

APPARATUS FOR CONTROLLING AN A-C POWERED ELEVATOR

Field of the Invention:

The present invention relates to an improved apparatus for controlling an elevator that is driven by an a-c motor.

5 Description of the Prior Art:

An induction motor is often used to drive the cage of an elevator. In this case, A-C power having a variable voltage and a variable frequency obtained through an inverter is supplied to the electric motor to control its running speed, as shown in Fig. 1.

10 In Fig. 1, reference numeral 1 denotes a D-C power supply, numeral 2 denotes a well known type of inverter which consists of transistors and diodes and which supplies A-C electric power of a variable voltage and a variable frequency of a pulse-width modulation system, numeral 3 denotes a three-phase induction motor which is powered by the inverter 2, numeral 4 denotes a drive sheave of a hoist which is driven by the electric motor, numeral 5 denotes a main wire wound around the sheave 4, numeral 6 denotes a cage connected to one end of the main wire 5, numeral 7 denotes a balance weight connected to the other end of the main wire 5, and numeral 8 denotes a control circuit for controlling the output voltage and output

frequency of the inverter based upon a voltage instruction value V_r and a frequency instruction value F_r . Here, the voltage instruction value V_r varies nearly in proportion to the frequency instruction value F_r .

5 Being controlled by the control circuit 8, the inverter 2 generates an A-C electric power having a variable voltage and a variable frequency with a phase sequence that corresponds to the operation direction of the cage 6. Therefore, the motor 3 starts to run in a direction
10 determined by the phase sequence of inputs. Thereafter, the voltage on the outputs of the inverter 2 control the running speed of the motor, thereby controlling the running speed of the cage 6.

The running speed of the cage 6 must be controlled
15 over a wide range of speeds from the start to the stop thereof. As is well known, however, when the motor 3 is driven by the inverter 2, the motor 3 develops a torque ripple having a frequency of $6nf$ (where n is 1, 2, 3, ----, and f is the output frequency of the inverter 2). When
20 the torque ripple approaches the resonance frequency of the mechanical system of the elevator (for example, the natural frequency of the main rope 5), vibration is transmitted into the cage 6 which greatly reduces the comfort of the passengers therein.

SUMMARY OF THE INVENTION

25 The present invention is introduced to improve the above-mentioned defect. Namely, the object of the invention is to provide an apparatus for controlling an A-C

powered elevator, in which when the frequency instruction value lies within a predetermined range of frequencies, an A-C electric power having a frequency which lies outside the above-mentioned frequency range is produced by an inverter, so that the torque ripple of the electric motor will not be within the resonance frequency of the mechanical system.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram illustrating the setup of a conventional apparatus for controlling an A-C powered elevator;

Fig. 2 is a diagram illustrating the setup of an apparatus for controlling an A-C powered elevator according to an embodiment of the present invention;

Fig. 3 is a diagram illustrating the input/output characteristics of the frequency converter circuit of Fig. 2;

Fig. 4 is a diagram of curves which represent running speed vs. torque characteristics of the motor of Fig. 2;

Fig. 5 is a diagram illustrating the input/output characteristics of a voltage converter circuit;

Fig. 6 is a diagram in which the frequency converter circuit and the voltage converter circuit are realized using digital circuits;

Fig. 7 is a diagram which schematically illustrates the contents recorded in a function-generating ROM of Fig. 6; and

Fig. 8 is a flow chart illustrating the operation of Fig. 7.

In the drawings, the same reference numerals denote the same or corresponding portions.

5 The invention will be described by way of example with reference to the drawings.

An embodiment of the invention will be described below in conjunction with Figs. 2 and 3, in which reference numeral 9 denotes a frequency conversion computer which
10 converts the frequency instruction value F_r into a frequency instruction value F_{r1} and sends it to the control circuit 8. The other portions are the same as those of Fig. 1.

Fig. 3 illustrates the relationship between the frequency instruction value F_r and the frequency instruction value F_{r1} , wherein F_c denotes an output frequency of the
15 inverter 2 at which the generated torque ripple is at the resonant frequency of the mechanical system of the elevator. The frequency F_c lies between a frequency F_1 and a frequency F_2 , wherein $F_1 < F_c < F_2$. In Fig. 3, the value of F_{r1} is
20 as follows:

$$\text{When } F_1 \leq F_r < F_2, \quad F_{r1} = F_2$$

$$\text{For all other cases,} \quad F_{r1} = F_r$$

Consequently, if the frequency instruction value F_r is given, the frequency conversion computer 9 generates the
25 frequency instruction value F_{r1} according to the relation of Fig. 3. Therefore, the control circuit 8 controls the inverter 2 so that it produces the output frequency F_{r1} .

Accordingly, if the frequency instruction value F_r increases and reaches F_1 , the frequency instruction value F_{r1} becomes F_2 , and the frequency instruction value F_2 is maintained until the value F_r reaches the value F_2 . Further, when
5 the frequency instruction value F_r decreases below F_2 , the frequency instruction value F_{r1} is held at F_2 until the frequency instruction value F_r becomes F_1 , at which time, the frequency instruction value F_{r1} changes to become F_1 .
10 Consequently, the inverter 2 does not produce the frequency F_c which causes resonance to develop in the mechanical system of the elevator. Accordingly, resonance does not occur in the mechanical system, and the comfort of the passengers in the cage 6 is maintained.

However, in the above case, if only the frequency
15 instruction value F_r is changed, the frequency instruction value F_r goes out of phase with respect to the voltage instruction value V_r . Therefore, the motor 3 produces a sudden change in torque which affects the running of the cage 6 and similarly affects the comfort the occupants
20 in the cage. To prevent this effect from occurring, it is desirable to provide a voltage conversion computer (not shown) in addition to the frequency conversion computer 9, in order to convert the voltage instruction value V_r into a voltage instruction value V_{r1} and apply it to the control circuit 8
25 while adjusting the output voltage of the inverter 2 simultaneously. This is explained below in conjunction with Fig. 4.

The torque produced by an induction motor is approximately given by the following equation, assuming that
30 the slip frequency varies within a small range.

$$T = K \cdot \frac{1}{R_2} \left(\frac{V_0}{F_0} \right)^2 \cdot F_S \quad \dots\dots(1)$$

wherein: R_2 denotes a secondary resistance converted into the primary side, F_0 denotes a primary frequency, F_S denotes a slip frequency, and V_0 denotes a voltage on the primary terminal. In the above equation (1), if V_0/F_0 is held constant, the torque T varies in proportion to the slip frequency F_S .

The following description considers the control operation where V_0/F_0 remains constant.

First, the case where the motor 3 is being accelerated is considered. The voltage instruction value V_{r1} reaches the voltage V_1 just before the frequency instruction value F_{r1} reaches the frequency F_1 , and the operating point lies at a point A on a curve 11. As the frequency given by the frequency instruction value F_{r1} changes from F_1 to F_2 , the voltage instruction value V_{r1} changes from V_1 to V_2 , so that the running speed vs. torque characteristics of the motor 3 are represented by a curve 12.

The torque T just before it varies is given by,

$$T = K \cdot \frac{1}{R_2} \left(\frac{V_1}{F_1} \right)^2 F_S \quad \dots\dots(2)$$

and the torque immediately after it is varied is given by,

$$T = K \cdot \frac{1}{R_2} \left(\frac{V_2}{F_2} \right)^2 \cdot \{F_S + (F_2 - F_1)\} \quad \dots\dots(3)$$

Since the equation (2) is equal to the equation (3),

$$V_2 = \frac{F_2}{F_1} V_1 \sqrt{\frac{F_S}{F_S + (F_2 - F_1)}} \quad \dots\dots(4)$$

The characteristics in this case are as represented by a curve 12 in Fig. 4. Since the control operation is carried out with V_0/F_0 being constant, the value $V_1 \cdot F_2/F_1$ of the equation (4) is equal to the voltage V_3 when the frequency instruction value Fr is F_2 . That is,

$$V_2 = V_3 \sqrt{\frac{F_S}{F_S + (F_2 - F_1)}} \quad \dots\dots(5)$$

Therefore, even when the frequency instruction value Fr_1 is changed, the operation point A does not change, and the torque does not change, either. Thereafter, the voltage instruction value Vr_1 is gradually increased from V_2 to V_3 so that the operation point moves on a line $\overline{AB}$ until the frequency instruction value Fr reaches F_2 . Therefore, the voltage instruction value Vr_1 should change according to

$$\begin{aligned} Vr_1 &= V_3 \sqrt{\frac{F_S}{F_S + (F_2 - Fr)}} \\ &= V_3 \sqrt{\frac{F_S}{F_S + \frac{1}{a}(V_3 - Vr)}} \quad \dots\dots(6) \end{aligned}$$

wherein: a denotes V_0/F_0 , Vr denotes a voltage instruction value before being varied, and Fr denotes a frequency instruction value before being varied.

Fig. 5 shows the relation between Vr and Vr_1 given by the equation (6). The curve 13 of Fig. 4 represents the running speed vs. torque characteristics when the frequency instruction value Fr_1 is F_2 , and the voltage instruction value Vr_1 is V_3 . By adjusting the voltage simultaneously

as mentioned above, it is possible to change the frequency without permitting the torque to be varied.

Fig. 6 is a diagram of a circuit setup for carrying out the above-mentioned control operation in a digital manner. In Fig. 6, reference numeral 11 denotes a CPU, numeral 12 denotes a function-generating ROM, numerals 13 and 14 denote A/D converters, numerals 15 and 16 denote D/A converters, and numeral 17 denotes a bus conductor of the CPU.

The frequency instruction value F_r and the voltage instruction value V_r are converted into digital quantities by the A/D converters 13, 14, and are sent to the CPU 11 which calculates the frequency instruction value F_{r1} shown in Fig. 3 responsive to the frequency instruction value F_r and produces an output through the D/A converter 15.

As will be obvious from the above description, the CPU 11 performs the following simple calculations:

$$\begin{aligned} \text{When } F_r < F_1, & \quad F_{r1} = F_r \\ \text{When } F_1 \leq F_r \leq F_2, & \quad F_{r1} = F_2 \quad \dots\dots(7) \\ \text{When } F_r > F_2 & \quad F_{r1} = F_r \end{aligned}$$

Further, when the voltage instruction is to be changed in order to prevent a sudden variation in torque, the following values are stored in the function-generating ROM 12, and a voltage instruction value V_{r1} corresponding to the voltage instruction V_r is read from the ROM 12, and is produced as follows:

$$\begin{aligned}
 &\text{When } V_r < V_1, & V_{r1} &= V_r \\
 &\text{When } V_1 \leq V_r \leq V_3, & V_{r1} &= V_1 \frac{F_2}{F_1} \sqrt{\frac{F_s}{F_s + \frac{1}{a}(V_3 - V_r)}} \\
 &\text{When } V_r > V_3, & V_{r1} &= V_r \quad \dots\dots(8)
 \end{aligned}$$

5 That is, the voltage instruction value V_r is compared with values stored in the ROM, wherein values given by the above equation (8) are stored in a form of a Table in the ROM. This state is illustrated in Fig. 7, and a flow chart for this case is shown in Fig. 8.

10 Referring to Fig. 8, the voltage instruction value V_r is introduced in step 18 through the A/D converter 14 of Fig. 6, the contents V_{r1} of a corresponding address which corresponds to the voltage instruction V_r is read in step 19 from the ROM 12, and the thus read value is produced in step 20 through the D/A converter 16.

15 According to the present invention as described above, when a frequency instruction value for controlling the inverter lies within a predetermined frequency range, a frequency instruction value which lies outside the above-mentioned frequency range is inputted to the inverter. Therefore, resonance does not take place in the mechanical
20 system of the elevator, and the comfort of passengers in the cage can be improved.

Further, since the voltage instruction value changes together with the change in the frequency instruction value, sudden changes in torque are eliminated by changing
25 the value of the voltage instruction value accordingly in said predetermined frequency range.

CLAIMS

1. Apparatus for controlling an AC powered elevator, comprising an inverter connected to a DC power supply, the inverter being controlled by a varying voltage instruction value and a varying frequency instruction value, for inverting DC electric power into AC electric power having a variable voltage and a variable frequency for energising an AC electric motor to drive an elevator cage, and a frequency converter which, when the frequency instruction value is a frequency value within a range such as to develop resonance in a mechanical system of the elevator, provides said inverter with a converted frequency instruction value lying outside the resonance frequency range of said mechanical system, so as to suppress resonance in said system.

2. Apparatus for controlling an AC powered elevator according to claim 1, wherein when the resonance frequency range extends from a frequency F_1 to a frequency F_2 ($F_1 < F_2$), and the frequency instruction value and the converted frequency instruction value are respectively denoted by F_r and F_{r1} , the frequencies F_1 and F_2 being included in the frequency



instruction value F_r , said frequency converter delivers a converted frequency instruction value of:

$$\begin{array}{ll} F_{r1} = F_r & \text{for } F_r < F_1, \\ F_{r1} = F_2 & \text{for } F_1 \leq F_r \leq F_2, \text{ or} \\ F_{r1} = F_r & \text{for } F_2 < F_r \end{array}$$

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3. Apparatus for controlling an AC powered elevator according to claim 2, wherein the frequency instruction value F_r varies so as to increase or decrease linearly and when the frequency instruction value F_r approaches the range determined by the frequencies F_1 and F_2 in either direction, said frequency converter delivers the specified converted frequency instruction value.

4. Apparatus for controlling an AC powered elevator according to claim 3, wherein said frequency converter comprises: an A/D converter which converts the frequency instruction value F_r into a digital quantity; a CPU which, according to the output value of said A/D converter, effects a predetermined calculation for the frequency instruction value F_r so as to generate the frequency instruction value F_{r1} ; and a D/A converter which converts the output from said CPU into an analog quantity.



5. Apparatus for controlling an AC powered elevator according to any preceding claim, further comprising a voltage converter which, when said frequency converter operates, gives said inverter a voltage instruction value corresponding to the frequency instruction value delivered by said frequency converter.

6. Apparatus for controlling an AC powered elevator according to claim 5, wherein said voltage converter comprises: an A/D converter which converts a voltage instruction value V_r into a digital quantity; a ROM which pre-stores functional values corresponding to predetermined voltage instruction values V_{r1} ; a CPU which reads out the voltage instruction value V_{r1} of a corresponding address in said ROM in response to the output value of said A/D converter; and a D/A converter which converts the voltage instruction value V_{r1} into an analog quantity.

7. Apparatus for controlling an AC powered elevator, substantially as herein described with reference to Figures 2 to 8 of the drawings.

