Expanding Application of FRENIC-Lift Series for Elevators

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1. Introduction

In recent years the elevator industry has been transitioning from geared elevators that use standard induction motors (IM) to gearless elevators that use permanent magnet synchronous motors (PMSM). This transition is being implemented in order to reduce machine room size, conserve energy, and improve the ease maintenance. Meanwhile, in Europe, where elevators were first popularized, there is an exceedingly brisk business in modernizing aging elevators to inverter-based control. In cases where an existing motor and gears are to be reused, operation without a speed sensor is often required. Responding to this demand, "FRENIC-Lift series" is equipped with a new type of torque vector control that enables operation without a speed sensor, in addition to the vector control with speed sensor used previously.

This paper introduces the expanding application of FRENIC-Lift series of inverters for elevators.

2. Control Method of FRENIC-Lift Series

Control method of the inverter for elevator-use is shown in Table 1. Approaches for each control method in FRENIC-Lift series are described below.

2.1 Permanent magnetic synchronous motor drive

Gearless elevators that use a PMSM have good overall torque transmission efficiency, and the current control performance of the inverter has a greater effect on elevator car vibration than geared elevators. The FRENIC-Lift series uses a high-speed RISC (reduced instruction set computer) microprocessor to realize a current response which is five times that of the FRENIC 5000G11UD series of inverters for elevators.

Table 1 Control method of the inverter for elevator-use

Motor type	Control method
PMSM	Vector control with speed sensor
IM	Vector control with speed sensor
	Torque vector control (without speed sensor)

Figure 1 shows the current response characteristics. We can find out that the cutoff frequency at which the gain falls by −3 dB is 500 Hz. Close attention to the variation in sensing by the current sensor and to the reduction in unbalanced output voltage enabled an improvement in overall current control performance. As a result, elevator driving with reduced car vibration is possible.

In a PMSM, the rated voltage of the motor is determined according to the electromotive force that is determined by the rotating speed. Since there are various rated voltages for motors, the rated current is not uniform, even for the same motor output. The overload rating of the FRENIC-Lift series has been increased to 200% (for an allowable time of 10 s) compared to conventional models, so that even a motor having a low rated voltage and a high rated current can be driven without increasing the inverter capacity.

2.2 Induction motor drive

(1) Vector control with a speed sensor

A geared elevator that uses an IM is a drive system often generally used. The FRENIC-Lift series is standardly equipped with a feedback pulse detection circuit of a complementary output encoder. As a result, in the case where the encoder is of the complementary output type, the motor can be driven without adding any extra options.

In a geared elevator, a worm gear is generally

Fig.1 Current response characteristics

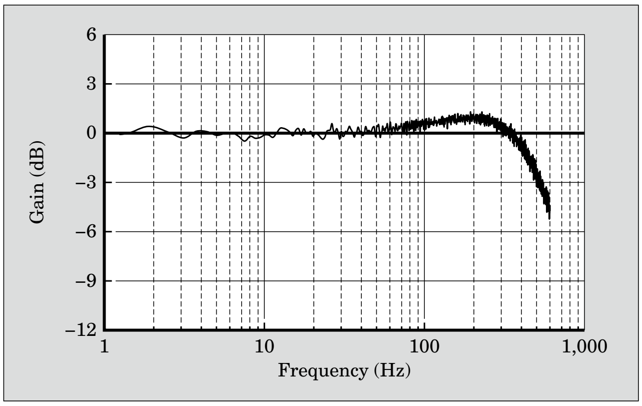
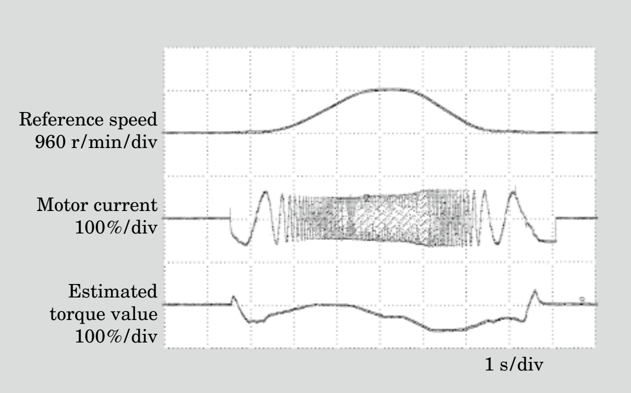


Fig.2 Characteristics of elevator operation by torque vector control (without a speed sensor)



used, and various such gears exist, from those having low mechanical efficiency to high efficiency ones. The FRENIC-Lift series provides convenient functions such as a soft-start function (two types) and ASR (automatic speed regulator) gain switching capable of smoothly starting even a traction machine having large static friction.

(2) Torque vector control (V/f control without a speed sensor)

In a geared elevator, when converting old equipment to inverter control, in some cases a speed sensor cannot be used. In such a case, the inverter utilizes torque vector control (V/f control without a speed sensor).

The torque vector control of the FRENIC-Lift series provides that reduced speed ripple, improved speed control accuracy and improved current respons to enable smoother startup than in conventional models.

Figure 2 shows various waveforms in the case where an elevator is driven by torque vector control. The upper plot shows the reference speed, the middle plot shows the motor current and the lower plot shows the estimated motor torque value. This data was measured under no-load and rising operation (in the regenerative operation). From the estimated motor torque value during constant speed, we can find out that the traction machine has good mechanical efficiency. When the mechanical brake is released and the motor starts to move, the desired torque is generated quickly. It can be seen that torque ripple is suppressed to a low value, and even in the case of a highly efficient traction machine, the torque vector control of the FRENIC-Lift series is able to realize smooth control.

2.3 Wide variety of encoder interfaces

The FRENIC-Lift series is standardly equipped with an interface supporting 12 V and 15 V complementary output encoders as a speed sensor attached to the motor. Moreover, the various encoders listed in Table 2 can also be supported with the addition of an optional card. In PMSM driving, there exist several different methods having different rotor position detection methods. Thus, the FRENIC-Lift series provides a full lineup of optional cards to support nearly all encoders used in elevator applications.

Table 2 Applicable encoder interfaces

Motor type	Encoder type			Option
	Power supply	Output circuit/signal	Rotor position detection	
IM	12 V	Complementary	–	Unnecessary
	15 V			
	12 V	Open collector	–	
	15 V			
	5 V	Line driver	–	OPC-LM1-IL
PMSM	12 V	Complementary	Z	Unnecessary
	15 V			
	12 V	Open collector	Z	
	15 V			
	5 V	Line driver	Z	OPC-LM1-IL, OPC-LM1-PP
	5 V	Line driver	Gray code (4 bit)	OPC-LM1-PP
	5 V	Line driver	U, V, W	OPC-LM1-PP
	5 V	1 V_{P-P} Sinusoidal differential signals	EnDat2.1	OPC-LM1-PS, OPC-LM1-PS1
	5 V	1 V_{P-P} Sinusoidal differential signals	SIN/COS	OPC-LM1-PR

3. Functions

The FRENIC-Lift series is provided with functions for improving the quality of the elevator system. Some characteristic functions are described below.

3.1 Unbalanced load compensation

The elevator control generally uses a load sensor to reduce the vibration felt inside the car when the mechanical brake is released. The load sensor must be maintained regularly in order to be able to handle weak signals.

Figure 3 is a control block diagram of the FRENIC-Lift series. The automatic speed regulator is the function of causing the motor speed to follow the output of the ramp controller. In the control of the FRENIC-Lift series, the automatic speed regulator is compensated by an unbalanced load compensator. To verify the effect of the unbalanced load compensation, Fig. 4 shows the results of measured vibration in the elevator car. The motor is a PMSM, the elevator specifications are a rated speed of 1.75 m/s and a rated load of 1,000 kg, and no load sensor is used. If the unbalanced load compensator is not used, an extremely large amount of vibration will be generated when the mechanical brake is released. In contrast, if the unbalanced load compensator is used, no vibration is generated. By using this function, not only can the load sensor be omitted,

Fig. 3 Control block diagram

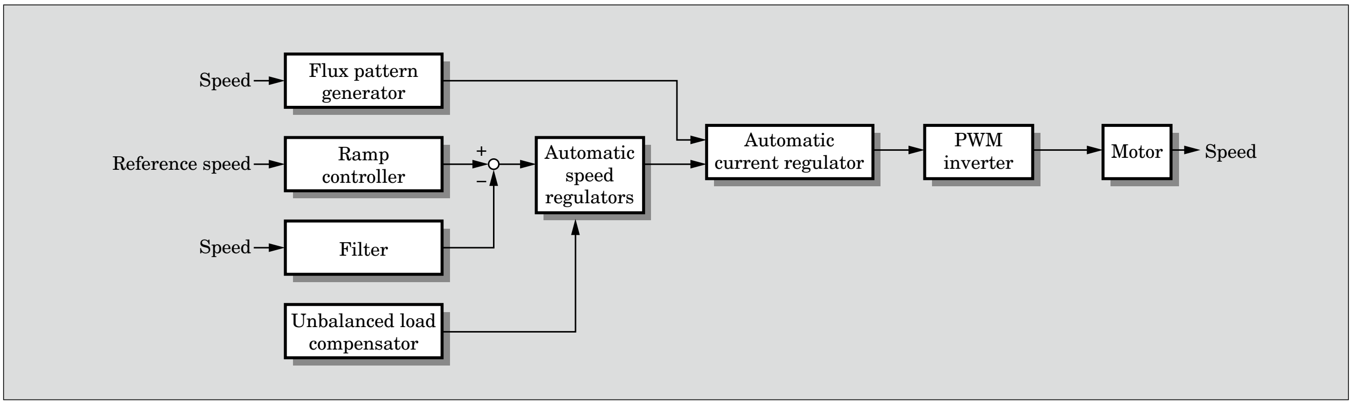
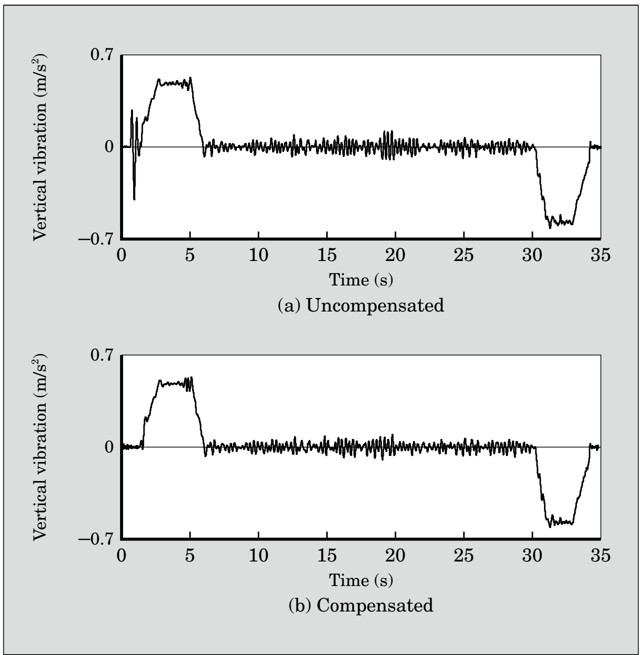


Fig.4 Car vibration (vertical)



but regular maintenance of the load sensor becomes unnecessary.

3.2 Automatic reset function

When a power failure occurs while an elevator is moving, the inverter detects the power failure and enters an alarm state. Furthermore, if highly-loaded operation is continued in a high temperature environment, the inverter itself will reach a high temperature and may enter an alarm state for protection. Usually, when the inverter enters an alarm state, the elevator controller will release the inverter alarm state after verifying that there is no danger. If the power supply and equipment conditions are good, there is only a very slight possibility that the inverter would enter an alarm state due to these causes. However, power failure occur frequently in some countries and an inverter may be installed in a high temperature area, and so it is necessary to consider these cases at the initial step of designing.

In the case of an inverter alarm due to a power failure or high temperature, the inverter itself will ascertain the cause. Additionally, the present inverter status is also ascertained, and thus the FRENIC-Lift series is equipped with a function that automatically releases the alarm state without requiring the input of a reset signal. This function is used particularly often in Europe and Asia.

3.3 Expanded functions during battery operation

An emergency stop made by an elevator due to a power failure may cause a passenger to become trapped in the elevator car. Consequently, recent elevators are commonly equipped with an emergency operation function that automatically switches over to battery power during a power failure and travels to the nearest floor. This function in the FRENIC-Lift series that switches over to battery power is called “battery operation.” Since a battery power source drives the elevator during battery powered operation, the elevator is generally operated at a low speed in order to reduce power consumption and to reduce the required battery capacity. Moreover, to move the elevator to the nearest floor more reliably, the elevator moves in the regenerative direction (direction in which the elevator would naturally fall). If the elevator were to move in the opposite direction (driving direction) and that the battery capacity was insufficient, the battery voltage would drop and operation would become impossible. Once the battery voltage drops, charging is required and the rescue of passengers would not be possible during an emergency. Thus, the elevator controller must somehow be aware of the running direction, which forms the regenerative direction.

The FRENIC-Lift series is equipped with new functions that output “recommended running direction for battery operation (RRD function)” prescribing the regenerative direction and “torque limitation for battery operation (TL function)” even if the elevator operates in the driving direction, the maximum torque is limited and a drop in battery voltage is suppressed. By using RRD function, the elevator controller can operate the elevator in the regenerative direction easily. By using

Table 3 Main specifications of CANopen

Item		Specification	Description
Communication protocol		CANopen	Based on ISO11898 (high-speed CAN)
Transmission method		Half-duplex transmission	
Network topology		Bus topology (multi-master)	
Bus arbitration		Carrier Sense Multiple Access with Nondestructive Bitwise Arbitration (CSMA/NBA)	When the transmission data collides, the object with higher priority is transmitted
Synchronization		Asynchronous transmission and phase correction	
Data length		8 byte (max.)	
Error detection		Cyclic redundancy check sequence	
Channel coding		Non-return-to-zero sequence and bit stuffing	When there are 5 consecutive bits at the same level on the bus, a reversing bit level is added
Maximum transmission rate		250 kbit/s	Transmission time of one frame is about 0.5 ms
Function	Heartbeat consumer	1 s	Operation of the elevator controller can be monitored
	Heartbeat producer	1 s	Elevator controller can monitor the operation of the inverter
	Event timer	20 ms	State data for the inverter is transmitted at a fixed cycle

TL function and presetting the torque limiting value according to the battery capacity, driving operation in a range in which battery voltage does not drop is easily realized.

3.4 Elevator system using a CAN

A CAN (controller area network) is a high-speed highly reliable network that has been used successfully in many applications mainly in the automotive industry. In elevator systems primarily in Europe, there are examples of the elevator controller and various switches, sensors, displays, and the like being connected with a CAN. Thus, it is relatively common for an elevator controller to be equipped with a CAN. The FRENIC-Lift series was designed to support CANopen, a type of open network by using CAN.

Table 3 shows the main CANopen specifications of the FRENIC-Lift. The maximum transmission rate of 250 kbit/s is extremely fast compared to serial communication using a protocol such as RS-485, moreover, bus arbitration is performed with CSMA/NBA (carrier sense multiple access with non-destructive bitwise arbitration) to enable highly efficient communication. For example, in the case that speed command are received from the elevator controller at a fixed cycle and the inverter state data are transmitted at a different cycle, even if the data collide with each other, arbitration will be performed automatically and the speed command can be prioritized. Also, the use of the CANopen function enables the elevator controller and the inverter to monitor the status of each other's operation, and to configure an even more reliable network.

4. Postscript

This paper has presented an overview of the FRENIC-Lift series of inverters for elevators. Fuji Electric intends to continue to develop new functions and to improve performance in response to market needs.