

PATENT SPECIFICATION

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- 26 369 (21) Application No. 43749/76 (22) Filed 21 Oct. 1976
(31) Convention Application No. 50/127423 (32) Filed 24 Oct. 1975 in
(33) Japan (JP)
(44) Complete Specification Published 27 Sep. 1978
(51) INT CL² B66B 1/30
(52) Index at Acceptance
G3N 251 265B 351 361 BX



(54) ELEVATOR SYSTEM CONTROL APPARATUS

- (71) We, HITACHI, LTD., a Corporation organised under the laws of Japan, of 5-1, 1-chome, Marunouchi, Chiyoda-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-
- 5 The present invention relates to an improvement in an elevator system control apparatus, in particular to the control of the starting of an elevator cage.
- 10 Many elevator systems are so constructed that an elevator cage and a counter-weight are slung over a sheave by means of rope, which sheave is driven by a motor. This mechanical system is held stationary by an electromagnetic brake while the elevator
- 15 cage is stopped. When the cage starts, the brake is set free while at the same time the drive motor is started in response to a speed command. If the difference in weight between the cage and the counter-weight
- 20 imposes an unbalanced torque on the sheave, the cage "jumps" or "reverses". In the event that the cage filled up to capacity starts upward, the fact that the cage is heavier than the counter-weight causes the
- 25 cage to move down (reverses) the instant the brake is set free. When the motor torque which increases with the speed command surpasses the unbalanced torque, the cage begins to move upward. In the case where
- 30 few passengers are present in the cage at the time of cage start upward, by contrast, the cage is abruptly accelerated or "jumps" upward.
- 35 In order to prevent the deterioration of the riding comfort of the elevator due to this phenomenon of jumping or reversal, it has been suggested that a motor torque offsetting the unbalanced torque be produced. The continuous detection of the magnitude
- 40 of the unbalanced torque is not expedient as it complicates the apparatus and increases the cost thereof.
- 45 As an alternative, a cage start control with a simple detector has been suggested. In such a cage start control, it is detected whether the load torque (unbalanced torque) applied to the motor by the cage and the counter-weight is a positive load torque likely to reverse the cage operation in the direction opposite to the motor drive torque or a reverse load torque likely to cause the cage to "jump" in the same direction as the motor drive torque. In what is called the "geared elevator" including a reduction gear between the motor and the sheave, the friction torque is so large that the amount of jump is small as compared with the average cage acceleration and therefore does not adversely affect the riding comfort so much. Further, the passengers are not made to feel ill at ease by any jumping so much as when there is a cage reversal accompanying a movement in the opposite direction. For these reasons, a start compensation signal is applied to the positive load torque thereby to produce a motor torque commensurate with the positive load torque, thus preventing the cage reversal. If the cage reversal is to be prevented in all cases, it is necessary to compensate for the positive load torque of every magnitude. In the conventional control apparatuses, however, the start compensation signal does not have a margin ample enough to compensate for every positive load torque. Therefore, it has been very difficult to provide allowance in design of the conventional control apparatus.
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- An object of the present invention is to provide a simple elevator control apparatus capable of being designed with an allowance, which, in an elevator system having a detector for detecting the load torque in steps and producing an output whereby the start compensation is effected at the time of cage start, provides good riding comfort

under all load conditions.

According to the present invention, there is provided a control apparatus for an elevator system comprising an elevator cage, a counter-weight, a sheave over which the elevator cage and the counter-weight are slung, and a motor for driving the sheave: the control apparatus comprising; speed command generator means which, in use, generates a signal determining a desired speed of the elevator cage and including an acceleration command device arranged to generate a cage acceleration command; control means which continuously control the torque generated in the motor in accordance with the output of the speed command generator means; detector means arranged to detect an unbalanced torque due to the difference between a torque applied to the motor by the cage and a torque applied to the motor by the counter-weight, the difference varying in accordance with the weight of the cage and its contents; compensation signal generator means arranged to generate a predetermined compensation signal, in accordance with the detected unbalanced torque, during a predetermined period of time from a point prior to cage start; and synthesizer means arranged to combine an output signal from the acceleration command device with the compensation signal so as to increase at cage acceleration control input to the control means at a rate smaller than the maximum rate of increase of the acceleration command.

The prior art and the present invention will be described in detail with reference to the accompanying drawings, in which:

Fig. 1 is a block diagram showing an example of the main circuit construction of an elevator system control apparatus to which the present invention is applicable;

Fig. 2 is a block diagram showing an example of the construction of a phase control device included in the control apparatus shown in Fig. 1;

Fig. 3 is a diagram showing an acceleration command circuit having a start compensation circuit in a conventional control apparatus;

Fig. 4 is a diagram showing an example of a load torque detector;

Fig. 5 is a diagram showing control signals for controlling the torque generated in a motor of the conventional control apparatus;

Fig. 6 is a diagram showing the control margin at the time of starting the elevator cage in the conventional control apparatus;

Fig. 7 is a diagram showing the motor torque, the load torque and the cage acceleration as relative to each other for explaining the diagram of Fig. 6;

Fig. 8 is a diagram showing an acceleration command circuit including a start com-

ensation circuit according to an embodiment of the present invention;

Figs. 9A and 9B are time charts showing operations of relays in an embodiment of the present invention;

Figs. 10A and 10B are diagrams showing control signals for controlling the torque generated in a motor of the control apparatus, according to the present invention.

Fig. 11 is a diagram showing the control margin at the time of starting the elevator cage according to the present invention; and

Fig. 12 is a diagram showing the motor torque, the load torque and the cage acceleration as relative to each other for explaining the diagram of Fig. 11.

A conventional simple start control apparatus will be described below with reference to Figs. 1 to 6. Although the description below includes an AC elevator system with a three-phase induction motor as a drive source, the control apparatus is of course applicable also to a DC elevator system using a DC motor.

The construction of the main circuit of the control apparatus for the AC elevator system is shown in Fig. 1. A power line connecting an AC power supply 10 and an induction motor 14 includes a phase-rotation changing device 11 and an acceleration control device 12 including reverse-parallel thyristors 121 and 122. This control device 12 is for controlling the drive torque of the motor 14. The other power line includes a deceleration control device 13 having a controlled rectifier circuit with a thyristor 131 for controlling the brake torque of the motor 14. The thyristors 121, 122 and 131 are phase-controlled by the output signal from a phase control device 17. The control device 17 compares the speed command generated by a speed command circuit 15 with an actual speed signal generated by a tachometer generator 16 producing an output signal proportional to the rotation of the motor 14, thus phase-controlling the thyristors in accordance with the deviation between the two signals compared. In other words, a speed feed-back control is effected. An elevator cage 20 is connected through an elevator rope 19 to a counter-weight 21 and suspended on a sheave 18 coupled to the motor 14. The torque of the motor 14 is transmitted to the elevator cage 20 via the sheave 18.

The construction of the phase control device is shown in Fig. 2. The power supply 10 is connected via a phase shifter power circuit 171 to acceleration and deceleration phase shifters 172 and 173. The output signals from the phase shifters 172 and 173 are applied to the thyristors in the acceleration and deceleration control devices 12 and 13 respectively. On the other hand, the out-

puts of the speed command circuit 15 and the tachometer generator 16 are applied to the comparators 174 and 175, the outputs of which are in turn applied to the phase shifters 172 and 173. When the signal level of the speed command is higher than that of an actual speed signal, the acceleration comparator 174 produces an output signal, so that the acceleration phase shifter 172 applies its output signal to the acceleration control device 12. When the signal level of the speed command is lower than that of the actual speed signal, by contrast, the deceleration comparator 175 produces an output signal, so that the deceleration phase shifter 173 applies an output signal to the deceleration control device 13. The speed command circuit 15 includes an acceleration command circuit and a deceleration command circuit. The acceleration command circuit is provided with a start compensation circuit for compensating for the load torque at the time of starting the elevator cage.

The acceleration command circuit including the start compensation circuit according to the prior art will be described below with reference to Fig. 3.

A DC voltage of a DC power supply DC is applied to a series circuit including resistors R_1 and R_2 through a contact Ca of a relay C not shown. The junction point of the resistors R_1 and R_2 is connected to the base of a transistor Tr through the resistor R_3 . The collector of the transistor Tr is connected to the DC power supply through the resistor R_4 and the diode SD while a capacitor C_1 is inserted between the collector and base thereof, thus making up a Miller integrator circuit. As a result, a linearly-increasing voltage is obtained across the resistor R_4 . A series circuit including the resistor R_5 and a relay contact Ea of a relay E of a load torque detector circuit shown in Fig. 4 is inserted as a start compensation circuit between the junction point a of the resistor R_4 and the diode SD and the emitter terminal b (the negative terminal of the DC power supply DC) of the transistor Tr. The relay E is energized when the load torque is opposite in direction to the drive torque of the motor, i.e. in the case of a positive load torque, such as when the cage is operated upward with a cage load greater than a predetermined load giving a balance in weight between the cage and the counterweight (such a predetermined load being defined here as a half of the rated load) or when the cage is operated downward with the cage load smaller than the predetermined load.

The operation of the relay E will be explained with reference to Fig. 4. When the load is increased beyond the predetermined load, a contact WS of a weighing instrument provided on the elevator cage is closed, so that a relay W is energized by a power supply

inserted between the lines M and N not shown in the drawing. At this time, a normally-open contact Wa is closed and its normally-closed contact Wb is opened. Relay contacts UP and DN are contacts of relays adapted to be energized when the cage is moving up and down respectively. When the cage moves up with a load more than the predetermined load, the contacts UP and Wa are turned on, and therefore the relay E is energized by the power supply inserted between the lines M and N through the contacts UP and Wa. When the cage moves down with a load below the predetermined load, on the other hand, the relay W is not energized and therefore the contact Wb remains closed. At this time the contact DN is turned on, thus energizing the relay E. A relay contact Aa' is adapted to be closed or turned on at the start of the operation of the cage and is associated with a relay A energized at the cage starting, which is not shown in the drawing. This relay contact Aa' and a contact Ea' of the relay E make up a hold circuit for the relay E during the cage operation.

A control signal S obtained from the acceleration command circuit and the start compensation circuit of Fig. 3 is shown in Fig. 5. This control signal S is applied to the phase control device 17 and, through the acceleration control device 12, controls the drive torque of the motor 14. The control signal S will be explained below with reference to the operation of the circuit of Fig. 3.

When the load torque is positive, simultaneously with the energization of the relay A at time point t_A , the relay E is energized thereby to turn on the contact Ea. A voltage is generated across the resistor R_4 due to division of the voltage of the power supply DC by the resistors R_4 and R_5 . Since the contact Aa of the relay A is turned on, this voltage is produced between the output terminals OUT₁ and OUT₂ through a smoothing circuit including resistors R_6 and R_7 and a capacitor C_2 . This voltage makes up a start compensation signal shown by S_1 in Fig. 5. When the relay C is energized and the contact Ca is turned on at the time point t_C , the transistor Tr begins to conduct. The capacitor C_1 which has been charged to the voltage of the DC power supply with the contact Ca turned off begins to discharge, so that the voltage across the resistor R_4 begins to increase. When the capacitor C_1 has completely discharged, the voltage across the resistor R_4 becomes almost equal to the voltage of the DC power supply DC. This voltage appears between the output terminals OUT₁ and OUT₂ because the contact Aa is in turned-on state, and makes up an acceleration command signal shown by S_2 in Fig. 5. In the event that the acceleration command voltage is lower than the start compensation

voltage, the potential of the capacitor C_1 is higher than that at the point a , and therefore the diode SD is in non-conductive state with a reverse voltage applied thereto, so that the start compensation voltage is produced across the resistor R_4 . When the acceleration command voltage is higher than the start compensation voltage, by contrast, the potential of the capacitor C_1 is reduced below that at the point a , so that a forward voltage is applied to the diode SD, thereby making it conduct, thus producing the acceleration command signal across the resistor R_4 . In other words, the circuit of Fig. 3 constitutes a higher priority circuit. The result is that the signal S shown by a solid line in Fig. 5 is produced between the output terminals OUT₁ and OUT₂. This is equivalent to say that when the signal S_1 is larger than signal S_2 , the signal S takes the form of signal S_1 , whereas when the signal S_2 is larger than the signal S_1 , the signal S assumes the form of signal S_2 .

When the cage is operating with a reverse load torque, the relay E is not energized. Therefore, from the time point t_A to t_C , the signal S is zero and, after t_C , assumes the form of S_2 . In the case where the cage load is equal to the predetermined load level or a half of the rated load, no load torque is ideally generated regardless of whether the cage is moving up or down (The operation in this case is referred hereinafter as the "zero load torque operation".) In this case, the relay contact Ea may be either turned on or off.

If the detection of the load conditions (that is, the magnitude of the unbalance torque) is effected in the two ranges of loads greater and smaller than the half of the rated load, as described above, when a load greater than the rated load is detected, the start compensation must be such as to satisfy any conditions between the full load of passengers and the half of the rated load. In the case where a load smaller than the half of the rated load is detected, on the other hand, the start compensation is required to meet every situation between the state of the cage loaded with one passenger and half of the rated load. Further, unless the start compensation is effected with an ample margin of the amplitude of the start signal, a disadvantageous design of the control apparatus is inevitable. Also, when the start compensation signal undergoes a change in the amplitude for some reason or other, the riding quality of the elevator cage loaded is undesirably reduced for a certain load condition. According to the conventional control signal generator circuit shown in Fig. 3, it is impossible to carry out the start compensation with an ample margin satisfying every load condition. This will be explained below with reference to Figs. 6 and 7.

Fig. 6 shows the range of good riding quality at the time of cage start by a shadowed area in a graph with the abscissa and ordinate representing the load torque and the magnitude of the start compensation signal, i.e. the magnitude of the motor start torque, respectively. The point N on the abscissa is representative of the maximum reverse load torque, the point Z the zero load torque, and the point P the maximum positive load torque. It is to explain how much start control of the same direction as the start compensation for the positive load torque is allowable for the reverse load torque that the region of the reverse load torque is shown in Fig. 6. At the maximum reverse load torque N, the cage is already likely to jump out when the signal S_1 is zero. In what is called the "geared elevator" provided with a reduction gear between the motor and the sheave, however, the friction torque is so large that the amount of jump is small as compared with the cage average acceleration, so that the riding comfort of the cage is not so much adversely affected. With the increase in the signal S_1 , the amount of jump is accordingly increased. The threshold point of the signal S_1 associated with the effected of the shock due to the jump on the riding quality is shown by the point F. In other words, the tolerable range of the signal S_1 associated with the maximum reverse load torque is represented by the range from point N to point F.

Assume that the load torque is zero. When the signal S_1 is zero, the cage neither jumps nor reverses. With increase of signal S_1 , the likelihood of jumping is gradually increased. The tolerable range of signal S_1 for the zero load torque is larger than the range for maximum reverse load torque and is shown by the range from point Z to point G.

In the range from the zero load torque Z to a positive load torque J, the cage is not reversed even in the absence of start compensation. This is also due to the large friction torque of the geared elevator.

Between the positive load torque J and the maximum positive load torque P, the cage is reversed in the absence of the start compensation, thus posing the problem of a deteriorated riding quality. To overcome this problem, the start compensation signals S_1 is produced by the circuit of Fig. 3, and the start compensation is effected to prevent the reversal. The amount of start compensation in this case will be explained with reference to Fig. 7 taking the case of the maximum positive load torque as an example.

In the foregoing description, the predetermined load giving a balance in weight between the cage and the counter-weight was defined as a half of the rated load for convenience of explanation. Actually, how-

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ever, the predetermined load is selected in the range from 40 to 50% of the rated load. Thus, when the cage is operated upward with the full load of passengers, the maximum positive load torque is generated. When the cage is loaded to the full capacity, the weight applied to the sheave reaches a maximum, so that the stationary friction of the mechanical system including the reduction gear takes a very great maximum value. Now, the minimum amount of start compensation eliminating the cage reversal against the maximum positive load torque P is represented by a point K' , which is substantially equal to the intersection between the line passing the point J in parallel to the line FG and the normal passing the point P in Fig. 6.

In the graphs of (A) to (D) of Fig. 7, the abscissa represents time, and the ordinate the load torque, the motor torque and the cage acceleration. The graph (A) shows the case in which the start compensation signal is represented by the point K'' which is smaller than the one represented by the point K' . A little after the time point t_A when the start compensation signal S_1 is generated, a start compensation current flows in the motor, thereby producing a start torque proportional to the square of the current. The start compensation signal S_1 and hence the start torque becomes constant after the lapse of a certain period of time following the generation of the start compensation signal S_1 . At the time point t_C , the acceleration command signal S_2 is generated. When this signal increases beyond the start compensation signal S_1 , the current flowing in the motor is increased thereby to increase the motor torque. With the further increase in the acceleration command signal, the phase shifter is saturated, so that the motor current becomes almost constant and so does the motor torque. This torque is called the acceleration torque. When the electromagnetic brake is released at the time point t_C , the cage begins to move with a time delay determined by the response delay of the mechanism of the elevator system including the reduction gear. This response delay tends to increase with a reduction in the amount of start compensation. If the start torque is smaller than the load torque, the reversal operation of the cage occurs. By increasing the start compensation signal S_1 , namely, the amount of start compensation up to the point K' so as to make the start torque equal to the load torque, the reversal operation is eliminated as shown in (B) of Fig. 7. When the positive load torque is at its maximum, however, the static friction is very large, as mentioned above, so that a very large start torque is required on the one hand and a large variation is involved from the static friction to the dynamic friction on

the other, resulting in a large variation in speed and hence a rather deteriorated riding quality. It is therefore necessary to further increase the start compensation signal S_1 up to a point K as shown in Fig. 6. If the change in acceleration is to have no effect on the riding comfort, the start compensation signal expressed by the point K must be large. This reduces the difference between the levels of the points K and G considerably, often rendering them almost at the same level. On the other hand, the friction torque of the mechanical system of the geared elevator permits an amount of compensation more than that represented by the point K , providing a good riding quality up to the amount of the start compensation represented by a point H , as shown in (C) of Fig. 7. If the amount of the compensation is represented by a point H' which is more than that represented by the point H , the start torque approaches the acceleration torque. The sudden acceleration of the cage with this torque deteriorates the riding quality because of a large rate of acceleration of the cage with this torque deteriorates the riding quality because of a large rate of acceleration change, i.e. a large physiological constant at the time of car start as shown in (D) of Fig. 7. Therefore, the tolerable range of the start compensation signal S_1 at the maximum positive load torque is from the point K to the point H .

In the circuit of Fig. 3, whether the load torque is positive or reverse is detected by one point detection, so that, if a positive load torque is involved, the start compensation is effected. If a good riding quality is to be assured for all positive load torques, the magnitude of the start compensation signal is required to be determined between the levels of the points K and G . This limits the margin of the start compensation signal considerably, sometimes permitting only one value to be taken for the compensating signal.

Additionally describing, in the case where the load torque is detected, for example, by two point detection instead of one point detection, in the ranges $N - N_1$, $N_1 - P_1$ and $P_1 - P$ as shown in Fig. 6, the tolerable range of the start compensation signal S_1 is from the level of the point J' to that of the point F' in the load torque range from N_1 to P_1 , while it is from the level of the point K to that of the point G' for the load torque range from P_1 to P .

This shortage of the margin of the magnitude of the start compensation signal S_1 for start compensation operation makes the design of the control apparatus difficult. Further, the variation, if any, in the magnitude of the start compensation signal S_1 for some reason or other makes satisfactory start compensation impossible for a certain

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load condition. This disadvantage of the conventional control apparatus is attributable to the fact that, because of the employment of the higher priority circuit for the start compensation signal S_1 and the acceleration command signal S_2 , the constant value S_1 is maintained during the time when the signal S_1 is greater than the signal S_2 , and that the output signal S changes at a

grad rate at the point when the signal S_2 becomes greater than the signal S_1 . This disadvantage is always involved in the case where the unbalanced load torque is detected not continuously but in several steps.

The present invention has been developed to overcome this disadvantage of the conventional control apparatus, and an embodiment thereof will be described below with reference to Figs. 8 to 12.

The acceleration command circuit including a start compensation circuit according to an embodiment of the present invention is shown in Fig. 8. In the drawing, like component elements are shown by like reference numerals as in Fig. 3. The acceleration command circuit according to this embodiment shown in the upper part of the drawing is similar to the acceleration command circuit shown in Fig. 3, excepting that, in the drawing under consideration, a parallel circuit including a resistor R_8 , a contact Da of a relay D not shown, and a normally-closed contact Eb of the relay E, is additionally provided. The start compensation circuit for generating a start compensation signal to be synthesized with an acceleration command signal is shown in the lower part of the drawing. In the start compensation circuit, a series circuit including a normally-closed contact Db of the relay D, a contact Ba of a relay B not shown, and resistors R_9 and R_{10} is connected to the DC power supply DC2. When the contacts Db and Ba are both turned on, a voltage is obtained across the resistor R_{10} due to division of the voltage of the power supply DC2 by the resistors R_9 and R_{10} . The voltage across the resistor R_{10} is applied between the junction points c and d through the diode SD_2 , the capacitor C_3 , the resistor R_{11} and the contact Ea. The relays B, C and D are adapted to be energized simultaneously with, or predetermined times after, the energization of the relay A at the time of cage start, respectively. The relations of time points of energization of the relays A, B, C and D are shown in Figs. 9A and 9B.

The control signal S obtained from the acceleration command circuit and the start compensation circuit of Fig. 8 is shown in Figs. 10A and 10B corresponding to the relay operations of Figs. 9A and 9B respectively. The control signal S will be explained below with reference to the operation of the

circuit of Fig. 8. Assume that the relay operation is as shown by the time chart of Fig. 9A. Reference is first made to the start compensation circuit. When a positive load torque is involved, simultaneously with the energization of the relay A at the time of cage start, the relay E is energized turning on the contact Ea. at the same time, the relay B is energized thereby to turn on the contact Ba. Under this condition, the relay contact Db is on, and therefore the capacitor C_3 is charged by the voltage across the resistor R_{10} produced due to division of the voltage of the DC power supply DC2 by the resistors R_9 and R_{10} . At time point t_D when the relay D is energized, the normally-closed contact Db is turned off, so that the DC power supply DC is separated from the circuit, thus causing the capacitor C_3 to discharge. The result is that the start compensation signal voltage as shown by S_1 in Fig. 10A is obtained between the junction points c and d. In the acceleration command circuit, on the other hand, when the contact Ca is turned on by the energization of the relay C at time point t_C , the voltage across the resistor R_4 begins to increase as explained with reference to the circuit of Fig. 3. The rate of increase in the voltage across resistor R_4 , however, is small because the turned-off condition of the contact Da causes the resistance component of the discharge circuit of the capacitor C_1 to be increased by the amount equivalent to the resistor R_8 , until the relay D is energized at time point t_D . In response to the turning on of the contact Da by the energization of the relay D, the rate of increase in the voltage across the resistor R_4 increases until it becomes substantially equal to the voltage across the DC power supply DC after complete discharge of the capacitor C_1 . Thus, the acceleration command signal voltage obtained between the junction points c and d assumes the form as shown by S_3 in Fig. 10A. The start compensation signal voltage is synthesized with the acceleration command voltage in a high-gain operational amplifier (not shown) at the output side. The output voltage of this high-gain operational amplifier constitutes the control signal for controlling the drive torque of the motor and is expressed as $S = S_1 + S_3$ in Fig. 10A.

When the reverse load torque is involved, on the other hand, the relay E is not energized and therefore the output signal S takes the form as shown by the dotted line S_2 in Fig. 10A as in the case of Fig. 3. In the case of the zero load torque, the relay E is either energized or not, so that the output signal S takes the form of either $S_1 + S_3$ or S_2 .

Another example of the control signal S according to the foregoing embodiment is shown in Fig. 10B, which corresponds to the case where the operations of the relays A, B,

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C and D are represented by the time chart of Fig. 9B. In both Fig. 10A and Fig. 10B, the rate of increase in the control signal S does not so greatly change as that of the control signal shown in Fig. 5 and, after the lapse of a certain period of time following the generation thereof, is smaller than that of the signal S_2 . During this certain period of time, the electromagnetic brake is in operation and therefore the cage is prevented from being started.

The signal S obtained by synthesizing the start compensation signal S_1 with the acceleration command signal S_3 as shown in Fig. 10A is used as a control signal, thus making possible the start compensation with an ample margin of the amplitude of the start compensation signal for all load torques. This will be explained below with reference to Figs. 11 and 12.

The diagram of Fig. 11 is similar to that of Fig. 6, in which the range of good riding quality is shown as shadowed portion. The tolerable range of the start compensation signal S_1 associated with the maximum positive load torque is from point K'' to point H. In spite of the fact that the magnitude of the start compensation signal S_1 represented by the point K'' is smaller than that at point K' in Fig. 6, the reversed operation of the cage does not occur. Further, the ceiling H of the tolerable range of the start compensation signal S_1 at the maximum positive load torque is substantially the same as in the case of Fig. 6.

The tolerable range of the start compensation signal S_1 associated with the maximum positive load torque will be explained below with reference to Fig. 12. The diagram of Fig. 12 which is similar to that of Fig. 7 shows the case in which the operations of the relays A, B, C and D are represented by the time chart of Fig. 9A, that is, the control signal of Fig. 10A is involved. The graph (A) of Fig. 12 shows the case where the start compensation signal is represented by K''. The start compensation signal is generated at time point t_A , and the speed command signal at time point t_C . The electromagnetic brake is released at time point t_C . The control signal S obtained by synthesizing the start compensation signal with the acceleration command signal increases continuously. Therefore, the motor torque which is generated with a certain time delay behind the control signal is also increased continuously until it reaches the same magnitude as the acceleration torque. At time point t_C when the electromagnetic brake is released, the start torque of the motor is smaller than the load torque. After a certain delay time due to the response delay of the mechanism of the elevator system, however, the motor torque is increased beyond the load torque and therefore no reversal operation of the

cage occurs. Also, since the rate of increase of the motor torque is smaller than in the conventional case of Fig. 7, the static friction affects less adversely the rate of change in acceleration. The graph (B) of Fig. 12 is shown for mere comparison with (B) of Fig. 7 and shows the case in which the start compensation signal S_1 assumes the magnitude as shown by K'. A good riding quality is obtained also in this case. The graph (C) of Fig. 12 shows the case in which the start compensation signal S_1 is represented by H. In this case, the start torque is larger than the load torque. Further, after the time point t_C , the motor torque increases continuously until it reaches the magnitude of the acceleration torque. In spite of this, since the torque increase from the start torque to the acceleration torque is small because of a large start torque, and also the response delay of the mechanical system is short, the relation almost the same as in (C) of Fig. 7 is obtained between the load torque and the motor torque at the time of cage start after the response delay, thus providing a good riding quality. The graph (D) of Fig. 12 shows the case in which the start compensation signal is represented by H' larger than H. AS IN THE CASE OF (D) of Fig. 7, the rate of change in acceleration at the time of cage start, i.e., the physiological constant is large, thereby the riding quality deteriorates.

The same can be said of the case in which the operations of the relays A, B, C and D are represented by the time chart of Fig. 9B, namely, the case in which the control signal is shown by Fig. 10B. In this case, however, the electromagnetic brake is released between time points t_B and t_D .

It will be seen from Fig. 11 that the magnitude of the start compensation signal for assuring the satisfactory riding quality at the time of cage start can be determined between the levels of points K'' and G for all load conditions involving positive load torques, thereby providing an ample control margin.

The embodiment of the present invention has been explained in the foregoing description with respect to the operation such that whether a load torque is positive or reverse was detected by means of one point detection and, when it is positive, the start compensation is effected. The present invention is, however, not limited to such an operation but may be applied also to the cases in which the load torque detection is conducted in the load torque ranges of $N - N_1$, $N_1 - P_1$ and $P_1 - P$ as shown in Fig. 11. In such a case, the tolerable value of the start compensation signal ranges from the levels of point J' to F' for the load torque range $N_1 - P_1$, and from the levels of points K'' to G' for the load torque range $P_1 - P$. In addition, the above

described embodiment of the present invention is also operable when the start compensation is effected for a reverse load torque.

WHAT WE CLAIM IS:-

- 5 1. A control for an elevator system comprising an elevator cage, a counter-weight, a sheave over which said elevator cage and said counter-weight are slung, and a motor for driving said sheave; said control
10 apparatus comprising:
speed command generator means which, in use, generate a signal determining a desired speed of said elevator cage and including an acceleration command device
15 arranged to generate a cage acceleration command;
control means which continuously control a torque generated in said motor in accordance with the output of said speed command generator means;
20 detector means arranged to detect an unbalanced torque due to a difference between a torque applied to said motor by said cage and a torque applied to said motor by said counter-weight, the difference varying in accordance with the weight of said cage and its contents;
25 compensation signal generator means arranged to generate a predetermined compensation signal, in accordance with the detected unbalanced torque, during a predetermined period of time from a point prior to cage start; and
30 synthesizer means arranged to combine the output signal from said acceleration command device with the compensation signal so as to increase at cage acceleration the control input to said control means at a rate smaller than the maximum rate of
35 increase in the acceleration command.
40 2. A control apparatus according to Claim 1, in which said acceleration command device includes a device for permitting the generation of the acceleration command
45 signal to start at a first predetermined time point before cage start, and said compensation signal generator means includes a device for permitting the generation of the compensation signal to start at a second
50 predetermined time point before cage start.
3. A control apparatus according to Claim 2, in which said acceleration command device includes a device for increasing the acceleration command signal from said
55 first predetermined time point to a third predetermined time point at a rate smaller than a rate of increase for the period after said third predetermined time point.
4. A control apparatus according to
60 Claim 2, in which said compensation signal generator means includes a device for increasing the compensation signal from said second predetermined time point to a third predetermined time point and decreasing
65 said compensation signal after said third

predetermined time point.

5. A control apparatus according to Claim 2, in which said acceleration command device includes a device for increasing the acceleration command signal from said first predetermined time point to a third predetermined time point at a rate smaller
70 than a rate of increase for the period after said third predetermined time point, and said compensation signal generator means
75 includes a device for increasing the compensation signal from said second predetermined time point to said third predetermined time point and decreasing the compensation signal after said third predetermined
80 time point.

6. A control apparatus according to any one of Claims 2, 3, 4 and 5, in which said acceleration command device comprises a DC power supply; a transistor having a collector connected to the positive terminal of
85 said DC power supply via a resistor, an emitter connected to the negative terminal of said DC power supply, and a base impressed with a control signal from said DC power
90 supply; and a capacitor inserted between said base and said emitter of said transistor; and said device for permitting the generation of the acceleration command signal comprises a normally-open contact, inserted
95 between said DC power supply and said base, of a relay to be energized at said first predetermined time point.

7. A control apparatus according to any one of Claims 2, 3, 4 and 5, in which said compensation signal generator means comprises a DC power supply, and a series circuit of resistors for dividing the voltage of
100 said DC power supply; and said device for permitting the generation of the compensation signal comprises a normally-open contact, inserted between said DC power supply and said series circuit, of a relay to be energized at said second predetermined time
105 point.
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8. A control apparatus according to Claim 3 or 5, in which said acceleration command device comprises a DC power supply; a transistor having a collector connected to the positive terminal of said DC
115 power supply via a resistor, an emitter connected to the negative terminal of said DC power supply, and a base impressed with a control signal from said DC power supply; and a capacitor connected between said base and said emitter of said transistor; and said
120 device for increasing the acceleration command signal at the smaller rate comprises a parallel circuit including a resistor and a normally-open contact of a relay energized at said third predetermined time point, connected
125 between said DC power supply and said base.

9. A control apparatus according to Claim 8, in which said device for permitting
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described embodiment of the present invention is also operable when the start compensation is effected for a reverse load torque.

WHAT WE CLAIM IS:-

- 5 1. A control for an elevator system comprising an elevator cage, a counter-weight, a sheave over which said elevator cage and said counter-weight are slung, and a motor for driving said sheave; said control
10 apparatus comprising:
speed command generator means which, in use, generate a signal determining a desired speed of said elevator cage and including an acceleration command device
15 arranged to generate a cage acceleration command;
control means which continuously control a torque generated in said motor in accordance with the output of said speed command generator means;
20 detector means arranged to detect an unbalanced torque due to a difference between a torque applied to said motor by said cage and a torque applied to said motor by said counter-weight, the difference varying
25 in accordance with the weight of said cage and its contents;
compensation signal generator means arranged to generate a predetermined compensation signal, in accordance with the detected unbalanced torque, during a predetermined period of time from a point prior to cage start; and
30 synthesizer means arranged to combine the output signal from said acceleration command device with the compensation signal so as to increase at cage acceleration the control input to said control means at a rate smaller than the maximum rate of
35 increase in the acceleration command.
40 2. A control apparatus according to Claim 1, in which said acceleration command device includes a device for permitting the generation of the acceleration command signal to start at a first predetermined time point before cage start, and said compensation
45 signal generator means includes a device for permitting the generation of the compensation signal to start at a second predetermined time point before cage start.
50 3. A control apparatus according to Claim 2, in which said acceleration command device includes a device for increasing the acceleration command signal from said first predetermined time point to a third
55 predetermined time point at a rate smaller than a rate of increase for the period after said third predetermined time point.
4. A control apparatus according to Claim 2, in which said compensation signal generator means includes a device for increasing the compensation signal from said second predetermined time point to a third predetermined time point and decreasing
60 said compensation signal after said third
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predetermined time point.

5. A control apparatus according to Claim 2, in which said acceleration command device includes a device for increasing the acceleration command signal from said first predetermined time point to a third predetermined time point at a rate smaller than a rate of increase for the period after said third predetermined time point, and said compensation signal generator means
70 includes a device for increasing the compensation signal from said second predetermined time point to said third predetermined time point and decreasing the compensation signal after said third predetermined
75 time point.
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6. A control apparatus according to any one of Claims 2, 3, 4 and 5, in which said acceleration command device comprises a DC power supply; a transistor having a collector connected to the positive terminal of said DC power supply via a resistor, an emitter connected to the negative terminal of said DC power supply, and a base impressed with a control signal from said DC power supply; and a capacitor inserted between said base and said emitter of said transistor; and said device for permitting the generation of the acceleration command signal
85 comprises a normally-open contact, inserted between said DC power supply and said base, of a relay to be energized at said first predetermined time point.
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7. A control apparatus according to any one of Claims 2, 3, 4 and 5, in which said compensation signal generator means comprises a DC power supply, and a series circuit of resistors for dividing the voltage of said DC power supply; and said device for permitting the generation of the compensation signal comprises a normally-open contact, inserted between said DC power supply and said series circuit, of a relay to be energized at said second predetermined time point.
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8. A control apparatus according to Claim 3 or 5, in which said acceleration command device comprises a DC power supply; a transistor having a collector connected to the positive terminal of said DC power supply via a resistor, an emitter connected to the negative terminal of said DC power supply, and a base impressed with a control signal from said DC power supply; and a capacitor connected between said base and said emitter of said transistor; and said device for increasing the acceleration command signal at the smaller rate comprises a parallel circuit including a resistor and a normally-open contact of a relay energized at said third predetermined time point, connected between said DC power supply and said base.
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9. A control apparatus according to Claim 8, in which said device for permitting
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the generation of the acceleration command signal comprises a normally-open contact, connected in series with said parallel circuit, of a relay to be energized at said first predetermined time point.

10. A control apparatus according to Claim 4 or 5, in which said compensation signal generator means comprises a DC power supply and a series circuit of resistors for dividing the voltage of said DC power supply; and said device for increasing and then decreasing said compensation signal comprises a capacitor charged by the voltage across one of the resistors of said series circuit and a normally-closed contact, inserted between said DC power supply and said series circuit, of a relay to be energized at said third predetermined time point.

11. A control apparatus according to Claim 10, in which said device for permitting the generation of the compensation signal comprises a normally-open contact, inserted between said DC power supply and said series circuit, of a relay to be energized at said second predetermined time point.

12. A control apparatus according to Claim 5, in which said acceleration command device comprises a DC power supply, a transistor having a collector connected to the positive terminal of said DC power supply through a resistor and an emitter connected to the negative terminal of said DC power supply and a base impressed with a control signal from said DC power supply, and a capacitor inserted between said base and said collector of said transistor; said device for increasing said acceleration command signal at the smaller rate comprises a circuit including a resistor and a normally-open contact of a relay energized at said third predetermined time point, connected in parallel and inserted between said DC power supply and said base; said compensation signal generator means comprises

another DC power supply and a series circuit of resistors for dividing the voltage of said another DC power supply; and said device for increasing and then decreasing said compensation signal comprises a capacitor charged by a voltage across one of said resistors included in said series circuit and a normally-closed contact, inserted between said DC power supply and said series circuit, of a relay to be energized at said third predetermined time point.

13. A control apparatus according to any one of the preceding claims, in which said detector means detects whether said unbalanced torque is in the same direction or not as the drive torque of said motor, and said compensation signal generator means includes a device for permitting the generation of the compensation signal when the direction of said unbalanced torque is different from that of the drive torque of said motor.

14. A control apparatus according to Claim 13, in which said detector means includes a device for detecting a cage load comprising the weight of the cage and its contents, a device for detecting the direction of motion of the cage, and a relay energized when the unbalanced torque is in a direction different from that of the drive torque of said motor; and the last said device for permitting the generation of the compensation signal includes a normally-open contact of the last said relay disposed on the output side of said compensation signal generator means.

15. A control apparatus substantially as hereinbefore described with reference to Figures 8 to 12 of the accompanying drawings.

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