Variable-speed Elevator System with Programmable Electric Safety Device

Authors: Yoshitaka Kariya* and Akihiro Chida*

Today, users demand improvements in elevator waiting time and traveling time. Therefore, Mitsubishi Electric Corporation has developed an elevator system which can vary the traveling speed within the allowable speed range of the drive system based on the number of passengers in the car (or the weight of the load being carried) and which can travel faster than its rated speed. We began marketing this system in January 2005.

Mitsubishi’s standard-type machine-roomless elevator series “AXIEZ” incorporates a SETS (Smooth Emergency Terminal Slowdown) device, which is the world’s first programmable electric safety device developed by us as a terminal slowdown device for steplessly checking overspeed. This SETS device saves space by reducing the hoistway space. By combining the SETS device with the variable speed elevator system, we have achieved the difficult feat of improving operation efficiency while saving space.

This paper introduces technologies behind the variable-speed elevator system and the programmable electric safety device.

1. Principle of Changing Traveling Speed

Generally, the required motor power $P_m$ is given by the equation:

$$P_m = (M_{car} - M_{cwt}) \times V/\eta$$

where

- $M_{car}$: Weight on the car side (= the sum of the weight of the car itself and the weight of the payload)
- $M_{cwt}$: Weight of counterweight
- $\eta$: Efficiency of elevator system ($\eta < 1$)
- $V$: Traveling speed

Since the weight of the counterweight is chosen to balance the weight of the car plus half of the rated load-carrying capacity, the motor capacity $P_{int}$ can be chosen by using the following equation according to the capacity that is required when the car is loaded with its rated payload.

$$P_{int} = M_{c} \times 0.5 \times V_{c} / \eta_{c}$$

where

- $M_{c}$: Rated load-carrying capacity
- $V_{c}$: Rated velocity

Therefore, provided the speed is varied while maintaining $P_m \leq P_{nt}$, in other words, increasing the speed within a range in which the following expression holds

$$V \leq M_{c} \times 0.5 / (M_{car} - M_{cwt}) \times V_{c}$$

it is possible to increase the speed without having to increase the motor capacity. The above equation means that the closer the car’s payload is to half the rated load-carrying capacity, the faster the speed can be increased. However, in addition to motor capacity constraints, the increase in speed is limited by the following:

- The motor current should not exceed the rated current (i.e., the motor current that is drawn when the elevator loaded with its rated payload travels at its rated speed).
- Constraints that arise from equipment performance which is affected by traveling speed such as noise generated during driving operation, and the braking performance and the like of the safety device.

2. Specifications of Variable-speed Elevator

The specifications of AXIEZ-series elevator systems with variable speed are shown in Table 1. The relationship between the load weight being carried and the speed is shown in Fig. 1. Speeds exceeding the rate speed are referred to as rated speed 1 at middle load (maximum speed) and rated speed 2 at middle load in the order of decreasing traveling speed. In the case of a model whose rated speed is 60 m/min., the maximum speed is 90 m/min. Since the difference between this maximum speed and the rated speed is too large, the midway point between these figures or 75 m/min. is set as the rated speed 2 at middle load for higher operation efficiency.

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*Inazawawa Works
3. Variable-speed Elevator’s Operation Start Sequence

The operation start sequence of a variable-speed elevator system is shown in the flowchart in Fig. 2. As shown, the weight of the load inside the car is determined by a signal from the weighing device at the time of startup. In relation to the proportion of the load in the car as calculated from the weight of the load being carried, a speed setting at which to operate is made. To alert passengers when high-speed operation above the rated speed is about to start, the message “High-speed operation mode” is displayed on an LCD panel or display light inside the car.

Furthermore, to monitor the status of the drive system and protect it in the event of overheating, the following capabilities are provided:

- A capability to reduce speed upon detecting overheating in the drive system when traveling above the rated speed in the event of a failure in the weighing device or the like
- A capability to temporarily suspend variable-speed operation upon detecting overheating in the motor, inverter or the like, and then to resume the variable-speed operation when no longer overheated.

4. Effects of Variable-speed Elevator

This variable-speed elevator system offers the following benefits:

4.1 Improved efficiency through shorter waiting times

In computer simulations, variable-speed elevators in condominiums and office buildings reduced waiting times by up to 15% in relatively congested conditions such as during morning rush hours compared with conventional elevators. When cars are empty or loaded to near their capacity, there is no improvement since the cars travel at their rated speed. However, even during normal use, efficiency is improved by about 10%.

4.2 Improved efficiency through shorter ride times

Since travel speed can be increased by a factor of up to 1.5, ride times can be reduced. Particularly over longer travel distances, ride times are reduced more significantly.

4.3 Power consumption

Even though the elevator travels faster, the travel time is shorter, so the workload remains unchanged.
from operation at a fixed speed. Therefore, power consumption remains almost the same as with any comparable conventional elevator.

5. System Configuration Using Programmable Electric Safety Device (SETS Device)

Figure 3 shows an elevator configuration with an electric safety device (SETS device). As shown, the same as conventional elevators, the variable-speed elevator system includes the following:

i) Speed monitoring by a governor
ii) A final limit switch which closes when the terminal floor is exceeded
iii) A buffer which dampens shock in the event of the car or the counterweight colliding with the bottom of the hoistway

However, our newly developed programmable electric safety device (SETS device) can reduce the collision speed of the car (see Fig. 4) so a buffer having a shorter stroke is sufficient.

The SETS device to be added has the following:
iv) The encoder of the governor, which outputs two signals electrically independent of each other
v) The standard position sensors, one installed near the upper end of the hoistway and the other near the lower end
vi) The SETS control PCB to which the outputs of the above sensors are fed. The SETS control PCB, which exists in isolation from the control panel, detects the position and speed of the car and judges whether or not the car exceeded any preset speeds as a function of the car position near the terminal floor. If it detects overspeed, it operates the brake to forcibly decelerate the car and thereby reduce the speed of an imminent collision with the buffer.

6. Speed Monitoring by SETS Device

Figure 4 shows an overspeed monitor pattern of a conventional elevator and that of an elevator with the SETS device. Unlike the conventional elevator’s gov-
error-based overspeed monitoring with a single decision level, the SETS device, which can electrically monitor for possible speed anomalies, can detect any overspeed quicker during deceleration in the terminal-floor section of the hoistway with reference to the car’s position. Since the device thus minimizes the speed of collision with the buffer, the buffer can be downsized. As a result, we have achieved the industry’s smallest headroom of 3,000 mm at rated speeds of 105 m/min. or less in the upper-end portion of a hoistway (when a standard slim, deluxe ceiling is used) while maintaining the same level of safety, and have attained a shortening of up to 15%.

Our variable-speed elevator system with programmable electric safety device greatly improves operation efficiency for the benefit of users, while saving space for the benefit of building proprietors.

We will continue to working to meet diverse needs for elevators.

![Fig. 4 Overspeed monitoring pattern](image-url)