

SPEED CONTROL APPARATUS FOR ELEVATOR

The present invention relates to a speed control apparatus for an elevator wherein a cage is driven by supplying an induction motor with alternating current subjected to pulse width modulation.

Description of the Prior Art

- 5 Fig. 5 is a block diagram in which, by way of example, the arrangement of a prior-art speed control apparatus for an elevator disclosed in the official gazette of Japanese Patent Application Laying-open No. 56-123795 is shown along with a driving system for a cage. Referring
- 10 to the figure, the alternating current of a three-phase A. C. power source 1 is rectified by a converter 2, and the rectified output is smoothed by a capacitor 3, whereupon alternating current subjected to pulse width modulation by an inverter 4 is applied to an induction motor 5.
- 15 A speed detector 6 such as tachometer generator, and the sheave 7 of a hoisting machine are directly coupled to the induction motor 5. Further, a cage 9 is coupled to one end of a main rope 8 wound round the sheave 7, and a counterweight 10 to the other end thereof. Besides,
- 20 the speed command S11 of a speed command generator 11 as a reference for driving the cage at an appropriate

speed and the speed detection signal S6 of the speed
detector 6 are input to a microcomputer 20, in which
for the purpose of the vector control of the induction
motor 5, a slip frequency command and a primary current
5 command are calculated and also the instantaneous current
command S20 of the induction motor 5 is evaluated. This
instantaneous current command is applied to a pulse width
modulation circuit (hereinbelow, called "PWM circuit")
13 along with the current detection signal S12 of a
10 current detector 12 which detects the output current
of the inverter 4. The PWM circuit 13 calculates the
deviation between the instantaneous current command
S20 and the current detection signal S12, prepares a
pulse width modulation signal for rendering this deviation
15 null, and applies this signal to a base drive circuit
14. The base drive circuit 14 prepares the base signals
of transistors constituting the inverter 4 on the basis
of the pulse width modulation signal, so as to control
the "on" times of the transistors.

20 The microcomputer 20 is composed of interface circuits
21 and 22 for accepting the speed command S11 and the
speed detection signal S6, a microprocessor 23, a ROM
24 and a RAM 25 for storing the data and programs of
the microprocessor, and a D/A converter 26 for converting
25 a digital quantity into an analog quantity and delivering

the latter as the output.

Since the control circuitry shown in Fig. 5 subjects the induction motor 5 to the slip frequency control, the microcomputer 20 executes the calculation of the following equation:

$$I_1 = I_M \sqrt{1 + \left(\frac{L_2}{R_2} \omega_s\right)^2} \quad \dots (1)$$

where

I_1 : primary current value,

I_M : secondary excitation current,

L_2 : secondary inductance,

R_2 : secondary resistance,

ω_s : slip frequency command.

In this regard, the secondary resistance R_2 in Eq. (1) ought to differ depending upon the ambient temperature of the induction motor and the temperature of the rotor thereof and changes in a relationship indicated by the following equation by way of example:

$$R_2 = R_{20} \cdot \frac{234.5 + t}{234.5 + t_0} \quad \dots (2)$$

where

R_2 : secondary resistance at a temperature t ,

R_{20} : secondary resistance at a temperature t_0 .

Nevertheless, in the prior-art speed control apparatus shown in Fig. 5, a fixed value has been employed as the

secondary resistance. This has led to the disadvantage that the overvoltage of the induction motor is incurred in the situation in which the secondary resistance value is large due to the temperature rise of the rotor, whereas the voltage of the induction motor lowers to incur an insufficient torque in the situation in which the secondary resistance value is small due to a low temperature.

The present invention has been made with the object of eliminating the disadvantage mentioned above.

According to the present invention there is provided a speed control apparatus for an elevator having an inverter which supplies alternating current to an induction motor for driving a cage of the elevator, the apparatus comprising : a current command calculating means which calculates using a speed command, a speed detection signal of the induction motor and a resistance value signal of a rotor of the induction motor, an instantaneous current command of the induction motor; a pulse width modulation circuit which subjects the inverter to a pulse width modulation control by the use of the said instantaneous current command and an output current detection signal of the inverter; a temperature detector which detects an ambient temperature of the induction motor; and a resistance value calculating

means which calculates a resistance value of the rotor by the use of the temperature detection signal of said temperature detector and which supplies the resistance value signal, which signal corresponds to the resistance value, to said current command calculating means for evaluation of the instantaneous current command.

In the embodiments of the invention, the resistance value of the rotor may be determined in dependence upon the heat generated in, and therefore the temperature rise, of the rotor as well as the temperature detection signal. The component of temperature rise of the rotor may be evaluated by means of an arithmetic unit employing a microprocessor.

Brief Description of the Drawings

Fig. 1 is a block diagram showing the arrangement of an embodiment of the present invention;

Fig. 2 is a flow chart for explaining the operation of the embodiment;

Fig. 3 is a functional block diagram for explaining the general operation of an arithmetic unit in the embodiment;

Fig. 4 is a flow chart for explaining another embodiment; and

Fig. 5 is a block diagram showing the arrangement of a prior-art apparatus.

~~Preferred Embodiments of the Invention~~

Fig. 1 is a block diagram which shows the arrangement of one embodiment of the present invention, and in which parts assigned the same symbols as in Fig. 5 are identical elements respectively.

In hardware, the embodiment differs from the arrangement of Fig. 5 in the point of being additionally provided with a temperature detector 15 which detects the ambient temperature of the induction motor 5, for example, the temperature of a machinery room, and an interface 27 which accepts the temperature detection signal of the temperature detector 15 into the microprocessor 23.

The operation of the present embodiment arranged as stated above will be described below by referring to a flow chart in Fig. 2 and a functional block diagram in Fig. 3, with the addition of the new constituents centered.

Now, letting I_2 denote the secondary current calculated in terms of the primary side, namely, the current of the rotor, the quantity of heat generation P_w of the rotor is evaluated by the following equation:

$$P_w = m\gamma I_2^2 \quad \dots (3)$$

where m : number of phases on the primary side,
 γ : secondary resistance calculated in terms of the primary side.

Accordingly, when the thermal time constant of the rotor is denoted by T and the radiation resistance thereof by R_c , the temperature rise $\Delta\theta_\gamma$ of the rotor is found in accordance with the following equation:

$$\Delta\theta_\gamma = R_c \int_0^t (1 - e^{-\frac{t}{T}}) P_w dt \quad \dots (4)$$

Besides, considering the fact that the temperature change of the machinery room is comparatively moderate, the temperature θ_γ of the rotor is evaluated by:

$$\theta_\gamma = \int_0^t (1 - e^{-\frac{t}{T}}) dt + \theta_a \quad \dots (5)$$

Here, θ_a denotes the temperature of the machinery room.

Fig. 2 shows one example of processing steps for calculating the resistance value of the rotor in a micro-computer 20a. First, the calculation of Eq. (3) is executed to obtain the quantity of heat generation P_w

of the rotor (S101). Subsequently, the temperature rise of the rotor is evaluated in accordance with the differential equation of Eq. (4) (S102). After the temperature of the rotor has been evaluated by executing the calculation of Eq. (5), the resistance value R_2 of the rotor is calculated using Eq. (2) (S103, S104).

This resistance value R_2 is none other than a value obtained by compensating the component of temperature rise ascribable to the ambient temperature of the induction motor and the current supplied to this induction motor.

Fig. 3 is a functional block diagram for evaluating the instantaneous current command of the induction motor by the use of this resistance value.

Referring to the figure, the deviation between the speed detection signal S6 of the speed detector 6 and the speed command S11 of the speed command generator 11 is subjected to a PI control calculation by a PI (proportional-plus-integral) calculation block 31, to evaluate a torque current command S31 for producing a torque current I_T corresponding to a required torque. Subsequently, in accordance with this torque current command S31, a primary current block 32 executes the calculation of the following equation so as to evaluate a primary current command S32:

$$I_1 = \sqrt{I_M^2 + I_T^2} \quad \dots (6)$$

where I_M denotes an exciting current component. Beside
 a slip frequency block 33 evaluates a slip frequency
 command S33 in accordance with the calculation of the
 following equation on the basis of the torque current
 5 command S31 and the resistance value R_2 of the rotor
 explained with reference to Fig. 2:

$$\omega_s = \frac{R_2}{L_2 I_M} \cdot I_T \quad \dots (7)$$

Next, the slip frequency command S33 is added with
 the speed detection signal S6 of the speed detector
 10 6, and the phase angle command S34 of an output frequency
 is evaluated by an integral block 34. Subsequently,
 the phase angle command S34 is subjected to a sinusoidal
 wave calculation by a sinusoidal wave calculation block
 35, the sinusoidal value command S35 and the aforementioned
 15 primary current command S34 are multiplied by a multiplication
 block 36, and the instantaneous current S20 is output
 from the microcomputer 20a through the D/A converter 26
 shown in Fig. 1.

Thus, owing to the correction of the resistance
 20 value of the rotor, the optimum instantaneous current
 command is evaluated, and the overvoltage and the insufficient
 torque of the induction motor 5 are eliminated.

Now, Fig. 4 shows another embodiment of the present invention. Processing steps S203 - S206 are quite the same as those S101 - S104 shown in Fig. 2, respectively, and they are preceded by stages for evaluating the radiation
 5 resistance R_c and the thermal time constant T .

This corresponds to the fact that, when the induction motor employed is of the self-ventilating type, the radiation resistance R_c and the thermal time constant T varies depending upon the number of revolutions. More specifically,
 10 in a system such as the elevator wherein the running speed changes at every start, errors become large in the process of calculating the temperature when values obtained from an average running pattern are used. Particularly in the case of the self-ventilating type induction motor,
 15 therefore, the radiation resistance R_c is evaluated in correspondence with the number of revolutions N by the following equation:

$$R_c = R_{c0} \left(\frac{N}{N_0} \right)^{0.4 \text{ to } 0.5} \quad \dots (8)$$

on the basis of which the thermal time constant T is
 20 subsequently evaluated by the following equation:

$$T = T_0 \times \frac{R_c}{R_{c0}} \quad \dots (9)$$

whereby the temperature of the rotor is calculated at a higher precision.

Thus, the instantaneous current command which is higher in precision than that of the embodiment explained with reference to Figs. 1 to 3 is attained.

Although, in each of the foregoing embodiments,
 5 the instantaneous current command has been evaluated using the microcomputer, there may be means to execute calculative operations similar to those stated above, that is, a current command calculating portion which evaluates a primary current command and a slip frequency
 10 command and multiplies them thereby to obtain an instantaneous current command, and a resistance value calculating portion which evaluates the component of temperature rise of a rotor by the use of the instantaneous current command and also calculates the resistance value of
 15 the rotor by the use of the evaluated component of temperature rise and a temperature detection signal.

As apparent from the above description, according to the present invention, a speed control apparatus for an elevator comprises a temperature detector for
 20 detecting the ambient temperature of an induction motor, and a resistance value calculating portion for calculating the resistance value of a rotor by the use of the temperature detection signal of the temperature detector and an instantaneous current command, so that the optimum temperature
 25 compensation is performed by taking into account both

the component of temperature change in the surroundings of the induction motor and the component of temperature rise of the rotor, whereby the overvoltage and the insufficient torque of the induction motor can be reliably prevented.

**CLAIMS :**

1. A speed control apparatus for an elevator having an inverter which supplies alternating current to an induction motor for driving a cage of the elevator, the apparatus comprising : a current command calculating means which calculates using a speed command, a speed detection signal of the induction motor and a resistance value signal of a rotor of the induction motor, an instantaneous current command of the induction motor; a pulse width modulation circuit which subjects the inverter to a pulse width modulation control by the use of the said instantaneous current command and an output current detection signal of the inverter; a temperature detector which detects an ambient temperature of the induction motor; and a resistance value calculating means which calculates a resistance value of the rotor by the use of the temperature detection signal of said temperature detector and which supplies the resistance value signal, which signal corresponds to the resistance value, to said current command calculating means for evaluation of the instantaneous current command.

2. A speed control apparatus for an elevator according to Claim 1, wherein said temperature detector is arranged to detect the temperature of a machinery room in which the motor is installed.



3. A speed control apparatus for an elevator according to claim 1 or 2, wherein said current command calculating means evaluates a primary current command and a torque current command corresponding to a required torque of the induction motor on the basis of the speed command and the speed detection signal of the induction motor, evaluates a slip frequency command by the use of the torque current command and the resistance value signal of the rotor of the induction motor, and evaluates the instantaneous current command of the induction motor by the use of the slip frequency command, the speed detection signal and the primary current command.

4. A speed control apparatus for an elevator according to claim 1, 2 or 3, wherein said resistance value calculating means calculates a quantity of heat generation of the rotor of the motor, calculates a temperature rise of the rotor on the basis of the quantity of heat generation, and calculates the resistance value of the rotor by the use of the temperature rise value and the temperature detection signal.

5. A speed control apparatus for an elevator according to claim 4, wherein said resistance value calculating means calculates the quantity of heat generation of the rotor by the use of current flowing through the rotor.

6. A speed control apparatus for an elevator according to claim 4 or 5 wherein said resistance value calculating means adds the temperature rise value of the rotor and a temperature value indicated by the temperature detection signal, thereby to calculate the temperature of the rotor, and calculates the resistance value of the rotor by the use of the calculated temperature.

7. A speed control apparatus for an elevator according to any preceding claim, wherein the induction motor is of a self-ventilating type, and said resistance value calculating means calculates the resistance value of the rotor by the use of a radiation resistance value and a thermal time constant corrected in accordance with a number of revolutions.

8. A speed control apparatus for an elevator according to claim 7, wherein said resistance value calculating means calculates the temperature rise value of the rotor by the use of the corrected radiation resistance value and thermal time constant.

9. A speed control apparatus for an elevator substantially as herein described with reference to Figs. 1 to 3 or Fig. 4 of the accompanying drawings.

