ELEVATOR DRIVING SYSTEM

Inventors: Nobuo Mitsui, Katsuta; Tadao Kameyama, Higashi; Akinori Watanabe, Ibaraki; Isao Fukushima; Takanobu Hatakeyama, both of Katsuta, all of Japan

Assignee: Hitachi, Ltd., Tokyo, Japan

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ABSTRACT

An elevator driving system comprising a three-phase induction motor including three-phase armature windings having a plurality of terminals and arranged for change-over between the double star connection mode and the delta connection mode, means for connecting said armature windings in the double star connection mode to a three-phase a.c. power supply when the elevator is driven for service operation, means for connecting said armature windings in the delta connection mode to the three-phase a.c. power supply when the elevator car is driven for maintenance operation, means for changing over the connection mode of said armature windings to the delta connection during application of the brake, and a controlled rectifier circuit for applying a d.c. voltage across selected two terminals among said terminals during the same braking period.

18 Claims, 8 Drawing Figures
FIG. 5

REVOLUTION -- \( \frac{N}{NS} \times 100(\%) \)

TORQUE

\( \frac{(TB/TN) \times 100(\%)}{200} \)

- \( U_2 - V_2 \)
- \( U_1 - V_1 \)
- \( U_2 - W_1 \) \{ PX OPEN \}
- \( X - X - X - U_2 - U_1 \)
- \( \Delta - \Delta - U_2 - V_2 \) \{ PX CLOSED \}
ELEVATOR DRIVING SYSTEM

This invention relates to improvements in elevator driving systems, and more particularly to improvements in the elevator driving system in which the driving source is a three-phase induction motor.

Three-phase induction motors which are inexpensive are generally employed as a driving source for common-type elevators.

Elevator cars are driven at different operating speeds depending on the normal operation for carrying passengers and freight (hereinafter referred to as service operation) and the special operation for the purpose of maintenance or repair works (hereinafter referred to as maintenance operation). During the service operation, the speed of the elevator car is desirably as high as possible so as to improve the efficiency of transportation. On the other hand, during the maintenance operation, maintenance engineers work frequently on the roof of the elevator car, and therefore, the work will be attended with danger unless the elevator car is driven at a low speed. Thus, the driving source for the elevator car must be capable of realizing these two different speeds.

It is very difficult for a conventional three-phase induction motor to operate at both such high and low speeds. It is thus common practice to prepare two sets of armature windings in an induction motor for an elevator car so that one of the two sets of armature windings can be used for the service operation and the other set can be used for the maintenance operation. Further, during the service operation, the low-speed winding set is energized frequently for several seconds immediately before the stoppage of the elevator car at the target floor so that the elevator car can be stopped at the target floor with improved accuracy.

In the driving source having two sets of armature windings as above described, the number of poles is determined depending on the speed for service operation and the speed for maintenance operation. However, the induction motor having these two sets of armature windings is naturally bulky and expensive compared with common induction motors.

It is therefore an object of the present invention to provide an elevator driving system employing an induction motor which is relatively small in size and inexpensive.

Another object of the present invention is to provide an elevator driving system which can produce a sufficiently large braking torque thereby facilitating the control of an elevator car.

A first feature of the present invention resides in the fact that the elevator driving system comprises a three-phase induction motor including three-phase armature windings each having an intermediate terminal and arranged for change-over between the double star connection mode and the delta connection mode, means for connecting the intermediate terminals of the respective phase windings to a three-phase a.c. power supply so that the connection mode of said armature windings can be changed over from the delta connection mode to the double star connection mode when the elevator car is driven for service operation, and means for connecting the apex terminals (terminals at apexes of the delta or triangle) of the delta connection to the three-phase a.c. power supply when the elevator car is driven for maintenance operation.

A second feature of the present invention resides in the fact that the elevator driving system comprises further means for applying a d.c. voltage across two terminals selected from a group consisting of said apex terminals and said intermediate terminals while maintaining said armature windings in the delta connection mode when a brake is applied to the elevator car.

Other objects, features and advantages of the present invention will be apparent from the following detailed description of a preferred embodiment thereof taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a diagrammatic view showing the structure of an embodiment of the elevator driving system according to the present invention;

FIG. 2 is a connection diagram of the induction motor shown in FIG. 1 when the elevator car is started and accelerated for service operation;

FIG. 3 is a connection diagram of the induction motor when the elevator car is driven for maintenance operation;

FIGS. 4A to 4D are connection diagrams of the induction motor when a brake is applied to the elevator car; and

FIG. 5 is a graph showing the relation between the number of revolutions of the induction motor and the braking torque.

Referring now to FIG. 1, a three-phase a.c. power supply generally designated by U, V and W supplies power to an induction motor IM through a main switch K. This induction motor IM is desirably of the squirrel-cage type although the armature windings thereof are merely shown in FIG. 1. In FIG. 1, the armature windings are shown connected in the delta connection mode and have six terminals. More precisely, the armature windings include three intermediate terminals U₂, V₂ and W₂ in the respective phases in addition to the apex terminals U₁, V₁ and W₁ of the delta connection. It is apparent that the connection mode of the induction motor having such armature windings and terminals can be changed over between the double star connection and the delta connection. Contactors P₁, P₂, P₃, Pₓ₁, Pₓ₂ and S₁, S₂, S₃ are provided for carrying out such change-over.

When the contactors P₁, P₂, P₃ and Pₓ₁, Pₓ₂ are closed, the intermediate terminals U₂, V₂ and W₂ are connected to the three-phase a.c. power supply terminals U, V and W, and the apex terminals U₁, V₁ and W₁ are connected to each other as seen in FIG. 2 so that the three-phase induction motor IM operates with the double star connection mode. On the other hand, when the contactors S₁, S₂ and S₃ are closed, the apex terminals U₁, V₁ and W₁ of the delta connection are connected directly to the three-phase a.c. power supply terminals U, V and W as seen in FIG. 3 so that the three-phase induction motor IM operates now with the delta connection mode.

The number of poles in the double star connection mode differs from that in the delta connection mode, and the former is one-half of the latter. Therefore, when the number of poles in the former connection mode is four, the number of poles in the latter connection mode is eight, and the rotating speed of the induction motor in the former case is twice that in the latter case. It will thus be understood that a two-speed motor can be obtained by the provision of only one set of armature windings whose connection mode can be changed over in the manner above described, and an
undesirable increase in the size of the motor resulting in a high cost can be avoided. An electromagnetic brake MB, a tachometer generator TG and a sheave SH are operatively connected to the rotor of the induction motor IM. The sheave SH causes vertical movement of an elevator can CA and a counterweight CW through a rope RP.

In starting the elevator car CA for service operation, the contactors P1, P2, P3 and PX1, PX2 are closed and a notch control means (not shown) is actuated for accelerating the elevator car CA. A braking torque must be applied to the accelerated elevator car CA in order to stop the elevator car CA at the target floor. A large braking torque is required especially when the elevator car CA is moving upward with a full load or downward with a light or no load. Such a braking torque is produced in the induction motor and d.c. braking is generally employed for this purpose. However, due to the fact that the induction motor IM is operated with a connection mode as shown in FIG. 2, a sufficiently large braking torque cannot be obtained even when d.c. braking is applied to the induction motor in the state shown in FIG. 2. In order to obtain such a braking torque, the contactors PX1 and PX2 are opened to disconnect the apex terminals U1, V1 and W1 from each other, and after restoring the connection mode from the double star connection to the delta connection, a d.c. voltage is applied across the properly selected two terminals of the armature windings.

This d.c. voltage is obtained by a controlled rectifier circuit RE connected across the two terminals U and V of the a.c. power supply. The rectifier circuit RE is a bridge circuit composed of thyristors SCR1, SCR2 and diodes SR1, SR2. At the time at which the brake should be applied, contactors B1 and B2 are opened to turn off the thyristors SCR and SCR so as to produce a braking force corresponding to the firing angle. The rectifier circuit RE may be a bridge circuit composed of four thyristors, but it is preferable to include the diodes SR1 and SR2 in the arms thereof as shown in FIG. 1. Such an arrangement is advantageous in that it includes a route which can continuously supply braking current to the motor in the forward direction when viewed from the d.c. side of the rectifier circuit. Thus, a smooth braking torque can be obtained by the flywheel effect such that the direct current for braking can be continuously supplied in spite of on-off of the input current at the a.c. side. In this case, the d.c. braking is controlled by an electric circuit as shown in FIG. 4A in which the intermediate terminals U2 and V2 of the armature windings are connected across the rectifier circuit RE.

In the elevator system, the d.c. braking is generally controlled by comparing the instructed speed with the actual speed of the elevator car CA. It is desirable to generate a suitable speed instruction signal for decelerating the elevator car CA depending on the result of detection of the physical position of the elevator car CA in order to improve the accuracy with which the elevator car CA arrives at the target floor. This position detecting device comprises a position detector PT mounted to the elevator car CA and a plurality of detecting elements PP disposed in the shaft. The output of these detecting elements PP is applied to a speed instruction signal generator SP which generates a speed instruction signal depending on the physical position of the elevator car CA. This speed instruction signal is compared with the output of the tachometer generator TG in a comparator CM and the error therebetween is applied from the comparator CM to an automatic phase shift control PS which controls the turn-on of the thyristors SCR1 and SCR2. As the elevator car CA which is decelerated by the speed instruction signal approaches a point in close proximity to the target floor, the electromagnetic brake MG is energized by the output of the position detecting element PP so as to stop the elevator car CA at the target floor. In this manner, the elevator car CA can be smoothly and reliably stopped at the target floor, and yet, the accuracy of floor arrival is quite high so that the elevator car CA can be stopped within the range of ± 10 mm from the target floor level.

The above description has referred to the case in which the d.c. voltage is applied across the intermediate terminals U3 and V3 of the armature windings of the induction motor IM whose connection mode is changed over from the double star to the delta connection. However, a sufficiently large braking torque can be similarly obtained by applying such d.c. voltage across any other selected terminals when the connection mode of the armature windings is changed over from the double star to the delta connection.

Referring to FIG. 1 again, the contactors B1 and B2 connected at one terminal thereof to the d.c. terminals of the rectifier circuit RE may be connected at the other terminal thereof to the armature windings different from those above described. It has already been described that FIG. 4A represents an electric circuit in which the contactors B1 and B2 are connected at the other terminal thereof to the two intermediate terminals U2 and V2 of the armature windings respectively.

FIG. 4B shows an electric circuit in which the contactors B1 and B2 are connected at the other terminal thereof to the apex terminals U1 and V1 respectively of the armature windings for applying d.c. braking. In this case too, a braking torque which is substantially equal to that described with reference to FIG. 4A can be obtained.

FIG. 4C shows another electric circuit in which the contactors B3 and B4 are connected at the other terminal thereof to the apex terminal V1 among the apex terminals U1, V1 and W1 of the armature windings and to the intermediate terminal V2 disposed opposite to the apex terminal V1 respectively for applying d.c. braking. In this case, the braking torque is less than those described with reference to FIGS. 4A and 4B, but this arrangement is effective in that the temperature rise of the armature windings can be uniformized due to the fact that current flows uniformly through all the portions of the armature windings.

FIG. 4D shows another electric circuit in which the contactors B5 and B6 are connected at the other terminal thereof to the apex terminal U1 among the apex terminals U1, V1 and W1 of the armature windings and to the intermediate terminal U3 adjacent to the terminal U1 respectively for applying d.c. braking. This arrangement is not so satisfactory due to the fact that the braking torque is less than that obtained with the arrangement shown in FIG. 4C. However, the braking torque is more than when d.c. braking is applied in the state of the double star connection.

FIG. 5 is a graphic representation of the result of comparison between the values of the d.c. braking
troque. It will be seen from FIG. 5 that the value of the braking torque is quite small when d.c. voltage is applied across the terminals \( U_2 \) and \( V_2 \) in the state in which the contactors \( P_1 \) and \( P_2 \) are closed and the armature windings remain in the double star connection mode. A large braking torque can be obtained when d.c. braking is applied in the state in which the contactors \( P_1 \) and \( P_2 \) are opened to change over the connection mode from the double star to the delta connection. It will be seen that the value of the torque is maximum especially when d.c. voltage is applied across the terminals \( U_2 \) and \( V_2 \) or \( U_1 \) and \( V_1 \).

What we claim is:

1. An elevator driving system comprising:

   a three-phase induction motor including delta-connected armature windings and having apex terminals \((U_1, V_1, W_1)\) of the delta-connection and intermediate terminals \((U_2, V_2, W_2)\) of the respective phase windings;

   means for connecting said apex terminals to one another and for simultaneously connecting said intermediate terminals to a three-phase a.c. power supply for driving the elevator at a high speed; and

   means for disconnecting the mutual connection of said apex terminal and for simultaneously applying a d.c. voltage across two terminals arbitrarily selected from at least one of said apex terminals and said intermediate terminals for braking the elevator.

2. An elevator driving system as claimed in claim 1 wherein said d.c. voltage applying means comprises an a.c. power supply and a controlled rectifier circuit connected to said power supply and including a plurality of thyristors.

3. An elevator driving system as claimed in claim 2 wherein said controlled rectifier circuit includes a route which can continuously supply direct current in the forward direction.

4. An elevator driving system as claimed in claim 2, further comprising means for generating a speed instruction signal during application of the brake, means for detecting the rotating speed of said induction motor, means for comparing said speed instruction signal with the detected speed of said induction motor, and means for controlling said thyristors in response to the output of said comparing means.

5. An elevator driving system as claimed in claim 4 wherein means for detecting the physical position of the elevator car is further provided, and said speed instruction signal generating means responds to the output of said position detecting means.

6. An elevator driving system according to claim 1 wherein said means for disconnecting and for applying a d.c. voltage applies the d.c. voltage across two terminals arbitrarily selected from said apex terminals for braking the elevator.

7. An elevator driving system according to claim 1 wherein said means for disconnecting and for applying a d.c. voltage applies the d.c. voltage across two terminals arbitrarily selected from said intermediate terminals for braking the elevator.

8. An elevator driving system according to claim 1 wherein said means for disconnecting and for applying a d.c. voltage applies the d.c. voltage between an arbitrarily selected apex terminal and an intermediate terminal of the phase winding opposite the selected apex terminal for braking the elevator.

9. An elevator driving system according to claim 1 further comprising means for connecting said apex terminals to a three-phase a.c. power supply for driving the elevator at a high speed.

10. In an elevator driving system in which the elevator is driven by a three-phase induction motor at different speeds, and a control system is provided for the motor, the improvement comprising the three-phase induction motor having delta-connected armature windings, apex terminals for the delta-connection and intermediate terminals for the respective phase windings, the control system for the motor including means for connecting said apex terminals to one another and for simultaneously connecting said intermediate terminals to a three-phase a.c. power supply for driving the elevator at a high speed, and means for disconnecting the mutual connection of said apex terminals and for simultaneously applying a d.c. voltage across two terminals selected from at least one of said apex terminals and said intermediate terminals for braking the elevator.

11. In an elevator driving system according to claim 10, the control system further including means for connecting said apex terminals to a three-phase a.c. power supply for driving the elevator at a low speed.

12. A method for driving an elevator in which a three-phase induction motor having delta-connected armature windings, apex terminals of the delta-connection and intermediate terminals of the respective phase windings is provided, the method comprising the steps of connecting the apex terminals to one another and simultaneously connecting the intermediate terminals to a three-phase a.c. power supply for driving the elevator at a high speed, and disconnecting the mutual connection of the apex terminals and simultaneously applying a d.c. voltage across two terminals selected from at least one of the apex terminals and the intermediate terminals for braking operation of the elevator.

13. A method according to claim 12, wherein in the step of disconnecting and applying a d.c. voltage includes applying the voltage across two terminals selected from the apex terminals or braking operation of the elevator.

14. A method according to claim 12, wherein in the step of disconnecting and applying a d.c. voltage includes applying the voltage across two terminals selected from the intermediate terminals for braking operation of the elevator.

15. A method according to claim 12, wherein in the step of disconnecting and applying a d.c. voltage includes applying the voltage between an arbitrarily selected apex terminal and an intermediate terminal of the phase winding opposite the selected apex terminal for braking operation of the elevator.

16. A method according to claim 12, wherein in the step of disconnecting and applying a d.c. voltage includes applying the voltage via a controlled rectifier circuit having a plurality of thyristors and connected an a.c. power supply.

17. A method according to claim 16, further comprising the steps of generating a speed instruction signal during braking operation of the elevator, detecting the rotating speed of the induction motor, comparing the speed instruction signal with the detected speed of the induction motor, and controlling the thyristors in response to the result of the comparison.

18. A method according to claim 17, further comprising the steps of detecting the physical position of the elevator car and controlling the generation of the speed instruction signal in accordance with the detected position of the elevator car.