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(54) ELEVATOR 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:—

This invention relates to an improvement in a control apparatus for use in an AC-operated elevator.

The control apparatus for use in the AC-operated elevator with an induction motor as a driving source has undergone changes in the past.

Firstly, two induction motors each provided with a different synchronous speed have been used, in which the starting and accelerating operation of the elevator car is effected by use of the driving torque of the motor with the smaller number of poles (or a high-speed motor) while the decelerating operation thereof is accomplished by the regenerative braking torque of the motor with the larger number of poles (or a low-speed motor). The decelerated car is subjected to a creeping operation at a low speed which is in the vicinity of the synchronous speed of the low-speed motor, balancing the load torque and is then stopped by an electromagnetic brake at the destination. In such a control apparatus, the creeping operation at low speed results in a longer operating time and in addition provides an uncomfortable ride at the time of deceleration and stoppage.

Secondly, in order to obviate this disadvantage, a controlling apparatus of the speed feedback type has been employed in which the electric braking of the induction motor is utilized for deceleration. The electric braking operation is performed by a braking-torque control apparatus capable of continuously controlling DC braking, regenerative braking or reverse-phase braking torque by use of thyristors. This type of apparatus utilizes the conventional notch acceleration. At the time of deceleration, a speed command for decreasing the speed as a function of position is generated, so that a braking-torque control element using thyristors is controlled by differences between the actual speed and the

command speed. This construction makes it possible to keep deceleration speed characteristics substantially rectilinear until the car is stopped on the one hand and also to attain a shortened operation time as well as an improvement in the hitherto uncomfortable ride on the other.

A further development of the control apparatus includes driving torque control elements represented by thyristors in inverse-parallel connection as hereinafter described in order to provide smoother speed characteristics from starting of the car to its arrival at a given floor, thus permitting a speed feedback control over the entire range of car operation. More specifically, an acceleration speed command for increasing speed as a function of time and a deceleration speed command for decreasing speed as a function of position, are generated. During the accelerating operation, the thyristors in inverse-parallel connection (the driving torque control elements) are phase-controlled in accordance with the differences between the acceleration command speed and the actual speed. At the time of deceleration, on the other hand, the thyristors in the controlled rectifier circuit (the braking torque control elements associated with the DC braking) are phase-controlled in accordance with the differences between the actual speed and the deceleration command speed.

This type of control apparatus has the following shortcomings:

(1) False economy

There are the following problems with the speed feedback control by use of the thyristors in inverse-parallel connection, for instance, for the braking torque control elements and for the driving torque control elements: During the steady running operation after completion of acceleration control, the thyristors in inverse-parallel connection are preferably kept in a fully conducting state so as to enable the induction motor to produce a maximum output torque in order to raise the coefficient of thyristor utilization and achieve good control stability. During the accelerating operation, by contrast, the thyristors in inverse-parallel connection are controlled in accordance with the differences between a speed command voltage V_s and an actual

speed signal or voltage V_p of the tachometer generator. If the thyristors are to be successfully conducted fully during the steady running operation, it is necessary that the difference in voltage $V_s - V_p$ is set at a sufficiently large value. During the decelerating operation, however, the thyristors are used as braking torque control elements to be controlled in accordance with the difference between the actual speed signal V_p and the speed command voltage V_s , namely, $V_p - V_s$. In contrast with the accelerating operation, therefore, the actual speed signal V_p must be set higher than the speed command voltage V_s . During the decelerating operation, it is also necessary to adjust the gain of the control circuit by setting the two operating voltages at a sufficiently large level in order to increase the floor-arriving accuracy of the elevator car. For this reason, the operating voltage in the speed feedback control system must be set at different levels for the respective operations of acceleration and deceleration. This makes the circuit arrangement complex and high in cost.

(2) Low operating efficiency of elevator:

The elevator is given a speed command for progressively increasing the speed at a fixed rate and then is subjected to an acceleration control, so that a fixed acceleration time of the elevator car is obtained. By the way, with the fixed torque produced by a motor, the time required for acceleration of the elevator car is shorter under a light load than under a heavy load. Since the speed command provides a fixed acceleration time independently of the load according to the control apparatus under consideration, it is necessary that the acceleration time is inevitably set longer under a heavy load. Under a light load, therefore, the surplus torque of the motor is intentionally withheld to lengthen the acceleration time, resulting in a lower operating efficiency of the elevator car.

According to the present invention there is provided an AC-operated elevator control apparatus comprising: an induction motor arranged to drive an elevator car; driving torque control elements arranged to continuously control driving torque generated in said induction motor; braking torque control elements arranged to continuously control the braking torque generated in said induction motor; means for generating a speed command signal at least for deceleration of the elevator car; means for producing a speed signal representing the actual speed of the elevator car; acceleration control means arranged to control said driving torque control elements with an open control loop for speed regulation at the time of acceleration of the elevator car; and speed feedback control means arranged to control said braking torque control elements with a closed control loop for speed regulation in accordance with a

deviation signal representing the difference between said speed signal and said speed command signal at the time of deceleration of the elevator car.

Therefore, there is provided a economical apparatus for controlling an elevator which may give a satisfactory performance.

Furthermore, there is provided an elevator comprising driving torque control elements for continuously controlling the driving torque generated in an induction motor and braking torque control elements for continuously controlling the braking torque, the driving torque control elements are controlled with an open-loop control for speed regulation during the accelerating operation of the elevator car, while the braking torque control elements are subjected to a speed feedback control during the deceleration operation of the elevator car.

The driving torque control elements may be controlled by an acceleration command, a torque command or a speed command. It suffices if the driving torque is increased in such a manner that a feeling of a comfortable ride in the elevator car is not adversely affected by the acceleration. For the acceleration and torque other than the speed, therefore, a closed-loop (feedback) control is available.

A speed feedback control is effected at the time of deceleration, and therefore at least a device for producing a speed command during the decelerating operation is required. If the speed command generator is adapted to produce an acceleration command at the time of acceleration, a desired acceleration of the elevator car and the further simplification of the control apparatus may be achieved.

In the case of a single-speed motor, the DC braking and the reverse-phase braking torque may be used for a braking torque. When a two-speed motor is used, on the other hand, it may be considered for the two-speed motor to be switched over from a regenerative braking torque at the low speed side of its operation to the DC braking torque. However, for the control stability and simplicity of the apparatus, it is most suitable to control the DC braking torque.

The present invention will be apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:—

Figure 1 is a diagram showing the construction of an embodiment of the control apparatus for AC-operated elevator cars according to one embodiment of the present invention;

Figures 2a and 2b are diagrams for explaining the main circuit shown in the embodiment of Figure 1;

Figures 3a and 3b are diagrams showing the speed of the elevator car and the deceleration command voltage;

Figure 4 shows a characteristic diagram of

the phase shifter;

Figure 5 is a diagram for explaining an acceleration control device according to one embodiment of the invention;

- 5 Figure 6 is a circuit diagram showing a preferred embodiment of the acceleration and deceleration speed command generator according to one embodiment of the invention; Figures 7 and 8 are circuit diagrams showing a preferred embodiment of the phase shifter according to one embodiment of the invention; and

Figures 9 and 10 show modifications of the main circuit.

- 15 The present invention will be described in detail below with reference to the preferred embodiments shown in the accompanying drawings.

- 20 The construction of an embodiment of the control apparatus for the AC-operated elevator is shown in Figure 1.

- 25 An elevator car 1 and a counterweight 2 are hung on a sheave 4 by way of ropes 3. The sheave 4 is coupled to a three-phase induction motor 6 through a reduction gear (not shown) and an electromagnetic brake 5. The motor 6 is coupled to a tachometer generator 7.

- 30 The three-phase induction motor 6 is electrically connected to a three-phase AC power supply 8 through driving torque control elements or braking torque control elements. When contactors 9 (including contact elements 9—1, 9—2 and 9—3) are closed and contactors 13—1, 13—2 are open, for instance, the main circuit arrangement connected between the power supply 8 and the motor 6 may be formed as shown in Figure 2a. In other words, an inverse-parallel connection circuit of thyristors 11 and 12 is connected between the S-phase terminal of the three-phase AC power supply 8 and an input terminal of the inductor motor 6. It is well known that the torque generated in the induction motor can be regulated in a range between single-phase torque and three-phase torque by controlling a single-phase voltage by means of controlling the firing of the thyristors 11 and 12. In the embodiment under consideration, therefore, the thyristors in inverse-parallel connection are used for the driving torque regulating elements.

- 50 When the contactors 9 are opened and the contactors 13 (including contact elements 13—1 and 13—2) are closed, the main circuit arrangement is formed as shown in Figure 2b. In other words, the main circuit is adapted to make up a controlled rectifier circuit which receives AC power from the two phase terminals S and T of the three-phase power supply and then drain direct current into the three-phase induction motor 6 at the two terminals. This controlled rectifier circuit makes up a mixed bridge comprising the thyristors 11, 12 and diodes 14, 15. By controlling the firing of the thyristors 11 and

12, it is now possible to generate DC braking torque in the induction motor 6 and to regulate the magnitude thereof. In this case, the controlled rectifier circuit including the thyristors 11, 12 and diodes 14, 15 makes up braking torque regulating elements for the induction motor 6.

The speed command for deceleration generated by the acceleration and deceleration speed command generator 16 is applied to the comparator 17 where it is compared with the output of the tachometer generator 7. The resulting deviation signal is applied to the phase shifter 18 through an auxiliary contact element 13—3(a) of the contactor 13. On the other hand, the acceleration command output of the acceleration and deceleration speed command generator 16 is directly applied to the phase shifter 18 through an auxiliary contact element 13—3(b) of the contactor 13.

In this circuit arrangement, the contactor 9 is closed and then the acceleration and deceleration speed command generator 16 is actuated with the main circuit arranged as shown in Figure 2a at the time of starting the elevator car. It is here assumed that the command voltage generated by the acceleration and deceleration speed command generator 16 takes such a pattern as shown in Figure 3b.

When the speed characteristics as shown in Figure 3a are required for the elevator car, the command voltage should preferably undergo changes as shown in Figure 3b. The period of time from 0 to t_1 represents an acceleration period, the time from t_1 to t_2 a fixed speed period, and time from t_2 to t_3 a deceleration period. As will be seen from Figures 3a and 3b, the rise of the command voltage is set steeper than the actual speed increase of the elevator car in the acceleration period. This is for the purpose of fully conducting the thyristors in inverse-parallel connection before the fixed speed period to achieve stable speed control by taking advantage of maximum available torque of the induction motor. To achieve this purpose, the phase shifter should be adapted to produce a signal of the largest conduction angle in the course of the acceleration period from 0 to t_1 .

The conduction angle characteristics versus the input voltage of the phase shifter 18 are shown in Figure 4. It will be noted that the conduction angle increases linearly with respect to the input voltage increase of 0 to V_1 . After the input voltage exceeds V_1 , the conduction angle does not increase. The largest conduction angle is thus θ_s , where the thyristors 11 and 12 are considered to be in a fully conducting state.

When the phase shifter of such characteristics is used, the command voltage generated by the acceleration & deceleration speed command generator 16 has such a steep rise that it reaches the saturation voltage V_1 of the

phase shifter 18 at the time point t_{11} in the course of the acceleration period, as shown in Figure 3b. By the way, V_2 shows the maximum value of the command voltage. The length of this period from 0 to t_{11} should be determined in such a manner that the rate of acceleration change (referred to as physiological constant), which generally should not be higher than 2 m/sec^2 , does not adversely affect a feeling of undergoing a comfortable ride and that the acceleration torque can be raised as quickly as possible to utilize the maximum torque of the motor. Generally, the maximum acceleration is 1 m/sec^2 , and it is on this that a speed change at the time of acceleration is determined.

The manner in which the speed at the time of acceleration is determined will be explained with reference to Figure 5. In this drawing, time is plotted on the horizontal axis and acceleration (m/sec^2) and speed (m/sec) on the vertical axis. Assuming that the maximum acceleration is 1 m/sec^2 and rate of acceleration change (physiological constant) 2 m/sec^2 as mentioned above, an acceleration curve α is obtained. The speed change associated with this curve takes the form of curve v . The range of fixed acceleration begins at 0.5 sec. while the thyristors are preferably fully conducting, that is, the phase shifter 18 is saturated.

Accordingly, the command voltage to be applied to the phase shifter 18 may be one which reaches the saturation voltage V_1 of the phase shifter 18 at time point t_{11} , say, 0.5 sec. and limits the rate of acceleration change within an allowable range before the time point t_{11} . At or after the time point t_{11} , the phase shifter 18 is kept saturated as long as a voltage not lower than V_1 is maintained, so that the thyristors are also maintained in a fully conducting state. As a result, the motor is freely accelerated with a full or maximum voltage supplied thereto and maintains a steady running operation in the vicinity of the synchronous speed. The command voltage applied to the phase shifter 18 therefore may be increased up to a given initial value V_2 of the command voltage required at the time of deceleration as shown in Figure 3b.

In this way, when a command voltage is produced by the acceleration & deceleration speed command generator 16 and applied through the contact element 13—3(b) to the phase shifter 18, the elevator car is accelerated substantially in the manner as diagrammatically illustrated in Figure 3a. In this case, the rate of acceleration change should be set within the allowable range during the up travel under no load and the down travel under full load which is the most favorable condition for acceleration of the elevator car. This most favorable condition is available only for a short period of time up to time point t_{11} in Figure 3b, after that, acceleration is

supported by the maximum torque of the motor independently of load. Thus, the elevator car is accelerated up to the synchronous speed or the vicinity thereof in a shorter period of time at the time of up travel under no load or down travel under full load, while a little more time is required for the elevator car to be accelerated up to the synchronous speed level or the vicinity thereof at the time of up travel under full load or down travel under no load.

This system provides the shortest acceleration time on a certain condition of a feeling of a comfortable ride, motor power capacity and maximum allowable current value, thereby attaining the highest operating efficiency of the motor and other devices while shortening the elevator operating time.

When a steady running elevator car reaches a deceleration-starting point at a destination floor, a well-known position detector is actuated thereby to cut off the contactors 9 while closing the contactors 13.

The configuration of the main circuit is changed over to the connection as shown in Figure 2b. The output of the acceleration & deceleration speed command generator 16, after being compared with the output of the tachometer generator 7, is applied to the phase shifter 18 through the contact element 13—3(a), thus making up a speed feedback control system to provide the DC braking torque. After passing the deceleration-starting point, the acceleration & deceleration speed command generator 16 produces a speed command as shown in Figure 3b which decreases as a function of position, according to a well-known method. Let the speed command be V_s and the output voltage of the speed generator 7 be V_p . The thyristors 11 and 12 are phase-controlled in such a manner as to meet $V_p - V_s = 0$. The elevator car is accordingly reduced in speed in response to the speed command as shown in Figure 3a.

When the elevator car thus is reduced in speed down to a slow speed about to stop or very low speed, the elevator car is held stationary by the electromagnetic braking device 5.

The diagram of of Figure 6 shows a preferred embodiment of the circuit of the acceleration & deceleration speed command generator 16 capable of producing both an acceleration command and a speed command for deceleration in the common circuit thereof.

A DC power supply 19 is for generating a voltage V_2 and is connected to the resistors 210, 211 212 ... 21n through a contact element 20 which is adapted to close at the time of the starting of the elevator car. The resistors 211, 212, ... 21n are connected in shunt with the contact elements 221, 222 ... 22n respectively. These contact elements are position-detecting contactors which are closed at the time of

starting and opened in sequence as the elevator car approaches a destination after passing the deceleration start point. A time-constant circuit including a resistor 23 and a capacitor 24 is connected across a resistor 210, so that a command voltage is generated from the terminals 25 and 26 of the capacitor 24.

When the contact 20 is closed in response to the elevator start command, the full-voltage V_2 of the power supply 19 is applied to the resistor 210. The voltage across the capacitor 24, namely, the command voltage is increased by the time constant due to the resistor 23 and the capacitor 24. The final value of this voltage is equal to the source voltage V_2 , and the time constant may be so selected that the rate of initial voltage increase corresponds to the rate of acceleration change mentioned earlier. With the approach to V_2 , the rate of command voltage increase is decreased, even though after saturation of the phase shifter 18, the thyristors 11 and 12 are kept fully conducted independently of the rate of acceleration change as mentioned already. It suffices, therefore, if the command voltage reaches the source voltage V_2 prior to the elevator car reaching the deceleration start point.

Following the deceleration start point, the contact elements 221, 222, ... 22n are opened in the order according to elevator position, so that the voltage across the resistor 210 drops in steps. The voltage across the capacitor 24 or the output voltage thereof is smoothed by the time constant, making it possible to obtain a deceleration speed command which is reduced substantially in a straight line.

Figures 7 and 8 show a preferred embodiment of the phase shifter 18 which is arranged to be able to control the firing of the thyristors 11 and 12 used in common for acceleration, steady running and deceleration periods of the elevator operation through a single circuit.

The voltage applied to the thyristors 11 and 12 is an S-phase voltage in the case of Figure 2a and a line voltage between S and T in the case of Figure 2b, and then power supply for the phase shifter 18 is switched over accordingly.

A switching circuit of the power supply for the phase shifter is shown in Figure 7. During the acceleration and steady running periods, the contact element 27 is closed. The resistors 28 and 29 have the same resistance value. The transformer 30 is thus supplied with the S-phase voltage. The terminals 31, 32 and 33 are connected to the terminals denoted by identical reference numerals in Figure 8, by way of the secondary winding with an intermediate tap. In the deceleration period, on the other hand, the contact element 27 is opened, so that the transformer 30 is supplied with the S-T line voltage. In similar fashion, power is supplied to a pulse generator circuit in Figure 8.

In Figure 8, the diodes 34 and 35 are for full-wave rectification of the secondary voltage of the transformer 30. The full-rectified voltage appearing between points 36 and 31 is applied to the series-circuit of the resistor 37 and the zener diode 38. A full-wave rectified voltage clipped by the zener voltage is produced across the zener diode 38, namely, between points 60 and 31. A unijunction transistor 39, a capacitor 40 and resistors 41 to 43 make up a well-known pulse generator circuit, which is capable of producing a pulse voltage across the resistor 42 at a phase corresponding to the magnitude of the control voltage applied between the base 45 of the transistor 44 and the terminal 31.

This pulse voltage is produced in each half cycle of the source voltage of the phase shifter. In order to distribute this pulse voltage between the thyristors 11 and 12, a couple of lines are provided; one line from terminals 32 and 31 containing series-connection of diode 46, a resistor 47, a pulse transformer 48 and a thyristor 49, and the other line from terminals 33 to 31 containing series-connection of diode 50, a resistor 51, a pulse transformer 52 and a thyristor 53. The pulse signal is applied as a gate signal to the thyristors 49 and 53 in respective lines. Since these thyristors are supplied with different half-wave rectified voltages, they conduct alternately every half wave, thus enabling the amplified pulse voltage to be applied to the pulse transformers 48 and 52. The terminals g_1 , k_1 and g_2 , k_2 of the secondary windings of the pulse transformers 48 and 52 are connected respectively to the terminals of identical reference numerals of the thyristors 11 and 12 in Figure 1.

This circuit arrangement permits a phase shifter circuit to control in common the firing of the thyristors in the driving torque controlling elements and braking torque control elements.

It will be understood from the foregoing description that, a simple and economical apparatus for controlling the elevator with satisfactory performance is provided for the AC-operated elevator in which the driving torque control elements are controlled with an open loop control for a speed at the time of acceleration while the braking torque control elements are subjected to a speed feedback control at the time of deceleration.

In the case where the driving torque control elements are controlled to produce the full output early in the acceleration period, both the coefficient of utilization of the apparatus and the operating efficiency of the elevator car are improved. Specifically, consider a conventional AC-operated elevator car at the speed of 60 m/min which is subjected to speed feedback control over the whole range. The acceleration time of 2 seconds is always required since it is unified with the acceleration time under the heaviest load such as

imposed by down travel under no load and up travel under full load. According to the aforementioned embodiment of the present invention, by contrast, the acceleration time is 1 second in the case of down travel under full load and up travel under no load, though the acceleration time for the down travel under no load and the up travel under full load remains the same as that for the conventional apparatus. The average acceleration time for the apparatus according to the invention is therefore 1.5 seconds, and the operating efficiency is greatly improved.

Even in the conventional system, it is possible to achieve an acceleration time as short as that for the apparatus according to the invention by increasing the allowable value of the starting current with the same motor. The starting current, however, is increased by 25% to 30% as compared with the embodiment under consideration, inevitably resulting in an increased capacity of the power supply equipment.

In addition, a further improved economy of the apparatus is attained by providing a common device for producing the acceleration command for acceleration and the speed command for deceleration.

The driving torque control elements may preferably be comprised of the thyristors in inverse-parallel connection inserted between the AC power supply and the induction motor as shown in Figure 2a. In addition to the single-phase control, the two-phase or three-phase control is possible as shown in Figures 9 and 10, respectively. In the drawings, reference numerals 54 to 59 show thyristors.

Instead of a couple of thyristors in inverse-parallel connection, a thyristor and a diode may be connected in inverse-parallel thereby to accomplish the primary voltage control for any of single to three phases.

In the last-mentioned case, the single phase control is economically preferable so that the driving torque control by the primary voltage control is used only for a short period of time after starting the elevator car and also in view of the waveform of current flowing into the motor from the power supply.

In the case of primary single phase control which is effected by the thyristors in inverse-parallel connection as the driving torque control elements for the reason described above, a more economical apparatus is realized if the thyristors are used as the braking torque control elements in the manner as described with reference to Figures 1 and 2.

WHAT WE CLAIM IS:—

1. An AC-operated elevator control apparatus comprising: an induction motor arranged to drive an elevator car; driving torque control elements arranged to continuously control driving torque generated in said induction motor; braking torque control ele-

ments arranged to continuously control the braking torque generated in said induction motor; means for generating a speed command signal at least for deceleration of the elevator car; means for producing a speed signal representing the actual speed of the elevator car; acceleration control means arranged to control said driving torque control elements with an open control loop for speed regulation at the time of acceleration of the elevator car; and speed feedback control means arranged to control said braking torque control elements with a closed control loop for speed regulation in accordance with a deviation signal representing the difference between said speed signal and said speed command signal at the time of deceleration of the elevator car.

2. An AC-operated elevator control apparatus according to Claim 1, in which said acceleration control means includes means for generating a predetermined torque-increasing command signal and means for controlling said driving torque control elements in response to an output of said command signal generator means.

3. An AC-operated elevator control apparatus according to Claim 1, in which said speed command signal generator means is arranged to produce a command voltage which is increased at the time of acceleration of the elevator car and switched to effect a speed command signal at the time of deceleration, said apparatus further including means for controlling said driving torque control elements in accordance with said command voltage at the time of acceleration of the elevator car.

4. An AC-operated elevator control apparatus according to Claim 1, in which said driving torque control elements and said braking torque control elements comprise a bridge circuit and a plurality of change-over contactors, said bridge circuit including two series-connected thyristors and two series-connected diodes connected in parallel with said thyristors, said bridge circuit being variable in accordance with said driving torque control elements which include said thyristors in inverse-parallel connection or said braking torque control elements which include a controlled rectifier circuit.

5. An AC-operated elevator control apparatus according to Claim 4, further comprising a phase shifter with two output terminals permanently connected to the gates and the cathodes of said two thyristors respectively.

6. An AC-operated elevator control apparatus according to Claim 5, further comprising means for disconnecting from said phase shifter a voltage applied thereto from a three-phase AC power supply said voltage being a single-phase voltage at the time of acceleration of the elevator car and a D.C.

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imposed by down travel under no load and up travel under full load. According to the aforementioned embodiment of the present invention, by contrast, the acceleration time is 1 second in the case of down travel under full load and up travel under no load, though the acceleration time for the down travel under no load and the up travel under full load remains the same as that for the conventional apparatus. The average acceleration time for the apparatus according to the invention is therefore 1.5 seconds, and the operating efficiency is greatly improved.

Even in the conventional system, it is possible to achieve an acceleration time as short as that for the apparatus according to the invention by increasing the allowable value of the starting current with the same motor. The starting current, however, is increased by 25% to 30% as compared with the embodiment under consideration, inevitably resulting in an increased capacity of the power supply equipment.

In addition, a further improved economy of the apparatus is attained by providing a common device for producing the acceleration command for acceleration and the speed command for deceleration.

The driving torque control elements may preferably be comprised of the thyristors in inverse-parallel connection inserted between the AC power supply and the induction motor as shown in Figure 2a. In addition to the single-phase control, the two-phase or three-phase control is possible as shown in Figures 9 and 10, respectively. In the drawings, reference numerals 54 to 59 show thyristors.

Instead of a couple of thyristors in inverse-parallel connection, a thyristor and a diode may be connected in inverse-parallel thereby to accomplish the primary voltage control for any of single to three phases.

In the last-mentioned case, the single phase control is economically preferable so that the driving torque control by the primary voltage control is used only for a short period of time after starting the elevator car and also in view of the waveform of current flowing into the motor from the power supply.

In the case of primary single phase control which is effected by the thyristors in inverse-parallel connection as the driving torque control elements for the reason described above, a more economical apparatus is realized if the thyristors are used as the braking torque control elements in the manner as described with reference to Figures 1 and 2.

WHAT WE CLAIM IS:—

1. An AC-operated elevator control apparatus comprising: an induction motor arranged to drive an elevator car; driving torque control elements arranged to continuously control driving torque generated in said induction motor; braking torque control ele-

ments arranged to continuously control the braking torque generated in said induction motor; means for generating a speed command signal at least for deceleration of the elevator car; means for producing a speed signal representing the actual speed of the elevator car; acceleration control means arranged to control said driving torque control elements with an open control loop for speed regulation at the time of acceleration of the elevator car; and speed feedback control means arranged to control said braking torque control elements with a closed control loop for speed regulation in accordance with a deviation signal representing the difference between said speed signal and said speed command signal at the time of deceleration of the elevator car.

2. An AC-operated elevator control apparatus according to Claim 1, in which said acceleration control means includes means for generating a predetermined torque-increasing command signal and means for controlling said driving torque control elements in response to an output of said command signal generator means.

3. An AC-operated elevator control apparatus according to Claim 1, in which said speed command signal generator means is arranged to produce a command voltage which is increased at the time of acceleration of the elevator car and switched to effect a speed command signal at the time of deceleration, said apparatus further including means for controlling said driving torque control elements in accordance with said command voltage at the time of acceleration of the elevator car.

4. An AC-operated elevator control apparatus according to Claim 1, in which said driving torque control elements and said braking torque control elements comprise a bridge circuit and a plurality of change-over contactors, said bridge circuit including two series-connected thyristors and two series-connected diodes connected in parallel with said thyristors, said bridge circuit being variable in accordance with said driving torque control elements which include said thyristors in inverse-parallel connection or said braking torque control elements which include a controlled rectifier circuit.

5. An AC-operated elevator control apparatus according to Claim 4, further comprising a phase shifter with two output terminals permanently connected to the gates and the cathodes of said two thyristors respectively.

6. An AC-operated elevator control apparatus according to Claim 5, further comprising means for disconnecting from said phase shifter a voltage applied thereto from a three-phase AC power supply said voltage being a single-phase voltage at the time of acceleration of the elevator car and a D.C.



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- voltage at the time of deceleration of the elevator car.
7. An AC-operated elevator control apparatus as claimed in Claim 1, comprising a three-phase induction motor arranged to drive an elevator car, the driving and braking torque control elements being connected between said motor and a three-phase AC power supply connectible for continuously controlling the driving torque and the braking torque generated in said induction motor respectively, a tachometer generator coupled to said motor, first means arranged to produce a continuous speed command signal for increasing speed with time from the start of the elevator car and for decreasing speed in accordance with elevator car position at the time of deceleration of the elevator car, a phase shifter arranged to produce a phase-controlled firing signal for a plurality of thyristors, second means arranged to apply said speed command signal direct to said phase shifter at the time of acceleration of the elevator car, and third means arranged to apply a signal representing a deviation signal between the output signal of said tachometer generator and said speed command signal, said driving and braking torque control elements including a bridge circuit and a plurality of contactors switchable between different states at the time of acceleration and deceleration of the elevator car, said bridge circuit including two series-connected thyristors and two series-connected diodes permanently connected with said thyristors, said second means causing said driving and braking torque control elements to define said two thyristors in inverse-parallel connection at the time of acceleration of the elevator car, said third means causing said driving and braking torque control elements to define a controlled-rectifier circuit including said two thyristors and said two diodes at the time of deceleration of the elevator car.
8. An AC operated elevator control apparatus substantially as herein described with reference to the accompanying drawings.
- LANGNER PARRY,
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