open the contacts 91E1 and 91E2. The self-holding of the relay 11 is still maintained by the circuit from battery (+), contact 43D1, contact 911, contact 90B1, contact 90C1, contact 4T1, contact 116, relay 11, contact 127, contact ULS' to battery (−). When the car closes to the stop position of the target floor, the plate P faces the segment 91 so that the relay connected to the segment 91 is released thereby. Then the contact 911 is opened and also the self-holding circuit of the relay 11 is opened.

The contacts **111** to **113** open and the exciting current which has been supplied to the coil of the electromagnetic brake MB is interrupted. The braking effort takes effect and the car stops at the target floor.

When the car runs at an over-speed during the upward operation, the contact SDU′ is opened to release the relay **13** so that the contacts **131** and **132** open and the motor HM is separated from the alternating current source. Further, if the car reaches the upper limit of the elevator shaft, the contact ULS′ is opened to release the relay **11** so that the contacts **111** to **113** open and the electromagnetic brake MB takes effect simultaneously with separation of the motor HM from the alternating current source.

Now, the speed pattern generated by the pattern generators PG and APG, will be explained with reference to FIGS. **3***a*, **3***b* and **3***c*. FIG. **3***a* shows the auxiliary pattern generated by the auxiliary generator APG, in which the speed is plotted against time. FIG. **3***b* shows the main speed pattern generated by the pattern generator PG, in which the speed is plotted against distance. FIGS. **3***c* shows the combination pattern of the pattern shown in FIG. **3***a* with the pattern shown in FIG. **3***b*. The pattern shown in FIG. **3***a* may be produced by means of a condensor which starts to discharge when the plate P in FIG. **1** faces the segment **91**A. The pattern shown in FIG. **3***b* may be produced by using the outputs of the relays of the segments **91**A to **91**E as mentioned above. Both patterns generated as a direct current voltage may be easily superposed by a conventional analog adder to produce the pattern as shown in FIG. **3***c*.

Only the pattern shown in FIG. **3***b* has previously been employed. In this case, if the speed of the car exceeds the pattern speed, as shown by a line C in FIG. **4***a*, a braking current is suddenly built up, as shown by the dotted line g in FIG. **4***b*, since a positive deviation is previously produced between the pattern speed and the actual speed when the car reaches the deceleration starting point. Therefore, the speed of the car is rapidly reduced, as shown by the dotted line d in FIG. **4***a*, so that a shock occurs in the car. According to the pattern shown in FIG. **3***c*, the braking effort influencing point is varied as the time points t_2 and t_3. The braking currents are smoothly built up as shown by lines *e* and *f* in FIG. **4***b* since a negative deviation is always produced between the pattern speed and the actual speed at the deceleration starting point t_1.

The pattern shown in FIG. **3***c* can also be produced directly; however, this is inadvisable owing to the need for a complex and expensive pattern generator including a great many position detectors. On the contrary, the method of pattern generation as shown by FIGS. **3***a*, **3***b* and **3***c* does not need so many position detectors and the generator is simple and easy to manufacture.

Another modification of the invention will be explained in the following. An induction motor generally has such a characteristic that if the induction motor is excited by a constant direct current, the braking effect generated thereby is constant during any speed higher than a certain speed, but it becomes proportional to the number of rotations of the motor at a speed lower than said certain speed. Therefore, when the car continues to be decelerated by exciting the motor LM with a direct current, the dynamic braking effort becomes very small just before stopping so that the speed of the

car may not become low enough to provide a shockless braking effort by the electromagnetic brake. If the car is subjected to the braking effort by the electromagnetic brake under the aforementioned circumstance, not only will the shock occur, but also the landing accuracy becomes worse.

Accordingly, it will be better to control the car so that when it approaches a point which is a predetermined distance before the stop point of the target floor, the pattern shown in FIG. **3***c* becomes abruptly zero so that the deviation between the pattern speed and the actual speed is maintained at a significant level to supply a large current to the motor LM even at the low speed. The dynamic braking effort produced by the motor LM is increased thereby, and the speed of the car becomes low enough to effect a shockless braking effort by the electromagnetic brake.

The foregoing explanation relates to the upward operation of the car, but it will be apparent that the downward operation may be controlled in a similar manner.

While a particular embodiment of the invention has been illustrated and described, it will be obvious to those skilled in the art that various changes and modifications can be made without departing from the invention and it is intended in the appended claims to cover all such changes and modifications that fall within the true spirit and scope of the invention.

What is claimed is:

1. In a control apparatus for an elevator car driven by a two-speed alternating current motor system including a high speed alternating current sub-system and a low speed alternating current sub-system and electromagnetic brake means associated with said motor system for effecting a braking of the movement of the car, the improvement comprising supply means for controllably supplying a direct energizing current to said low speed sub-system of the motor system to effect deceleration by dynamic braking of said car, control means for controlling the direct current from said supply means according to the deviation between a particular positional speed pattern and the actual speed of the car during deceleration, and operating means responsive to the speed of the car for operating said electromagnetic brake means after the car is reduced to a prescribed speed by said control means and sufficiently approaches the target floor.

2. A control apparatus for an elevator car according to claim **1**, wherein the speed pattern has a particularly large deceleration in the initial part of the pattern.

3. A control apparatus for an elevator car according to claim **1**, wherein said control means includes a first speed pattern generator providing a speed pattern having a predetermined deceleration from a maximum speed of the car at a deceleration starting point to a stop point of the target floor and a second speed pattern generator providing a larger deceleration than the predetermined deceleration from a point higher than the maximum speed at the deceleration starting point to the initial point of the pattern of said first speed pattern generator, the outputs of said first and second speed pattern generators being combined to produce a composite speed pattern.

4. A control apparatus for an elevator car according to claim **3**, wherein said control means includes detecting means for detecting sequential positions located in spaced relationship prior to each floor at which said elevator may stop, said first speed pattern generator including means responsive to a request for deceleration of the elevator car for integrating the output of said detecting means as each sequential position is detected prior to a target floor.

5. A control apparatus for an elevator car according to claim **4**, wherein said first speed pattern generator is non-responsive to the last output of said detecting means prior to a target floor.

6. A control apparatus as defined in claim **4** wherein said operating means includes relay means responsive to a service request signal for connecting an alternating current source to said motor system to initiate movement of said car and holding means for maintaining operation of said relay means during movement of said car above a prescribed speed, said relay means having normally closed contacts in the energization circuit of said electromagnetic brake means so that said electromagnetic brake means is de-energized during operation of said relay means.

7. A control apparatus as defined in claim **6** wherein said operating means further includes protection means responsive to a signal from said detecting means detecting passage of said car beyond one of said sequential positions for overriding said holding means so as to deactivate said relay means and permit operation of said electromagnetic brake means.

8. A control apparatus for an elevator car according to claim **3**, wherein said second speed pattern generator includes a capacitor and means for initiating charging of said capacitor upon reaching a deceleration starting point.

9. A control apparatus for an elevator car according to claim **3**, wherein said control means includes means for reducing said composite speed pattern to zero at a point which is a predetermined distance prior to the stopping point at the target floor.

10. A control apparatus for an elevator car according to claim **1**, wherein said control means includes a voltage regulator connected between said supply means and said low speed sub-system, a phase shifter connected in control of said voltage regulator, a comparator having an output connected to said phase shifter, first and second pattern generators connected together to one input of said comparator, and a speed detecting generator connected to said motor system and having an output connected to a second input of said comparator.

11. A control apparatus for an elevator car according to claim **10**, wherein said control means includes means for reducing said speed pattern to zero at a point which is a predetermined distance prior to the stopping point at the target floor.

12. A control apparatus for an elevator car according to claim **10**, wherein said control means includes a current detector connected between said supply means and said voltage regulator for detecting operation of said control means to initiate said dynamic braking, said current detecting means effecting operation of said means for reducing said speed pattern to zero.

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