NEW TECHNOLOGY FOR ELEVATOR DRIVE SYSTEM

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ABSTRACT

Using the one-chip microcomputer and IGBT, we have considerably increased the compactness of our control circuit and reduced the electromagnetic noise with a higher switching frequency. As for the control circuit, we have reduced it by another 20%. We have also removed the need of AC Reactor which was previously used for noise reduction and at the same time, reduced the noise inside the machine room by another 4dB.

1. INTRODUCTION

Since 1985, we have been supplying inverter controlled elevators. This was made possible with the advancement of micro-computer technology and the big leap in the development of large capacity power transistors. With the application of vector theory in our inverter control, it is able to control an induction motor as efficiently as a DC motor. Induction motor, as compared to a DC motor, is smaller, cheaper, more reliable and is maintenance free. With all these advantages, inverter control has been adopted for all elevators ranging from low speed to high speed elevators. With the improvement in efficiency of one-chip microcomputer integrated with timer function, I/O function and ROM, etc., and the recent development of IGBT which is possible for high speed switching, we have started to put these technologies into practical use.

Considering the above circumstances, new devices are made use of to simplify the control circuit, reduce the magnetic noise and the size of control panel. A description of the contents of the development is as follows.

2. OUTLINE OF THE SYSTEM CONFIGURATION

Fig.1 shows the system configuration of control circuit which is developed presently.It features:

(1) With the application of space vector control, the current control circuit and the PWM control circuit are now being managed by software. The PWM pulse is output directly from the one-chip microcomputer.An A/D convertor is also integrated in the one-chip microcomputer, therefore the analog signal of the motor current is

input directly into the one-chip microcomputer without having to convert the output of CT from analog to digital signal. With the integration of current control circuit, PWM control circuit and A/D converter into the one-chip microcomputer, the hardware of the above control circuit is very much simplified.

(2) This ystem is constructed by the 2 microcomputer. One microcomputer is used to manage the PWM control and the other microcomputer is used to manage the main control of the elevator and thus, speed up the processing time. In addition to this, the speed of elevator, output of CT(Current Transformer) and various safety signals are input to both microcomputers for double checking, and when a break down of the microcomputer occurs, there is an external WDT(Watch Dog Timer), and a DP RAM(Dual Port RAM) to counter supervise each other. Hence, a high level of safety is maintained.

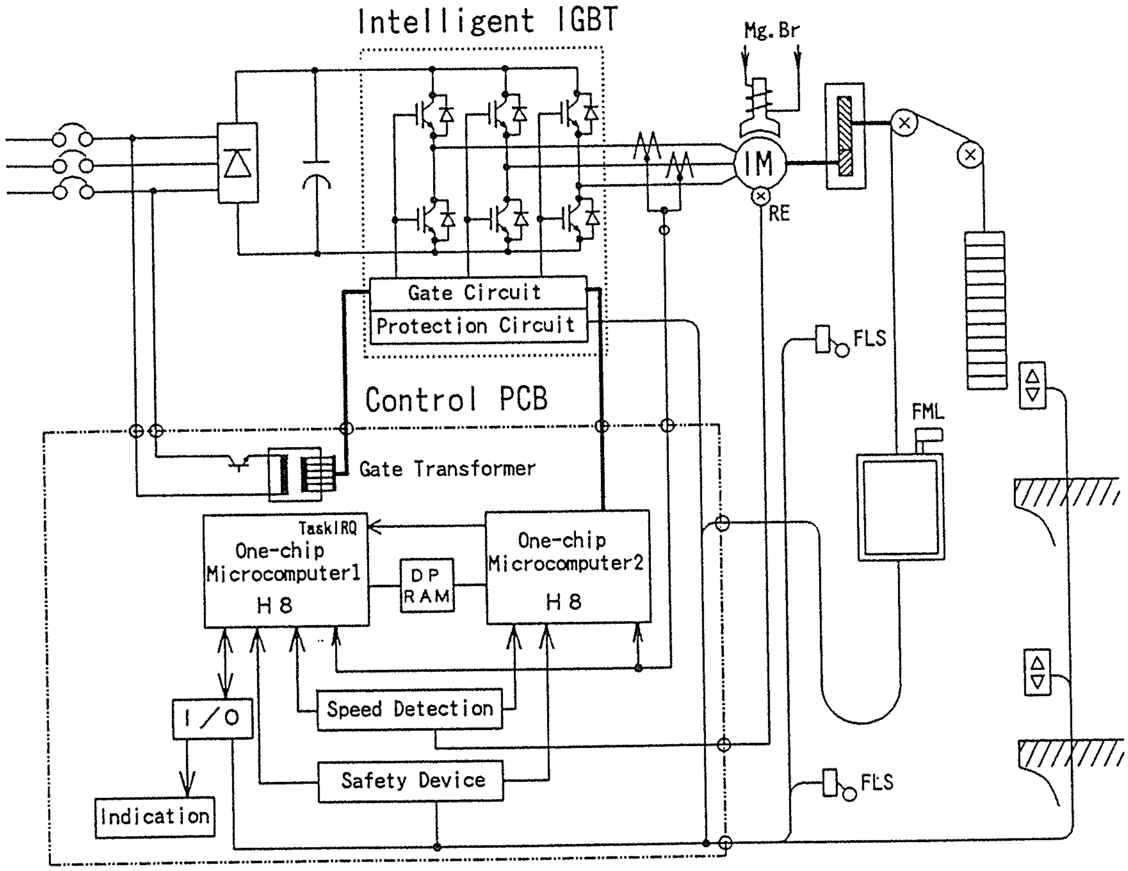


Fig.1 System Configuration

(3) With the use of the Intelligent IGBT in the main circuit, high switching frequency of 10KHz or more is made possible. IGBT is also incorporated with a gate circuit, therefore the gate circuit in the previous hardware control circuit is eliminated.

(4) IGBT has the high durability characteristic of a bi-polar transistor with large current capacity, high triggering speed of a MOS gate and also the characteristic of an FET(Field Effect Transistor) with actuating voltage. That is to say, the gate circuit only requires the current capacity needed to charge and discharge the capacitor inside IGBT. Therefore the gate transformer is smaller and easier to incorporate into the PCB.

3. DIGITAL SPEED CONTROL SYSTEM

3.1 Introduction to digital system

Fig.2 shows the system software flow block diagram. Slip frequency-type vector control is being adopted. The torque command T* is calculated using the deviation between speed command and speed feed-back ω r* which is input into ASR(Auto speed regulator).

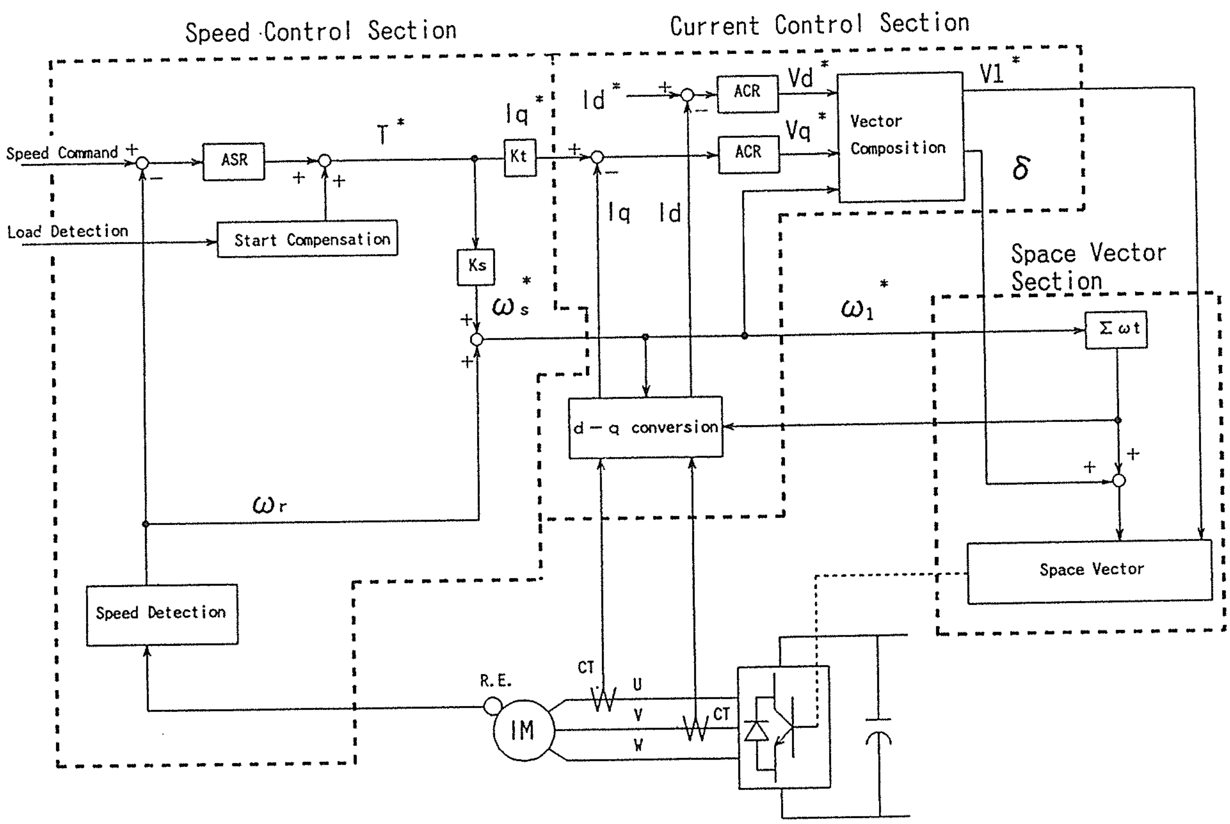


Fig.2 Control Block Diagram For Software Processing

Then T^* is use for calculating the torque current command Iq^* and the slip ωs^*. Slip ωs^* is then added to the speed feed-back ωr to obtain the primary frequency command ω_1^*. These 2 variables Iq^* and ω_1^* command value are sent to the current control system.

Motor current detected by hall CT is input to the A/D converter inside the microcomputer. The converted digital value is then fed into the p-q converter block to be converted into d and q axis components to obtain the torque current component Iq andexcitation current component Id. These components are subsequentlycompared with the torque current command Iq^* and excitation current command Id^* respectively, and the deviations are input into the respective ACR(Auto current regulator) to obtain the respective voltage command component, Vq^* and Vp^*. Primary voltage V_1^* and internal phase angle δ is being ouput after the resultant of Vq^* and Vp^* is obtained.

The above 3 variables, V_1^*, δ, ω_1^* are then input into the space vector block. Primary frequency command is integrated to obtain the phase angle of the internal electromotive voltage. The phase angle of primary voltage command is obtained by adding this value and the internal phase angle δ. Finally, PWM pulse is generated after inputting the phase angle of primary voltage command into the space vector block.

3.2 d-q convertor block

Fig.3 shows the vector conversion of 3 phase AC to d and q components.Firstly, convert 3 phase to $\alpha-\beta$ axis of the stator winding, then to p-q axis of the rotor shaft. Assuming Iu and Iv to be the current for U phase and V phase respectively, d and q axis various according to equation (1).

$$\begin{bmatrix} Iq \\ Id \end{bmatrix} = \begin{bmatrix} \mathrm{SIN}(\theta)/\sqrt{3}+\mathrm{COS}(\theta) & 2\,\mathrm{SIN}(\theta) \\ \mathrm{SIN}(\theta)-\mathrm{COS}(\theta)/\sqrt{3} & 2\,\mathrm{COS}(\theta) \end{bmatrix} \begin{bmatrix} Iu \\ Iv \end{bmatrix} \qquad (1)$$

3.3 Current control block and vector composition

Fig.4 shows equivalent circuit of the motor, while Fig.5 shows the voltage and current vectors of motor.

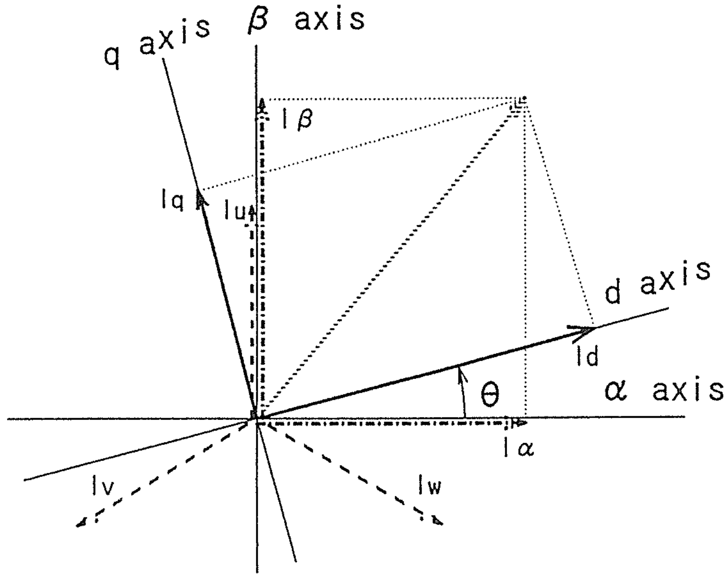


Fig.3 d-q conversion vector diagram

According to vector control theory, when the frequency is constant , if V2' in Fig.4 and 5 can be controlled constantly , secondary flux can be constant, thus motor torque will be proportional to the torque current component It, which is approximately equivalent to I2'. Therefore, the primary voltage is calculated by compensating the voltage drop across the resistance and inductance by the primary and secondary current.

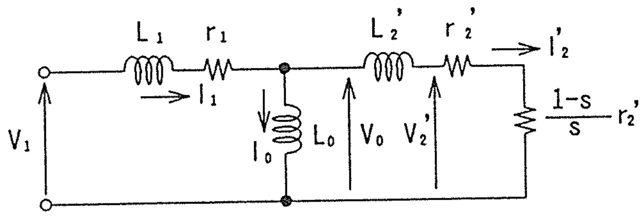


Fig.4 Equivalent circuit for motor

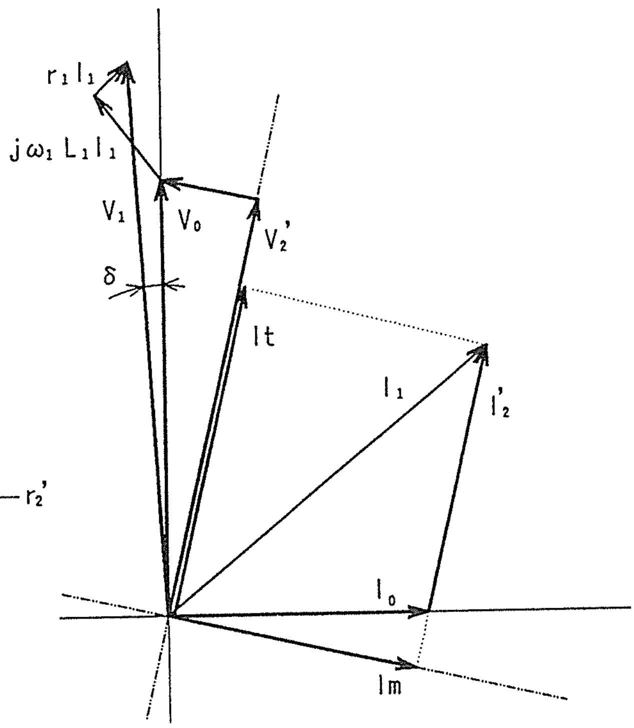


Fig.5 Voltage and current vector diagram

Here, if the primary motor current changes, according to Fig.5, voltage components, q and d axis will also be affected. In order to avoid this, it is necessary to have an interference prevention control in the actual control circuit. Fig.6 shows the current control system and vector composition block with the addition of interference prevention control.

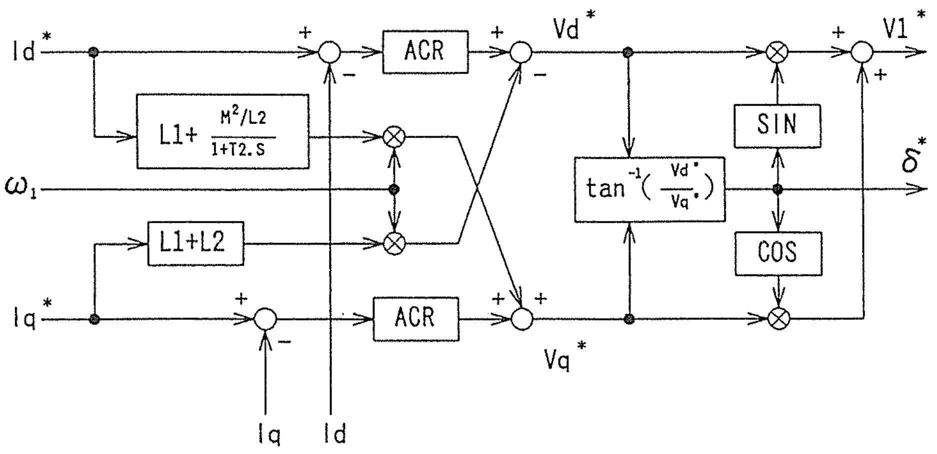


Fig.6 Current control circuit and vector composition

Vector composition circuit shows how V_1 shown in Fig.5, and internal phase angle is calculated from respective voltage command components Vq* and Vp*. Equation (2) and (3) shows the method of calculation.

$$\delta = \tan^{-1}(Vd^*/Vq^*) \quad (2)$$

$$V_1^* = Vd^* \times SIN(\delta) + Vq^* \times COS(\delta) \quad (3)$$

3.4 Space vector control

Fig.7 shows the theory of space vector. There are only 8 types of switching mode for 3 phase inverters.That is 6 types of resultant vector and 2 types of zero vectors. Take for example U^+ vector of mode 2, with P side arm of U phase and N side arm of V, W phase at "on" state, the vector state is (100). This is shown in Fig.7.

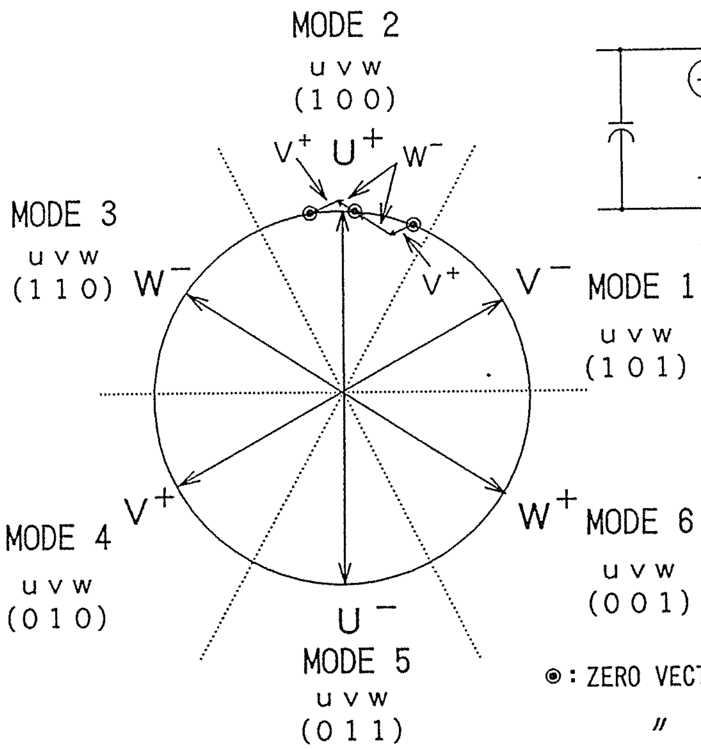
While selecting these space vectors, the magnetic flux of the motor must be controlled ideally to form a nice circle with 8 vectors for selection. These space vectors for PWM control system are used to decide the switching state of the inverter. In Fig.7(A) , the magnetic flux ring is divided into 6 regions of 60^0. In case of mode 2 for example, V^+, W^- and zero vector will be selected sequentially in order to stay as close to the magnatic ring as possible. Thus, PWM pulse can be obtained.

This method has the following advantages:

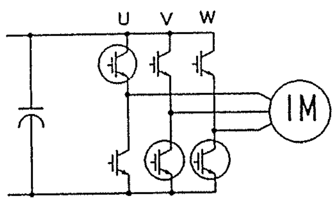
1) By comparing the calculations of pulsewidth of each respective U, V, W phase in the previous sine-wave modulation PWM control circuit and that of the present type which lump 3 phases together for calculation, PWM waveform calculation is very much shorten and simplified.

2) Space vectors are selected so as to form an ideal magnetic flux ring. Therefore, the change of inverter's frequency and slips have very rapid respond.

3)There is no voltage exhaustion and linear voltage control is possible at the maximum voltage.



(a) Space vector diagram



(b) U+vector(MODE 2) firing status

Fig.7 Theory of space vector

3.5 Correction of distorted output current waveform during low frequency.

In case of high switching frequency of PWM pulse, due to the non-lapping delay for preventing PN short, distortion of current waveform occurs. This occurrence is at the low frequency range. In another words, when the motor voltage is low, the distortion becomes significant. As for the elevator, high control efficiency is necessary for the low speed run just before the elevator stops, micro-leveling operation,etc., not only during high speed operation but also during low speed operation. Therefore, this distortion indeed becomes a serious problem during low speed operation.

Fig.8 shows how distortion occurs at low frequency range. Take U phase for example, period A represents the current during positive direction.The current flow through both arms during this period is shown in (b) where current ① and ② flows alternately. During calculation, the pulsewidth (indicated in thinner line) corresponds to the voltage command, but the actual voltage command(indicated in thicker line) being output is smaller due to the non-lapping delay for preventing the PN short. Thus the current waveform is being distorted as shown in (a). During low motor voltage, the voltage disturbance, relative to non-lapping delay, becomes significant and thus the distortion at low frequency range increases.

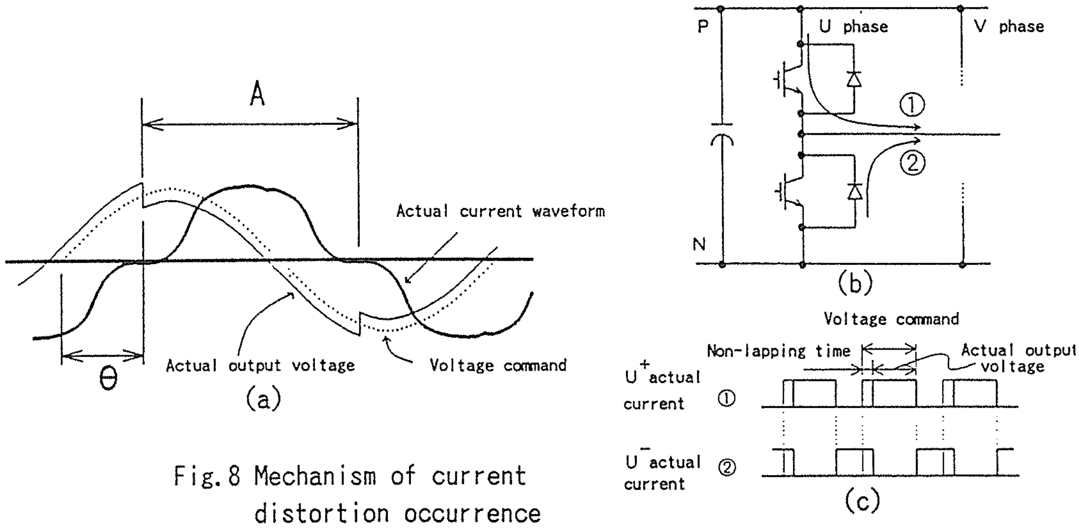


Fig.8 Mechanism of current distortion occurrence

Fig.9 shows voltage compensation method. To correct above distortion, the amount of voltage drop, due to the non-lapping delay, is added to the output. On the other hand, for the portion not represented by period A, the amount of voltage drop is subtracted from the output. Here, phase angle θ corresponding to

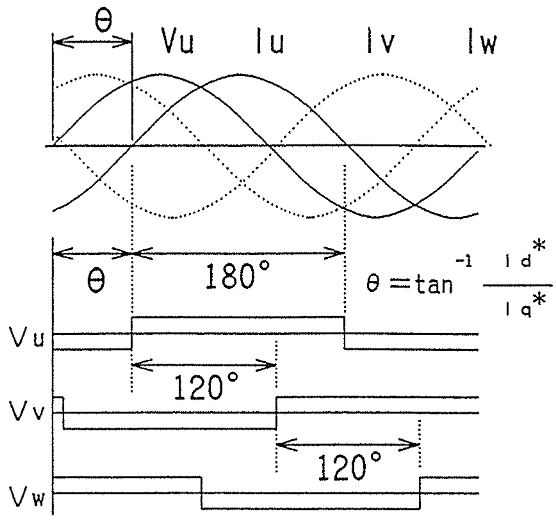
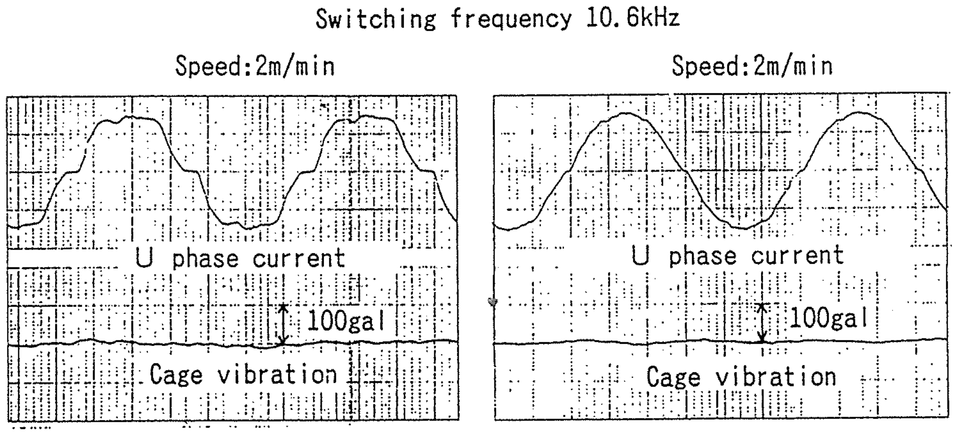


Fig.9 Voltage compensation method

the triggering edge is the lag in current with respect to the output voltage and ,therefore, can be estimated by:

$$\theta = \tan^{-1}(Id^*/Iq^*) \qquad (4)$$

The result of the correction is illustrated in Fig.10, with levator's rated speed at 60m/min, switching frequency of 10KHz and running at 2m/min.



(a)Without correction

(b)With correction

Fig.10 Effect of distortion correction

4. EXPERIMENTAL RESULT

4.1 Running Test result

Fig.11 shows running test result of an standard elevator. Helical gears with good efficiency is used for the traction machine. There is no problem in power running and regeneration, and an excellent result on the vibration during low speed operation is obtained.

4.2 Noise measuring result

Fig.12 shows the result of the measurement of noise in machine room. (a) shows the result of noise level of a standard elevator with the use of ACL used for noise reduction. (b) shows the result of noise level of the present developed system without the use of ACL. There is no problem of noise level being increased when switching frequency is around 10KHz. The noise level even decreases by about 4dB on the A scale without the use of AC reactor.

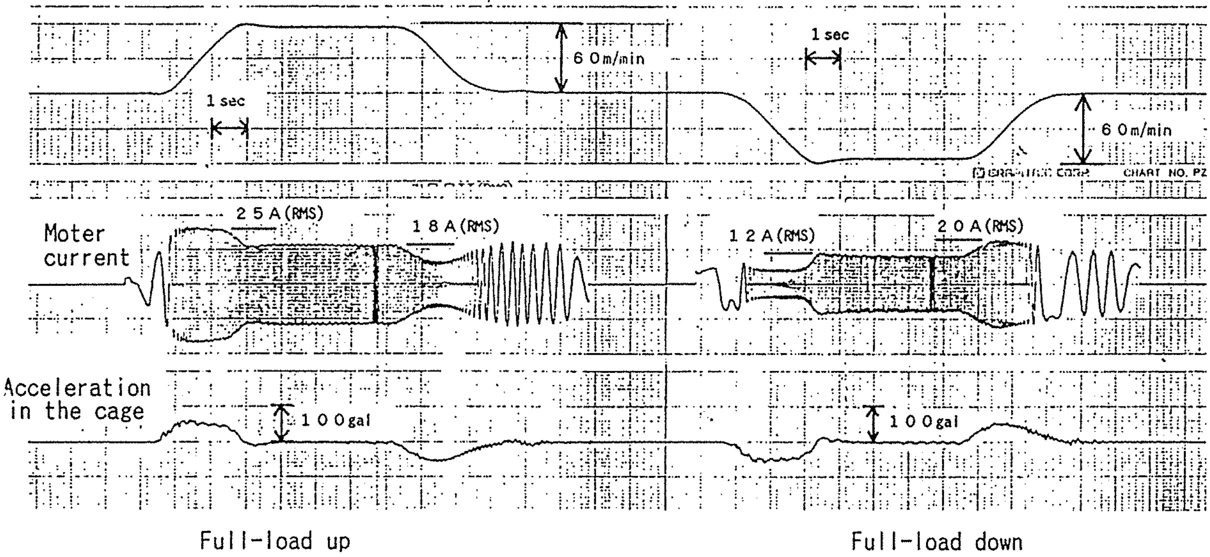


Fig. 11 Running characteristics

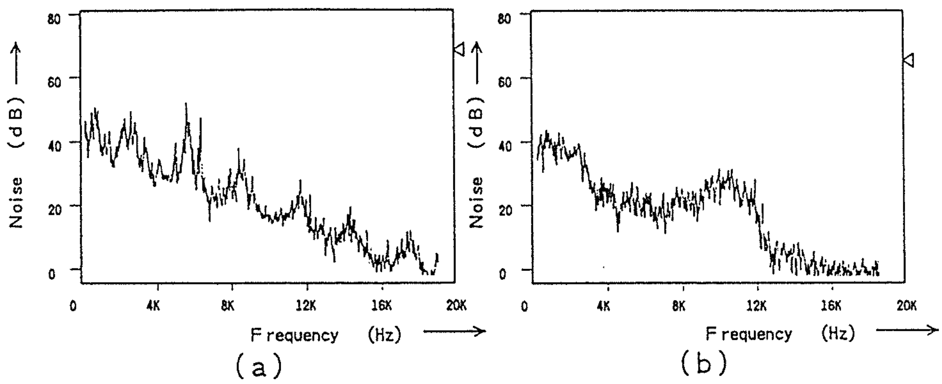


Fig. 12 Results of noise measurement in machine room

4. CONCLUSION

In conclusion, with the use of one-chip microcomputer and IGBT device, we have further increased the compactness of our control panel and reduce the noise level. In another words, with the use of one-chip microcomputer and the space vector control theory, the PWM control circuit which was organised in the hardware circuit in the pass, has now successfully being managed by software and thus the control circuit has also being simplified much further. And with the use IGBT, the need of AC reactor, used for noise reduction, is being eliminated, at the same time the noise in the machine room is being further reduced by another 4 dB.