A velocity control device by which acceleration, constant speed, and deceleration control of an induction motor are carried out through an inverter by open loop control, and deceleration control is carried out at a constant deceleration D when the elevator cage reaches the location of initiation of deceleration at a predetermined distance L from the location of floor arrival; in which detection is made as to when the inverter output current reaches a level that is lower than the overcurrent halt level, and constant speed control is carried out according to the speed \( V_t \) at the time of this detection, and, when the cage reaches the point of initiation of deceleration, the constant speed is maintained for a time \( T_1 \), where \( T_1 = (L/V_t) - (V/2D) \) and thereafter deceleration control is performed at the constant deceleration D. The invention prevents overcurrent halts caused by increasing elevator loads and increases floor arrival precision.

**FIG. 1**
This invention concerns a type of inverter-based velocity control device for elevator induction motors. More specifically, this invention concerns a type of accelerating/decelerating control unit of inductive motors in an open-loop velocity control system.

Recently, the induction motor has been adopted as the primary motor of elevators. The induction motor is usually driven by an inverter with variable voltage and variable frequency (VVVF). In this type of elevator driving device made of a combination of an induction motor and inverter, the velocity control of the induction motor is usually performed using the open-loop control by a voltage inverter for the low-velocity elevator, and using the velocity feedback control with a velocity detector in the medium- or high-speed elevator.

Among these methods, for the open-loop velocity control method, following the velocity pattern, the output frequency and the output voltage of the inverter are controlled so that acceleration, deceleration, or constant velocity is realized to conform to the velocity pattern. In this velocity control method, a velocity detector is not needed, and there is no need to have a backup means for solving faults in the velocity detection system. However, since there is no velocity detection that determines the motor speed, and hence the elevator cage velocity and lift distance data, the floor-settling precision is poor as the load varies.

The present applicant has proposed a velocity control scheme that solves the aforementioned problem by making correction for the variation portion of the load torque (see Japanese Kokai patent Application No. Hei 1[1989]-268479). The concept of this scheme is as follows: From the dc current of the inverter's principal circuit, the slip frequency of the motor is derived; from the aforementioned slip frequency, the output torque of the motor and the load torque of the motor are derived and the rotating speed is calculated; and from its difference from the velocity pattern, the frequency and voltage of the inverter are corrected.

In addition, the present applicant also proposed a scheme for correcting the torque boost for realizing a necessary driving force needed for the large load torque as the motor operates at a low speed. In this scheme, just as in the aforementioned scheme, the torque is detected from the dc current and the variation in the load torque is corrected (see Japanese Kokai Patent Application No. Hei 1-[1989]-252193).

For an inverter for an elevator using the open-loop velocity control method without a velocity sensor, in the conventional device, in a prescribed high-velocity region of the elevator, the slip frequency is derived by detecting the dc current; from the slip frequency, the motor velocity correction and the torque correction are performed, so as to improve the floor-setting accuracy.

However, in the open-loop velocity control method, the slip frequency increases as the load of the elevator increases, and the output current of the inverter rises.

As the inverter output current rises, if it exceeds the rating of the switch element of the reverse conversion main circuit, the switch element is damaged by the surge current. In order to protect the element and the motor (the load) when the output current rises and in case of commutation failure, a surge current protecting circuit is provided, and the inverter unit is stopped as the surge current is detected.

However, as the surge current shuts off the system, the operation of the elevator is stopped. The reliability of the system is decreased and frequent service and repair have to be performed.

In order to solve this problem, a scheme has been proposed to limit the inverter output current before the inverter output current rises to the surge current shutoff level. However, due to this current limitation, a significant difference arises between the velocity pattern and the elevator velocity, and the floor-setting position deviates significantly.

The purpose of this invention is to solve the aforementioned problems of the conventional methods by providing a type of velocity control device in which there is no surge current shutoff caused by an increase in the load of the elevator, and the floor-setting accuracy can be increased.

According to this invention, in order to solve the aforementioned problems, the inverter-based velocity control device for elevator induction motors performs open-loop velocity control with acceleration, deceleration, or constant velocity; in the deceleration control mode, as the cage of the elevator arrives at a deceleration start position at a prescribed distance L from the cage floor-settling position, deceleration D is carried out. This velocity control device has a judgment means for limiting the surge current, which can detect when the output current of the inverter reaches a surge current limiting level lower than the surge current shutoff level, and a velocity correction control means which in response to said detection performs a constant-velocity control with the velocity fixed at the current velocity Vf, with the constant-velocity control continued for time T1 from the time point when the cage arrives at the aforementioned deceleration start position, with T1 preferably determined by the following formula: T1 = (L/Vf) - (Vf/2D), and which then performs deceleration control with the aforementioned deceleration after said time T1.

According to this invention with the aforementioned configuration, before the surge current shutoff point, the output current of the inverter is
determined by the aforementioned surge current limit judgment means, and the operation is performed at a constant velocity \( V_c \), with \( V_l \) maintained for a prescribed time \( T_1 \) after the cage arrives at the deceleration start position; then, deceleration is performed at deceleration \( D \) identical to that of the velocity pattern. In this way, for the different constant velocities, the deceleration distance from the deceleration start point to the floor-settling point is the same, and the floor-settling accuracy is identical to that when the control is performed according to the velocity pattern.

An embodiment of the invention will now be described by way of example only and with reference to the drawings, in which:

Figure 1 is a schematic diagram of an inverter control circuit according to this invention.

Figure 2 shows waveforms of the operation of the circuit of Fig. 1.

Figure 1 is an equipment configuration diagram illustrating an application example of this invention. The ac power of ac power source (1) is converted to dc power by rectifier (2), and it is smoothed by capacitor (3). The dc power is then converted to ac power with output frequency and voltage controlled by a voltage inverter principal circuit (4), and sent to induction motor (5) used as the power source of the elevator. Control of the operation frequency and voltage of the inverter principal circuit (4) is carried out by control of the gate pulse frequency and pulse width from a controller (6). In this way, the operation speed of motor (5) drives the load of cage (8) and balance weight (9).

At control unit (6) with CPU (10) as its central portion, according to the operation commands of the elevator, a velocity pattern is formed or given, with prescribed acceleration/deceleration and with constant-velocity time corresponding to the lift distance (floor movement distance). CPU (10) obtains the inverter operation frequency and voltage (amplitude) from this velocity pattern and slip frequency \( S \) from slip operator circuit (11). From this frequency and voltage, gate pulses with PWM waveform can be obtained at PWM generating unit (12).

At the slip operator circuit (11), just as in the conventional case, from the detected signal \( i_{dc} \) of current detector (13) which detects dc current \( i_{dc} \) of inverter principal circuit (4) the current-torque conversion and the torque-slip frequency conversion are performed so as to derive the slip frequency \( S \). In addition, the present applicant once proposed a scheme of calculation of the slip frequency directly from the dc current detected value. This direct conversion scheme may also be adopted in this configuration.

At CPU (10), from slip frequency \( S \), the output torque of motor (5) and the load torque are derived, and the rotation speed of motor (5) is derived. The difference between the rotation speed and the velocity pattern is used as a correction signal of the inverter control output frequency. According to the corrected velocity, the commands of frequency \( f \) and voltage \( G \) are generated.

The portion of the configuration described up to now is identical to the conventional configuration. In this application example, there are also judgment means for limiting the surge current consisting of peak current detector (14), A/D converter (15) and surge current limit judgement unit (16), and a velocity correction control means in the case of surge current limit judgment using the computing function of CPU (10).

Peak current detector (14) detects peak value \( I_{pp} \) of detected current \( i_{dc} \) of current detector (13); A/D converter (15) converts peak value \( I_{pp} \) to a digital signal; and surge current limit judgment unit (16) determines when peak value \( I_{pp} \) in digital form reaches the surge current limit value. The surge current limit judgment means has the same configuration as that of the conventional surge current shutoff judgment means. However, the judgment level is set lower than the level of the surge current shutoff state, and it provides an output of judgment of the surge current limit before the surge current shutoff.

The velocity correction means set in CPU (10) performs constant-velocity control at the current velocity when the judgment of the surge current limit is made, with the constant-velocity control maintained for a prescribed time \( T_1 \) after cage (8) arrives at the deceleration start position, and it then performs the deceleration control with a deceleration identical to that in the velocity pattern after time \( T_1 \).

The velocity correction control of the aforementioned velocity correction control means can prevent surge current shutoff by making a constant-velocity control at the current velocity when the surge current limit is reached. In this constant-velocity control, the constant velocity is lower than the constant velocity of the velocity pattern. If the deceleration is carried out at the same deceleration as that of the velocity pattern from the point when cage (8) arrives at the deceleration start position, there would be a significant deviation from the desired floor-settling position when the cage is stopped. However, the constant-velocity control is continued for a prescribed time \( T_1 \), followed by deceleration at the same deceleration as that of the velocity pattern. In this way, the aforementioned problem can be solved and the floor-settling accuracy can be guaranteed.

Figure 2 shows the operation waveform diagram in this application example. In the same way as in the conventional scheme, the acceleration,
deceleration and constant-velocity control are performed by control device (6) according to the velocity pattern V. The deceleration control is performed at a prescribed deceleration when cage (8) of the elevator arrives at a deceleration start position P_b at a prescribed distance L from the floor-settling position. In this case, as indicated by the solid line, inverter output current I_{out} has a waveform with peaks in the acceleration and deceleration phases.

When the load of the elevator is increased, the inverter output current increases as indicated by the broken line and tends to reach surge current shutoff current I_{loc}. When the current reaches surge current limit current I_{loc} (S_{loc}) set at judgment unit (16) (time point t_i), the judgment output of said judgment unit (16) activates the velocity correction control means of CPU (10), so that the velocity is locked at the current velocity V_j instead of following the velocity of the velocity pattern V, and the constant-velocity control is carried out at said velocity V_j. In this way, inverter output current I_{out} does not rise to surge current shutoff judgment value I_{loc}, the surge current shutoff can be avoided, and the operation of the elevator can be continued.

Then, as cage (8) reaches deceleration start point P_b, a signal of arrival at the deceleration start point is sent to CPU (10). Upon receiving this signal, the velocity is maintained at V_j for a prescribed time of T_1. Then, from time point t_b after T_1, the cage is decelerated at a deceleration D identical to that of the velocity pattern V and is finally stopped.

In this deceleration control, time T_1 at which the area of region A is equal to the area of region B is determined beforehand. That is, in the velocity pattern V, the distance for deceleration to stop at a prescribed deceleration from deceleration start point P_b corresponds to the area of this portion, and the deceleration start point is set appropriately to ensure that the aforementioned distance is equal to the distance from the deceleration start point to the floor settlement point. On the other hand, from the judgment of the surge current limit, if the distance of deceleration to stop from velocity V_j at the same deceleration is identical to the aforementioned distance, the same floor-settling position can be reached. In this case, the distance corresponds to the area after deceleration start point P_b and time T_1 is calculated to ensure that the area of region A is equal to the area of region B.

This control scheme for matching the floor-settling position from a velocity different from the prescribed velocity of the velocity pattern has been proposed by the present applicant. Time T_1 can be calculated using the following formula:

\[ T_1 = \frac{(L - V_j \cdot T_1)}{V_j} - \frac{(V_j/2D)}{V_j} \]

where, L: distance between deceleration start position and floor-settling position, V_j: constant velocity, D: deceleration of the velocity pattern.

According to this invention, a surge current limit level is set and detected before the inverter output current rises to the surge current shutoff level due to increase in the load of the elevator; then, a constant-velocity control is performed with the velocity at the point of detection taken as the velocity; after a prescribed time T_1, which is determined to ensure the same deceleration distance as that of deceleration according to the velocity pattern after the cage arrives at the deceleration start point, deceleration is performed with the same deceleration as that of the velocity pattern. In this way, there is no surge current shutoff caused by increase in the elevator load, and the floor-settling precision can be made identical to that in the case of the velocity pattern.

**Claims**

1. A velocity control device for the inverter of an elevator induction motor for performing open-loop velocity control including acceleration, constant velocity and deceleration phases wherein in the deceleration control phase as the cage of the elevator arrives at a deceleration start position at a prescribed distance L from the cage floor-settling position, deceleration D is carried out; characterised by a judgment means which can detect when the output current of the inverter reaches a surge current limiting level lower than a surge current shutoff level, and a velocity correction control means which in response to said detection performs a constant-velocity control with the velocity fixed at the velocity V_j at the point of detection, with the constant-velocity control continued for a time T_1 from the time point when the cage arrives at the aforementioned deceleration start position, and which then performs deceleration control with the aforementioned deceleration after said time T_1, the time T_1 being selected such that the distance travelled during the time T_1 and the subsequent deceleration is L.

2. A velocity control device as claimed in claim 1 in which in the deceleration phase substantially constant deceleration D is carried out and wherein T_1 is selected according to the formula \[ T_1 = \frac{(L/V_j)}{V_j} - \frac{(V_j/2D)}{V_j} \]
FIG. 1
The present search report has been drawn up for all claims.

Examiner: CLEARY F. M.

Place of search: THE HAGUE

Date of completion of the search: 02 SEPTEMBER 1993

DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document with indication, where appropriate, of relevant passages</th>
<th>Relevant to claim</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>GB-A-2 156 610 (MITSUBISHI DENKI K.K) * page 2, line 29 - line 55 * * page 2, line 97 - page 33, line 39; figures 1-6 *</td>
<td>1</td>
</tr>
<tr>
<td>A</td>
<td>EP-A-0 338 777 (OTIS ELEVATOR COMPANY) * column 3, line 65 - column 4, line 52; figures 1-3 *</td>
<td>1</td>
</tr>
<tr>
<td>A</td>
<td>US-A-4 534 452 (OGASAWARA ET AL) * column 4, line 25 - column 5, line 24; figure 3 *</td>
<td>1</td>
</tr>
</tbody>
</table>

CLASSIFICATION OF THE APPLICATION (Int. Cl.5)

B66B1/30
B66B1/16