Latest Control Technology for High Speed Elevators

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ABSTRACT

Technologies for high speed and for enhanced transportation capacity have been demanded for elevator systems which have become main vertical transportation means in recent years due to effective utilization of land by urban development and to trends in buildings to become tall and large. Rope-type elevators driven by a motor, which are of the ordinary type, require a machine room installed atop hoist ways and this has been a major constraint on building design. For this reason, recent trends are for smaller machine rooms, necessitating smaller traction machines and control panels.

Designed to achieve high speed, miniaturization and high performance of these elevator components, Toshiba has developed a high-speed and high-performance processor for elevator controllers, a compact and light PMSM traction machines and vibration control in the elevator control system. These new technologies are reported below.

1. Introduction

Induction motors are mainly used at present as motors installed for elevators. Induction motors are becoming smaller in size and higher in performance. The performance of permanent magnets has significantly been enhanced in the past several years. Rare-earth magnets featuring a high magnetic flux density and a high coercive force have been produced and are used in motors for a variety of applications. By using a permanent magnet synchronous motor (PMSM), a high efficiency, high power factor, compactness and light weight can be achieved compared with an induction motor.

This paper introduces the latest technologies which have been incorporated in high-speed elevators.

2. Elevator Controller

2.1 Overview of PP7

Inverter control is widely used at present in drive systems of elevators from low and medium speed to ultrahigh speed. The control hardware has evolved from analog-digital hybrid circuits to microcomputers and fully-digital control using application specific ICs' (ASICs) and other devices, assuring high performance.

A high-performance processor ***PP7 (PPVII: Power electronics Processor for Various Inverter control Integration)*** developed specially for power electronics has been used in a high-speed elevator. This experiment has resulted in miniaturization and simplification of the control system and in easy development of systems of higher speeds.

The PP7 is a high-performance processor developed tailored to motor control and is a single-chip controller integrating:

1) 32bit CPU and CPU peripheral circuits
2) Power electronics digital circuits

Fig. 1 shows the internal configuration of the PP7 and a basic system for motor control using the PP7.

The CPU of the PP7 is composed of the following on-chip functions:

1) Arithmetic unit : arithmetical operations,
: limit and logic commands
2) Various controllers : Bus controller, interrupt controller
3) Large-capacity dual port registers
4) High-speed access memory

The CPU is an instruction system suitable for power electronics control.

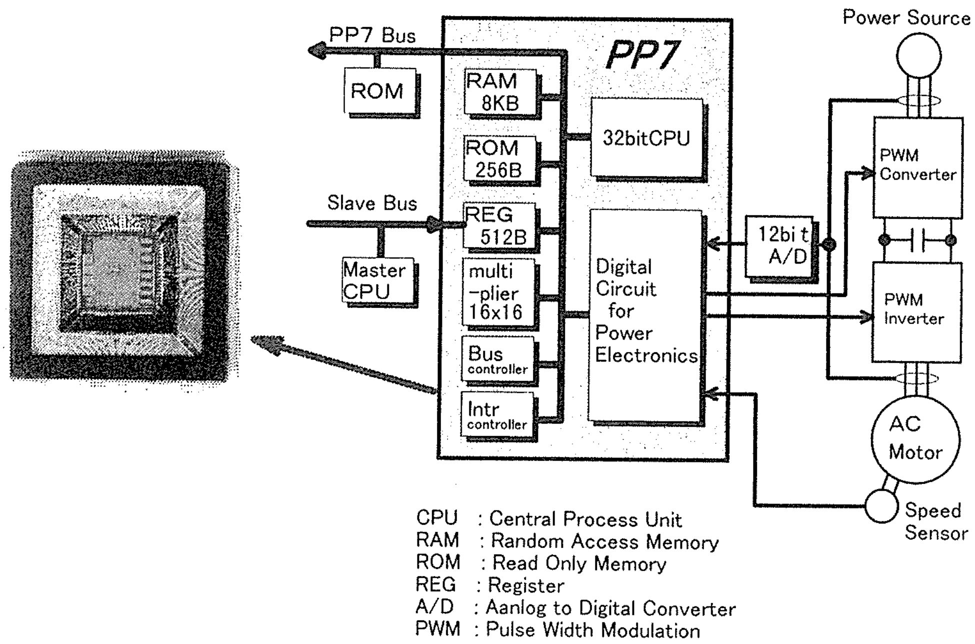

Fig. 1 External View of the PP7 chip
and Internal Configuration of the PP7
and a Basic System for Motor Control using the PP7.

The digital circuits for power electronics incorporate the following functions, suitable for motor control of a wide range:

1) PWM functions : triangular wave comparison system
: synchronization system, phase shifter
2) Vector control function
3) Phase sensor interfaces : PG, Resolver
4) Power source synchronous PLL function
5) A/D converter interface function
6) Multi-chip parallel processing interface

2.2 Overview of Elevator Controller

Fig. 2 shows the external view of the elevator controller which has been developed recently. The controller has been configured for common use not only in high-speed elevators, but also in standard, hydraulic and other types of elevators.

The controller configuration is shown below. A 32bit general-purpose CPU (intel®-80386EX) is used as a sequence control microcomputer and the PP7 mentioned earlier is used for motor control. The controller is also provided with circuits for cage position detection and for serial transmission with cage and hall printed circuit boards.

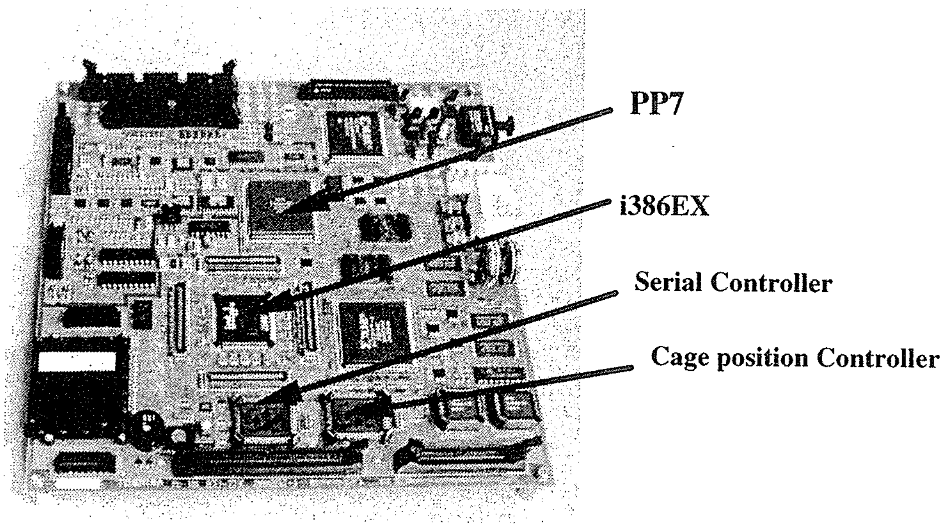

Fig. 2 External View of Elevator Controller

2.3 System Configuration

Fig. 3 shows the configuration of the drive system which uses the PP7.

By using the PP7, the hardware configuration of the control circuit board can be simplified drastically because converter control on the power source side and inverter control on the motor side can be processed entirely by the single-chip PP7.

The principal functions as the high-speed elevator control system are as follows:

Converter control on the power source side:
1) DC main circuit voltage control
2) Power-source power factor constant control

3) Current control
4) PWM control

Inverter control on the motor side:
1) Speed control
2) Load balance control
3) Vertical vibration control
4) Current control
5) PWM control

The PP7 can execute processing of various types in less than 25 μ s, and it has resulted in stability of control vibration and enhancement of system reliability. Furthermore, inverter control on the motor side also includes the elevator speed command operation function, protection function and basic elevator operation functions.

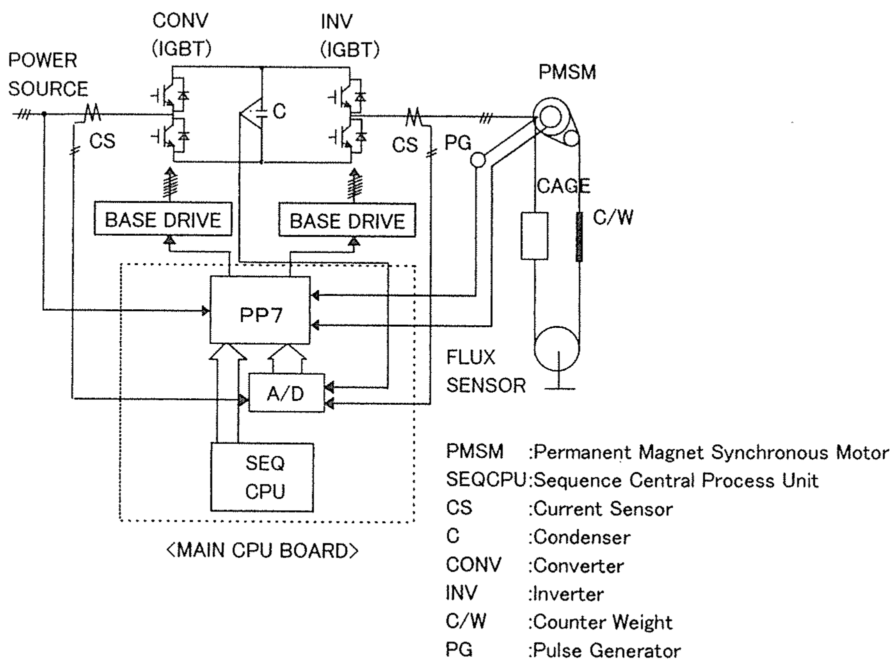

Fig. 3 Elevator Drive System Using PP7

3. Outer Rotor Traction Machine

In propelling higher speed and larger capacity of elevators, miniaturization, light weight, less maintenance care and a higher efficiency of motors are desired. Toshiba has developed a permanent magnet synchronous motor (PMSM), which uses a rare-earth permanent magnet, as a new motor to replace the induction motor.

The traction machine is of an outer rotor type, integrating the rotor and sheave. The brake is an electromagnetic disc brake, which assures compactness and light weight. Compared with a conventional traction machine of Toshiba with equal output, the weight could be reduced by about 40% and mass ratio, about 35%.

The induction motor used in the past is driven by vector control, which controls the exciting component current and torque component current independently. The PMSM does not require exciting current and can output the required torque by a minimum motor current by optimally controlling the current phase to the magnetic flux. This is an excellent energy saving function. In maintenance of the motor, the PMSM is cooled by an open natural cooling method, eliminating a blower for cooling.

The outer-rotor traction machine can be used within the service range of 240m/min in rated speed and 1800kg in maximum loading capacity. The maximum output can be produced to 300% of the rated output.

Fig. 4 shows the external view of the outer-rotor PMSM traction machine. Fig. 5 compares the dimensions of the conventional traction machine and of the outer-rotor traction machine. Table 1 presents the main specification of the motor.

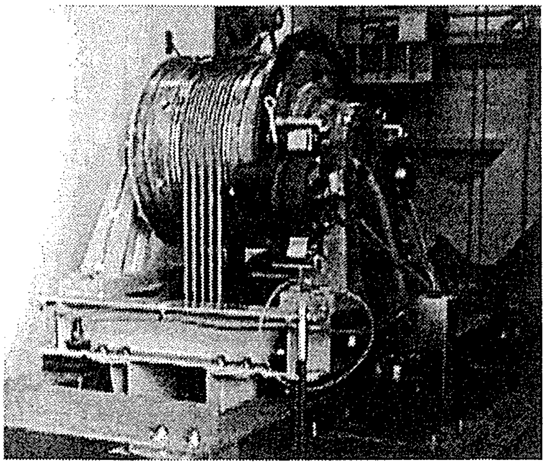

Fig. 4 External View of PMSM Traction Machine

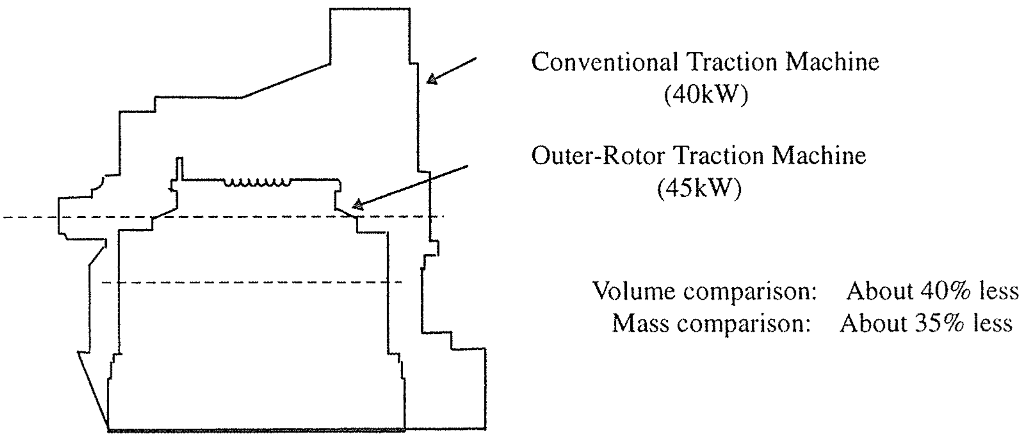

Fig. 5 Comparison of Conventional and Outer-Rotor Traction Machines

Table1 Main Specification

	Type	Outer-Rotor Traction Machine
Rate	Poles	16
	Output	45kW
	Voltage	330V
	Current	96A
	Efficiency	94%
	Speed	240m/min
	Load Capacity	1800kg

4. Vibration Control Technology

Generally, the elevator system contains a complex machine system and has a resonance point, which adversely affects the riding comfort. This resonance point works in an unstable direction with the control system and delicately affects adjustment of speed and current control. Depending on how adjustment is made, the cage sometimes vibrates vertically.

The conventional high-speed elevator drive system additionally installs the following control operation loop with the speed control system to improve vibration inside the cage caused by resonance of the control system. The output of the speed-control operation section is simulated by an inertia system, which considers the machine system as a perfect rigid body. The speed signal thus obtained is compared with the real speed signal and a speed fluctuation element by vibration contained in the real speed is extracted. This element is compensated for phase and gain and Simulator Following Control (SFC) for feed forward control operational processing is added to the torque command to control vibration.

New vibration control technology suiting high-speed elevators running in high rise buildings has been developed using ILQ (Inverse Linear Quadratic) control, which is the optimum control design theory. ILQ control is a theory to designate speed control performance, which is set as a target, and to design equipment which accomplishes it. It features to change the resonance frequency and damping coefficient to a condition which makes the resonance frequency and damping coefficient, which are causing vibration less easy to vibrate, by operating a reference given the drive system. The controller using this theory could reduce low-frequency vibration caused by elasticity of the rope by feeding back the cage acceleration signal. Fig. 6 shows control block diagram. The section encircled by dotted lines is the block added for damping control.

Figs. 7 and 8 show computer simulation results in the proposed vibration control. As a condition at this time, the simulation was made assuming that torque ripples and disturbance would virtually be impressed. The torque ripples were impressed excessively than in normal condition. The results shown in Fig. 8 indicate that acceleration fluctuations of the cage when vibration and disturbance were impressed had been reduced by the torque ripples. These results show that the riding comfort has been improved.

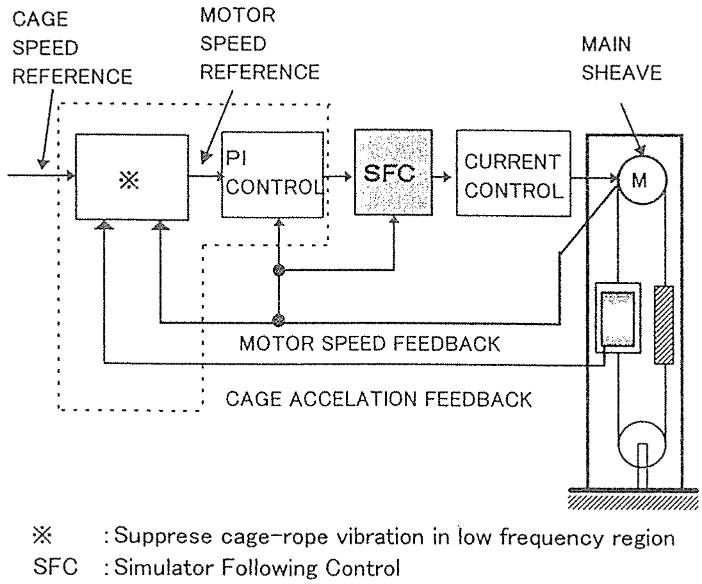

Fig. 6 Control Block Diagram

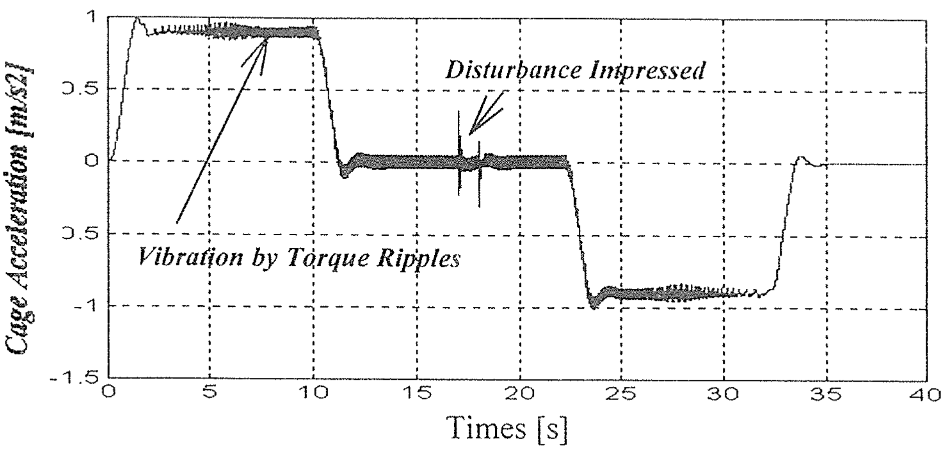

Fig. 7 Control System at Present (Loading Capacity: No load, running up)

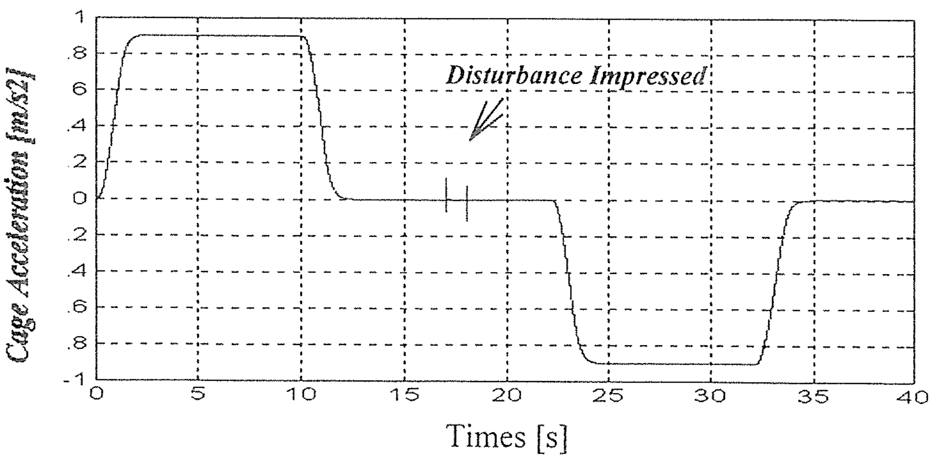

Fig. 8 Control System by Vibration Control (Loading Capacity: No load, running up)

Figs. 9 and 10 show results of cage running when disturbance (excitation) was caused during cage running. As a condition at this time, vibration of the cage when passengers inside the cage jumped during cage running was measured. As a result, the time between start of vibration and end of it after excitation was reduced, indicating that the vibration control was effective.

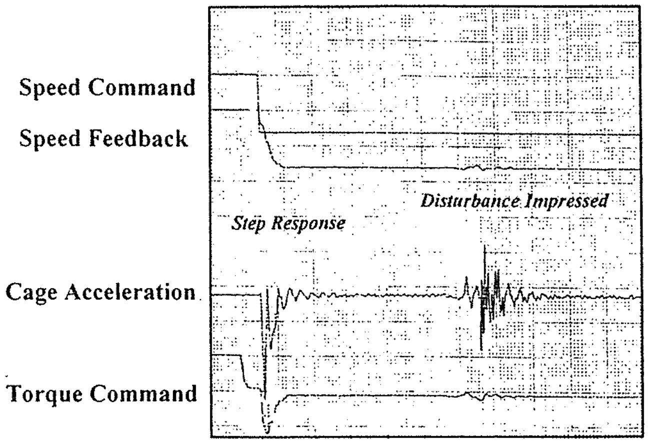

Fig. 9 Running under Present Control System

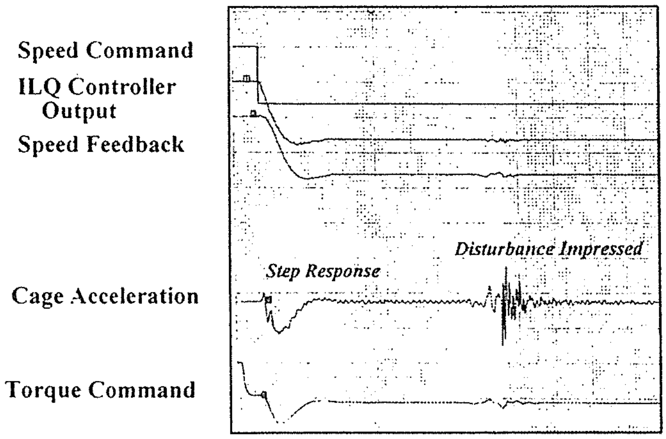

Fig. 10 Running under Vibration Control

5. Operational Characteristics

Fig. 11 shows operational characteristics of a high-speed elevator running at 240m/min. The elevator speed was controlled from elevator running start till stop following the speed command, achieving stable torque and speed control following the torque command. The motor current frequency was about several Hertz even at a rated elevator speed and was very low. The waveform becomes a sine wave with fewer current ripples by sine-wave PWM control.

The power source current was controlled to the power factor of 1.0 by the converter on the power source side. The current increased or decreased almost proportional to the motor output and was regenerated to the power source in the elevator deceleration region.

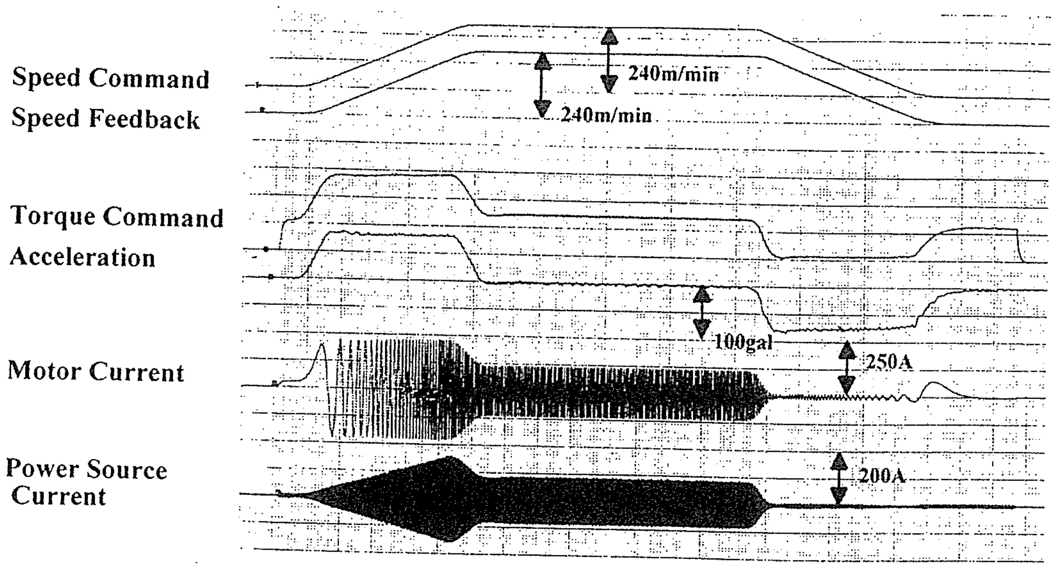

Fig. 11 Operational Characteristics of High-Speed Elevator

6. Conclusion

The traction machine could be made compact and light using a PMSM traction machine. The use of a high-performance control processor (PP7) in the elevator drive system simplified the control system. High-speed operational processing could improve the vibration damping performance to enhance the control performance of the elevator system.

Toshiba will make efforts to enhance performance and reliability of these components to supply intelligent elevator systems which meet the sophisticated needs of its customers.

References

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Biography

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