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(54) ELEVATOR DRIVING SYSTEM

(71) We, HITACHI LTD., a Corporation organized 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 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 provide 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 motor 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.

An elevator driving system in accordance with the invention comprises an induction motor including armature windings adapted to be converted between a smaller pole-number connection mode and a larger pole-number connection mode; first means for converting said armature windings into said smaller pole-number connection mode and simultaneously connecting said armature windings in said smaller pole-number connection mode to a three-phase a.c. power supply for driving the elevator at a high speed; and second means for converting said armature windings into said larger pole-number connection mode and simultaneously connecting said armature windings in said larger pole-number connection mode to a d.c. power supply for braking or decelerating the elevator.

One embodiment of the invention will now be described by way of example with reference to 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;

- 5 Figs. 4A to 4D are connection diagrams of the induction motor when the elevator car is braked; and

- 10 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 only the armature windings thereof are 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 U_2 , V_2 and W_2 in the respective phases in addition to the apex terminals U_1 , V_1 and W_1 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 P_1 , P_2 , P_3 , $Px1$, $Px2$ and S_1 , S_2 , S_3 are provided for carrying out such change-over.

When the contactors P_1 , P_2 , P_3 and $Px1$, $Px2$ are closed, the intermediate terminals U_2 , V_2 and W_2 are connected to the three-phase a.c. power supply terminals U, V and W, and the apex terminals U_1 , V_1 and W_1 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 S_1 , S_2 and S_3 are closed, the apex terminals U_1 , V_1 and W_1 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 1/2 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.

- 65 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 car CA and a counter-weight CW through a rope RP.

In starting the elevator car CA for service operation, the contactors P_1 , P_2 , P_3 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 U_1 , V_1 and W_1 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 SCR_1 , SCR_2 and diodes SR_1 , SR_2 . At the time at which the brake should be applied, contactors B_1 and B_2 are closed to complete the circuit from RE to IM 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 SR_1 and SR_2 in the arms thereof as shown in Fig. 1. Such an arrangement is advantageous in that it includes a circuit path 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 U_2 and V_2 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 pulse phase shifter 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 MB 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 U₂ and V₂ 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 terminal of the armature windings different from those above described. It has been already 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 B₂ and B₁ 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 equalised 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 B₁ and B₂ 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 U₂ adjacent to the terminals 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 torque. It will be seen from Fig. 5 that the value of the braking torque is quite small when d.c. voltage is applied across terminals U₂ and V₂ in the state in which the contactors Px1 and Px2 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 Px1 and Px2 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 U₂ and V₂ or U₁ and V₁.

WHAT WE CLAIM IS:—

1. An elevator driving system comprising: an induction motor including armature windings adapted to be converted between a smaller pole-number connection mode and a larger pole-number connection mode; first means for converting said armature windings into said smaller pole-number connection mode and simultaneously connecting said armature windings in said smaller pole-number connection mode to a three-phase a.c. power supply for driving the elevator at a high speed; and second means for converting said armature



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 pulse phase shifter 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 MB 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 U₂ and V₂ 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 terminal of the armature windings different from those above described. It has been already 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 B₂ and B₁ 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 equalised 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 B₁ and B₂ 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 U₂ adjacent to the terminals 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 torque. It will be seen from Fig. 5 that the value of the braking torque is quite small when d.c. voltage is applied across terminals U₂ and V₂ in the state in which the contactors Px1 and Px2 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 Px1 and Px2 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 U₂ and V₂ or U₁ and V₁.

WHAT WE CLAIM IS:—

1. An elevator driving system comprising: an induction motor including armature windings adapted to be converted between a smaller pole-number connection mode and a larger pole-number connection mode; first means for converting said armature windings into said smaller pole-number connection mode and simultaneously connecting said armature windings in said smaller pole-number connection mode to a three-phase a.c. power supply for driving the elevator at a high speed; and second means for converting said armature

- windings into said larger pole-number connection mode and simultaneously connecting said armature windings in said larger pole-number connection mode to a d.c. power supply for braking or decelerating the elevator.
2. An elevator driving system according to Claim 1, wherein said induction motor is 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; wherein said first means is 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 wherein said second means is means for disconnecting the mutual connection of said apex terminals and for simultaneously applying a d.c. voltage across two terminals selected from said apex terminals and said intermediate terminals for braking or decelerating the elevator.
3. An elevator driving system according to Claim 2, wherein said means for disconnecting and for applying a d.c. voltage applies the d.c. voltage across two terminals selected from said apex terminals for braking or decelerating the elevator.
4. An elevator driving system according to Claim 2, wherein said means for disconnecting and for applying a d.c. voltage applies the d.c. voltage across two terminals selected from said intermediate terminals for braking or decelerating the elevator.
5. An elevator driving system according to Claim 2, wherein said means for disconnecting and for applying a d.c. voltage applies the d.c. voltage between selected apex terminal and an intermediate terminal of the phase winding opposite the selected apex terminal for braking or decelerating the elevator.
6. An elevator driving system as claimed in Claim 2, 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.
7. An elevator driving system as claimed in Claim 6, wherein said controlled rectifier circuit includes a path which can continuously supply direct current to the motor.
8. An elevator driving system as claimed in Claim 6, further comprising means for generating a speed instruction signal during braking, 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.

9. An elevator driving system as claimed in Claim 8, 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.

10. An elevator driving system according to Claim 2, further comprising means for connecting said apex terminals to a three-phase a.c. power supply for driving the elevator at a low speed.

11. 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 said apex terminals and said intermediate terminals for braking or decelerating the elevator.

12. In an elevator driving system according to Claim 11, 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.

13. A method for driving an elevator in which an induction motor including armature windings is adapted to be converted between a smaller pole-number connection mode and a larger pole-number connection mode, the method comprising the steps of converting said armature windings into said smaller pole-number connection mode and simultaneously connecting said armature windings in said smaller pole-number connection mode to a three-phase a.c. power supply for driving the elevator at a high speed; and converting said armature windings into said larger pole-number connection mode and simultaneously connecting said armature windings in said larger pole-number connection mode to a d.c. power supply for braking or decelerating the elevator.

14. A method for driving an elevator according to Claim 13, in which said induction motor is a three-phase induction motor having delta-connected armature windings, apex terminals of the delta-connection and intermediate terminals of the respective phase windings; wherein the step of converting said armature windings into said smaller pole-number connection mode and



- connecting said armature windings to a three-phase a.c. power supply includes 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 the step of converting said armature windings into said larger pole-number connection mode and connecting to a d.c. power supply includes disconnecting the mutual connection of the apex terminals and simultaneously applying a d.c. voltage across two terminals selected from the apex terminals and the intermediate terminals for braking or decelerating operation of the elevator.
15. A method according to Claim 14, wherein the step of disconnecting and applying a d.c. voltage includes applying the voltage across two terminals selected from the apex terminals for braking or decelerating operation of the elevator.
16. A method according to Claim 14, wherein the step of disconnecting and applying a d.c. voltage includes applying the voltage across two terminals selected from the intermediate terminals for braking or decelerating operation of the elevator.
17. A method according to Claim 14, wherein the step of disconnecting and applying a d.c. voltage includes applying the voltage between a selected apex terminal and an intermediate terminal of the phase winding opposite to the selected apex terminal for braking or deceleration operation of the elevator.
18. A method according to Claim 14, wherein 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 to an a.c. power supply.
19. A method according to Claim 18, 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.
20. A method according to Claim 19, 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.
21. An elevator driving system constructed and arranged substantially as herein described with reference to the accompanying drawings.
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