

AN APPARATUS FOR CONTROLLING AC ELEVATORS

5

The present invention relates to an apparatus for controlling AC elevators, and more specifically to a control apparatus for AC elevators, in which an induction motor for driving an elevator cage is controlled by using a frequency converter.

Recently, as disclosed in, for example, Japanese Utility Model Laid-open Publication No.56-132274, an elevator control system has been developed, in which an induction motor for driving an elevator cage is controlled by using a frequency converter (called an inverter device, hereinafter). Such an inverter device usually has a converter unit capable of converting AC electric power to DC electric power, a smoothing capacitor connected across output terminals of the converter unit for smoothing the output voltage of the converter unit and an inverter unit connected to the converter unit and inverting the converted DC electric power into AC electric power. The AC electric power of the constant frequency, which is supplied to the inverter device from a commercial electric source, is converted to the AC electric power of the variable frequencies, which is fed to the induction motor.

With this, the induction motor can be very effectively controlled from the start of the elevator to the stop thereof, by varying the output voltage and frequency of the inverter device. Consequently, the consumption of electric power is much improved, and in addition a high accuracy of control can be attained.

As is well known, voltage and current controlled by the inverter device include many and different harmonics, which cause noise. The inverter device and various kinds of control equipment are usually accommodated in a unitary control cubicle, and this is particularly true of elevator systems and therefore there is the possibility that noise generated in the inverter device can easily enter the control equipment and is emitted everywhere inside the building through a tail code which connects the elevator cage and the control equipment and communicates signals and electric power therebetween, or through wiring which is provided within the building for signal communication between the control equipment and devices such as hall call button switches and indicators equipped in elevator halls of floors.

The emitted noise interferes other electric appliances, such as audio appliances, computers and the like existing within the building. This problem is more serious, because the elevator is usually located near office rooms or living rooms.

The present invention seeks to suppress the generation of electromagnetic noise and provides an apparatus for controlling an AC elevator capable of serving a plurality of floors, comprising an AC power source;

an elevator cage, in which cage means are provided for generating call signals indicating floors at which the elevator cage is required to stop;

18 button switches, provided in the respective floors, for producing hall call signals indicating the existence of the request for service of the elevator cage at corresponding floors;

an induction motor for driving the elevator cage to make it travel through an elevator duct;

a converter unit, connected to the AC power source, for converting AC electric power from that source to DC electric power, which converter unit comprises a plurality of first switching elements;

a first capacitor connected to the converter unit in a parallel relationship with respect to the AC power source;

an inverter unit for inverting the DC electric power converted in the converter unit into AC electric power to be supplied to the induction motor, which inverter unit comprises a plurality of second switching elements;

a second capacitor connected to the inverter unit in a parallel relationship with respect to the induction motor;

a DC reactor connected between the converted unit and the inverter unit; and control means electrically coupled to the elevator cage through a tail code movable up and down within the elevator duct with the travel of the elevator cage, through which the cage call signals are transmittable to the control means, and with the call button switches through wiring, through which wiring the hall call signals are transmittable to the control means, whereby the control means produces gate signals for switching the first and the second switching elements on

19

the basis of the cage call signals and the hall call signals.

With an apparatus according to the present invention the waveforms of both the input side and the output side of the inverter device are much improved, and therefore the magnitude of electromagnetic noise waves may be low.

Embodiments of the present invention will now be described in detail, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 schematically shows a known elevator control apparatus;

Fig. 2 illustrates schematically the installation of elevator facilities within a building;

Figs. 3(a) and 3(b) illustrate the operation of the apparatus of Fig. 1;

Fig. 4 schematically shows an elevator control apparatus according to an embodiment of the present invention



Figs. 5(a) and 5(b) are explanatory drawings of the operation of the apparatus of Fig. 4;

Fig. 6 shows an example of the manner of accommodating various devices and equipment in an elevator control cubicle;

Fig. 7 is a diagram showing an example of the effects according to the present invention;

Fig. 8 schematically shows an inverter controller according to another embodiment of the present invention;

Fig. 9 shows the detailed structure of a distribution/composition circuit employed in the inverter controller of Fig. 8; and

Fig. 10 is a diagram for explaining the operation of the inverter controller of Fig. 8.

Before explaining the present invention, the description will be made of an prior art and its problems, referring to Figs. 1 to 3.

Fig. 1 schematically shows the structure of a typical one example of a known elevator control system. In the figure, an elevator cage 1 is coupled to a balance weight 2 through a rope 3, which is driven by an induction motor 4. The motor 4 is supplied with AC electric power from an AC power source 5 through an inverter device 6. The inverter device 6 comprises a converter unit 61 which converts AC electric power to DC electric power, a smoothing capacitor 62 and an inverter unit 63 which inverts the converted DC electric power into AC electric power. Across terminals of the converter unit 61, there is provided a discharging circuit 24, the conduction of which is controlled by a discharge controller 25. The discharging circuit 24 serves to protect the capacitor 62 from over-charge which occurs during the regenerative operation of the elevator, i.e.,

21

the no load up travel or the full load down travel of the elevator cage 1, because the converter unit 61 has no regenerative function.

5 The control apparatus for the inverter device 6
comprises an operation controller 11, a speed command
device 12, a speed controller 13 and an inverter
controller 15. The operation controller 11 manages the
service of the elevator on the basis of hall call signals
which are sent through a wiring 10 from a call button
10 switch 9 provided in a hall of a floor and cage call
signals which are generated in the elevator cage 1 and
sent through a tail code 8. The speed command device 12
produces a speed command in response to a signal from the
operation controller 11. The speed controller 13 controls
15 the travelling speed of the elevator cage 1 in accordance
with the speed command from the speed command device 12.
For that purpose, an actual speed signal and a current
signal are also given to the speed controller 13 from a
speed detector 16 and a current detector 17, respectively.
20 The inverter controller 15 controls the inverter unit 63
on the basis of a signal from the speed controller 13.
Further, reference numeral 18 denotes a control contactor
which is maintained closed during operation and
reference numeral 19 a breaker which is opened in an
25 emergency.

Fig. 2 shows an example of the arrangement of
elevator facilities within a building. In the figure, a
control cubicle 31 closely accommodates the inverter
device 6 as well as control equipment such as the device
30 and controllers mentioned above. To the cubicle 31,
electric power is supplied through a power line 32 from
power equipment 33. Further, as described above, the
tail code 8 extends from the operation controller 11
in the cubicle 31 to the elevator cage 1, and moves up
35 and down within the elevator duct with the elevator cage
1. Also, wiring 10 is arranged within the elevator

duct from the cubicle 31, and connects the operation controller 11 to the call button switches 9 provided in halls of every floors.

The following will now discuss the influence of electromagnetic noise waves produced during the operation of the inverter device 6.

In Fig. 1, the inverter unit 63 of the inverter device 6 inverts the constant DC voltage appearing across the capacitor 62 into the AC voltage by the pulse width modulation (PWM) control. Fig. 3(a) shows the waveform of the voltage produced by the PWM control. The constant DC voltage is chopped at high frequencies in such a manner that, when the chopped voltage pulses are smoothed, the smoothed voltage changes almost sinusoidally. As shown in Fig. 3(b), when such voltage is applied to the induction motor 4, the current of the sinusoidal waveform including harmonics flows through the motor 4.

Although the current becomes like a sine wave due to reactors 26 inserted between the inverter unit 63 and the motor 4 and the reactance of the induction motor 4, the voltage applied to the motor 4 remains in a PWM-controlled pulse form and therefore includes harmonic ripples. Usually, in order to eliminate the ripples in the voltage, a smoothing capacitor is employed. If, however, such a capacitor is connected at the output end of the inverter unit 63 as shown in Fig. 1, an abrupt charging current flows into the capacitor, so that transistors of the inverter unit 63 are destroyed. Therefore, such a capacitor may not be utilized. Further, the reactance of the reactor 26 may not be made too large, because the voltage drop across the reactor 26 causes the insufficient input voltage of the motor 4.

In this way, since the inverter device 6 described above can not be equipped with sufficient countermeasures against harmonics, both output voltage and current include a large quantity of and various kinds of the harmonics.

Because of these harmonics, harmonic noise is induced in control equipment which is accommodated in the cubicle 31 very closely to the inverter device 6. The noise generated in the cubicle 31 is emitted into the inside of the building through the tail code 8 and the wiring 10 connected to the control equipment. In particular, the tail code 8 effectively functions as an antenna for emitting the electromagnetic waves of noise.

On the other hand, also in the side of the converter unit 61, the current including a large amount of harmonics is generated by the rectifier operation thereof, since the current flows intermittently. Such harmonics induce the electromagnetic noise, too, which invades the control equipment and is emitted into the inside of the building through the tail code 8 and the wiring 10. In addition, the harmonic current is also transferred through the power line 32 and power equipment 33 and 34 to electric appliances 35, such as audio appliances, computers etc., within the building. The influence is very serious in the case where they are an information processing system or a medical-electronic equipment of high sensitivity.

Referring now to Fig. 4, description will be made of an embodiment of the present invention. In the figure, like parts are denoted by the same reference numerals as in Fig. 1.

An inverter device 7 in the embodiment comprises a converter unit 71 and an inverter unit 73, which are connected through a DC reactor 72. The converter unit 71 of this embodiment comprises transistors RP, SP, TP, RN, SN and TN as switching elements. There is further provided a converter controller 14, which controls base signals of those transistors. Accordingly, the converter unit 71 can not only convert AC electric power into DC electric power, but also control the output voltage thereof. Further, smoothing capacitors 21 and 22 are provided at the input end of the converter unit 71 and the output end of the inverter unit 73, respectively.

34

In the figure, the speed controller 13 receives a speed command from the speed command device 12 and a speed feedback signal from the speed detector 16, and produces control signals to the converter controller 14 and the inverter controller 15 in accordance with the difference therebetween. The converter controller 14 produces base signals of the transistors RP, SP, TP, RN, SN and TN on the basis of the control signal from the speed controller 13, and controls the output voltage of the converter unit 71 by means of the PWM control. Although this PWM control causes harmonics in the input

i.e., in the AC side, of the converter unit 71, the input current of the AC side are smoothed by the capacitor 21, and therefore the waveform of the input current is much improved, compared with that in the case of Fig. 1.

The inverter unit 73, which comprises transistors UP, VP, WP, UN, VN and WN as switching elements, is controlled by the PWM, similarly to the inverter unit 63 of Fig. 1. As a result, the current which is supplied from the converter unit 71 is chopped with high frequencies as shown by reference numeral 51 in Fig. 5(a). The pulse current is smoothed by the capacitor 22, which usually has a larger smoothing effect against rippled current than the reactor 26 shown in Fig. 1. The thus obtained current has an almost sinusoidal waveform including few harmonics, as shown by reference numeral 52 in Fig. 5(a). The voltage appearing across the capacitor 22 also has a sinusoidal waveform. A small quantity of harmonics included in the current can be smoothed by the reactance of the motor 4.

In this manner, according to this embodiment, the waveforms of the voltage and current, which are input to and output from the inverter device 7, can be made almost a sinusoidal wave, as shown in Fig. 5(b). Consequently, little noise is generated, compared with the prior art as shown in Fig. 1. Further, it can be prevented by

the reactor 72 with the charging current flowing into the capacitor 22, and therefore the transistors of the inverter unit 73 are not destroyed by the abrupt charging current.

5 As already described, the DC current supplied for the inverter unit 73 can be controlled by the converter unit 71. Accordingly, the relationship between the waveforms of the pulse current as shown by reference numeral 51 in Fig. 5(a) and the current 52 smoothed by
10 the capacitor 22 can always be maintained in spite of the magnitude of the current. This fact means that a favorable output waveform can be obtained even when the elevator cage 1 travels at a low speed below its rated speed.

15 As mentioned above, the present invention permits a ~~significant reduction in the~~ harmonic noise generated in a main circuit formed by an AC source, the inverter device and the induction motor. The harmonic noise does not
20 invade into the control equipment within the cubicle 31 by the electromagnetic induction, and therefore ~~the~~ inductive interference within the building can be prevented.

 If, when the equipment shown in Fig. 4 is installed in the cubicle 31, parts surrounded by a two-dotted chain
25 line in the figure are shielded by conductive material, the effect of preventing inductive interference is further enhanced. Fig. 6 shows an example thereof, in which major parts of the control equipment (only the operation controller 11 and the speed controller 13 are
30 shown in Fig. 6) are positioned at a certain appropriate location within the cubicle 31, and the capacitors 21, 22, the converter unit 71, the reactor 72 and the inverter unit 73 are separated from the control equipment by
35 surrounding them as a whole with a metal plate 27 of the good conductivity. With this arrangement, the main circuit of the inverter device 7 can be

(A)
electromagnetically shielded against the control equipment, and the invasion of electromagnetic noise waves into the control equipment can be prevented.

Moreover, as apparent from Fig. 5(b), since the waveforms of the voltage and current are improved, the sound noise made during the rotation of the motor 4 is significantly reduced. As shown in Fig. 7, according to the present invention, the level of the sound noise may be reduced by about 10dB over the whole load condition of the motor 4, compared with the prior art. This level is almost the same as the level of the sound noise made when the motor 4 operates under application of a commercial source, which has an almost perfect sinusoidal waveform.

The electromagnetic noise waves affect not only the various kinds of external electric appliances, but also the control operation of the inverter device 7 itself. Therefore, the converter controller 14 and the inverter controller 15 must have a countermeasure for preventing malfunction of the inverter device caused by the noise, in order to achieve reliable operation of the elevator. Referring next to Figs. 8 to 10, the explanation will be done of such a countermeasure.

In the inverter device 7 of the type as described above, any one of the transistors UP, VP, WP, which form a group of the positive arms of the three phase bridge circuit (Gratz connection) and any one of the transistors UN, VN, WN, which form a group of the negative arms thereof are to be always in the conductive condition. Thus, the circuit of the DC source (the converter unit 71) - the reactor 72 - one of the positive arms of the inverter unit 73 - a load (the motor 4) - one of the negative arms of the inverter unit 73 - the DC source has always to be closed during the operation of the inverter device 7. If, however, the base signal of a transistor to be conductive mistakenly disappears, the aforesaid closed circuit is opened. As a result, there is lost a

27

loop (circuit) for circulating the energy stored in the reactor 72, which has the considerably large inductance, so that the high voltage is induced across the reactor 72 and the over-voltage is applied to a transistor of the opened arm, resulting in the breakdown of the transistor.

Fig. 8 shows an inverter controller 15 according to this embodiment, by which the occurrence of the aforesaid inconvenience is prevented. In the figure, the control signal from the speed controller 13 is fed to the inverter controller 15 in the form of a frequency command f_c . In response to the frequency command f_c , a pattern generator 81 and a distribution signal generator 82 produced a PWM pattern signal G_p and distribution signals A to F, respectively. The PWM pattern signal G_p is repeated every 60 degrees which corresponds to a sixth of one cycle of the output current of the inverter unit 73. The distribution signals A to F have the phase difference of 60 degree in terms of the electric angle.

Receiving the pattern signal G_p and the distribution signals A to F, a distribution/composition circuit 83 produces base signals T_{UP} , T_{VP} and T_{UN} , T_{VN} , which are led to the base electrodes of the transistors UP, VP, UN and VN, respectively. Further, the base signals T_{UP} and T_{VP} are coupled to a NOR gate 84, whereby a base signal T_{WP} to the transistor WP is formed, and similarly the base signals T_{UN} and T_{VN} are coupled to a NOR gate 85, whereby a base signal T_{WN} to the transistor WN is formed.

Fig. 9 shows the detailed structure of the distribution/composition circuit 83. This circuit 83 consists of various kinds of logic gate circuits, i.e., AND gates 90 to 93, AND gates 94 to 97 having inverse input terminals and OR gates 100 to 103. Four sets of logical circuits, which produce the respective base signals, have the same combination of the logic gates, and only the combinations of input signals received thereby are different from one another.

28

In such a circuit, the pattern signal G_p is ANDed in the AND gate 90 with the distribution signal A to form a signal PA. Further, an inverse of the pattern signal G_p is ANDed in the AND gate 94 with the distribution signal C to form a signal PC. Both the signals PA and PC are ORed in the OR gate 100, whereby the base signal T_{up} is produced. The similar logical operation is applied to the production of the other base signals T_{vp} , T_{un} and T_{vn} . The base signals T_{wp} and T_{wn} are, as described above, obtained by NORing the base signals T_{up} and T_{vp} , and T_{un} and T_{vn} , respectively.

Referring to Fig. 10, the operation of this embodiment will be explained as follows. Figs. 10(a) to 10(f) show the base signals T_{up} , T_{vp} , T_{wp} , T_{un} , T_{vn} , and T_{wn} , which are obtained in the above described manner. Figs. 10(g) to 10(i) show the output currents i_{uI} , i_{vI} and i_{wI} of the inverter unit 73 (pulse-formed solid line) and the load currents i_u , i_v and i_w flowing through the motor 4 (sinusoidal broken line).

The transistors become conductive only when the corresponding base signals are high. Therefore, the output current i_{uI} of the inverter unit 73 has the same conducting pattern as the signal pattern of the base signal T_{up} in its positive half cycle and the same conducting pattern as the signal pattern of the base signal T_{un} in its negative half cycle. The same is true of the relationship between the output currents i_{vI} and i_{wI} and the base signals T_{vp} , T_{vn} and T_{wp} , T_{wn} . Such load currents are smoothed by the capacitor 22, so that the currents as shown by i_u , i_v and i_w in Figs. 10(g) to 10(i) flow through the motor 4.

Here assuming that noise which occurs at a time X affects the base signal T_{up} and, as a result, a slit of width d appears in the signal T_{up} . (cf. Fig. 10(a))

Then, due to the noise, the base signal T_{up} becomes zero for a duration d at the time X, and therefore

the transistor UP becomes nonconductive for this duration
d. In response to the fact that the signal T_{UP} becomes
low, the base signal T_{WP} becomes high by virtue of the
NOR gate 84. (cf. Fig. 10(c)) In normal operation,
5 the signal T_{WP} does not exist at the time X. This
base signal T_{WP} renders the transistor WP conductive.
Therefore, even if the transistor UP becomes
nonconductive, the loop for circulating the energy stored
in the reactor 72 is secured by the conduction of the
10 transistor WP. Thus, any one of the transistors UP, VP
and WP of the positive arms of the Gratz circuit can always
be maintained conductive.

It will be easily understood from the circuit
structure of Fig. 9 that, also in the case where the base
15 signal T_{UP} is affected by noise, the base signal T_{WP}
becomes high. Further, when either one of the transistors
UN and VN of the negative arms is made nonconductive by
noise, the transistor WN becomes conductive by the
function of the NOR gate 85, so that a loop for
20 circulating the energy stored in the reactor 72 is formed.

In this way, since, according to this embodiment,
the discharge loop of the energy of the reactor 72 is
always kept, the breakdown of the transistor by the over-
voltage can be prevented. Moreover, since the base
25 signals T_{WP} and T_{WN} are made by the NOR gates 84 and 85,
such logical circuits for forming the base signals as
those for the transistors UP, VP, UN and VN are
unnecessary for the transistors WP and WN, so that the
structure of the distribution/composition circuit 83 is
30 simplified as much.

Also the countermeasures against
noise, as mentioned above, can be applied to the converter
controller 14, since the converter unit 71 has quite the
same circuit arrangement as the inverter unit 73. In
35 this case, a DC voltage command is fed to the converter
controller 14 from the speed controller 13, in place of

the frequency command f_c in Fig. 8. Further, a signal synchronizing with the voltage of the AC source 5 has to be used as the distribution signal. These modifications are obvious to one ordinarily skilled in the art.

5 As described above, this embodiment can prevent the transistors from being destroyed by the over-voltage caused by noise. Therefore, the reliable operation of the elevator system can be accomplished.

10



(31)

CLAIMS

1. An apparatus for controlling an AC elevator capable of serving a plurality of floors, comprising:

an AC power source;

an elevator cage, in which means are provided for generating call signals indicating floors at which the elevator cage is required to stop;

button switches, provided in the respective floors, for producing hall call signals indicating the existence of the request for service of the elevator cage at corresponding floors;

an induction motor for driving the elevator cage to make it travel through an elevator duct;

a converter unit, connected to the AC power source, for converting AC electric power from that source to DC electric power, which converter unit comprises a plurality of first switching elements;

a first capacitor connected to the converter unit in a parallel relationship with respect to the AC power source;

an inverter unit for inverting the DC electric power converted in the converter unit into AC electric power to be supplied to the induction motor, which inverter unit comprises a plurality of second switching elements;

a second capacitor connected to the inverter unit in a parallel relationship with respect to the induction motor;

a DC reactor connected between the converter unit and the inverter unit; and

control means electrically coupled to the elevator



3

cage through a tail code movable up and down within the elevator duct with the travel of the elevator cage, through which the cage call signals are transmittable to the control means, and with the call button switches through wiring, through which wiring the hall call signals are transmittable to the control means, whereby the control means produces gate signals for switching the first and the second switching elements on the basis of the cage call signals and the hall call signals.

2. An apparatus according to claim 1, wherein each of the first and the second switching elements is composed of a power transistor and a diode connected in series with the power transistor.

3. An apparatus according to claim 1 or claim 2, wherein the inverter unit has switching elements connected in a three phase bridge circuit, and gate signals for switching elements of one phase of the three phase are produced on the basis of gate signals for switching elements of the remaining two phases.

4. An apparatus according to claim 3, wherein gate signals for switching elements of a positive arm and a negative arm of the one phase are produced on the basis of gate signals for switching elements of positive arms and negative arms of the remaining two phases, respectively.

5. An apparatus according to any one of the preceding claims wherein the converter unit has switching elements connected in a three phase bridge circuit, and gate signals for switching elements of one phase of the three phase are



33

17

produced on the basis of gate signals for switching elements of the remaining two phases.

6. An apparatus according to claim 5, wherein gate signals for switching elements of a positive arm and a negative arm of the one phase are produced on the basis of gate signals for switching elements of positive arms and negative arms of the remaining two phases, respectively.

7. An apparatus for controlling an AC elevator substantially as herein described with reference to and as illustrated in Figs. 4 to 7, or Figs. 8 to 10 of the accompanying drawings.
