FRENIC-Lift Series Inverters for Elevating Machinery

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1. Introduction

In elevator industry, system is transitioning from geared elevators that use standard induction motors to gearless elevators that use synchronous motors. Gearless elevators has already got the majority of new construction starts in Japan, and demand for their use is also increasing in rapidly growing markets in China and Europe. Inverters that drive gearless elevators are required to be small, thin, to have high overload capacity, and to deliver high performance and high functionality.

In consideration of these circumstances, Fuji Electric has newly developed FRENIC-Lift series inverters designed specifically for elevator machinery. This paper introduces the features of FRENIC-Lift series.

2. FRENIC-Lift Specifications and Features

FRENIC-Lift series was developed to provide powerful and high-performance inverters as well as easy-to-use. Input voltage is 3-phase 400 V, and output capacity ranges from 5.5 to 22 kW. Figure 1 shows external appearance of 11 kW model. Functionality is enhanced with the provision of many custom functions for elevator machinery, including the well-established vector control with speed sensor.

2.1 Hardware configuration for powerful and optimized elevator machinery

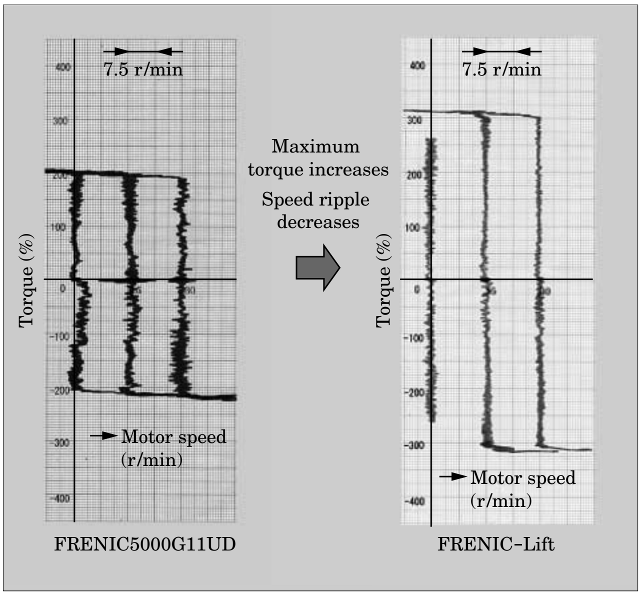
2.1.1 High overload capacity

Since maximum torque is needed during acceleration and deceleration for elevator-related applications, an ample overload capability is important. Moreover, required load inertia (at the motor shaft) of recently popularized gearless elevator is larger than that of geared elevator, and a larger torque is needed during acceleration and deceleration.

With FRENIC-Lift, specified thermal design based on operating pattern of elevator and lower generated loss due to the use of next-generation insulated gate bipolar transistor (IGBT) chip enabled the realization of 200 % – 10 s overload capacity. This value is significant improvement from the 150 % – 10 s overload capacity of previous model (FRENIC5000G11UD).

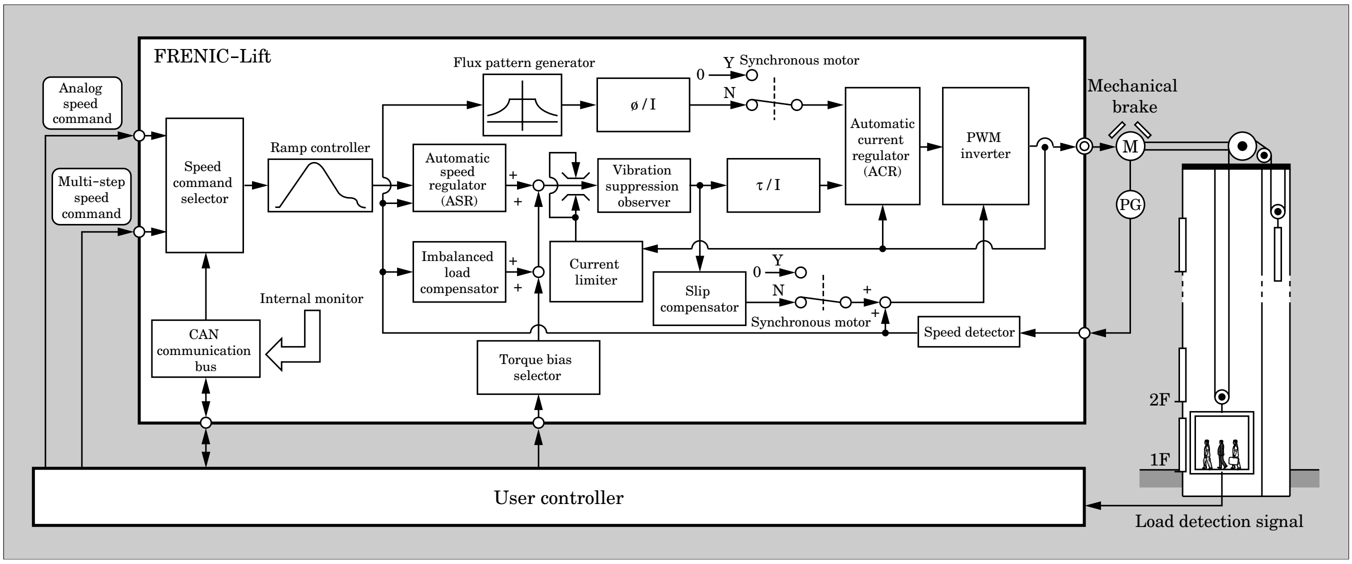
Fig.1 External view of FRENIC-Lift series

Fig.2 Speed vs. torque characteristics (at low speed)



Consequently, FRENIC-Lift series is well suited for applications for which prior models could not be used due to their limited overload capacity such as relatively high-speed elevators and gearless elevators

Fig.3 Control block diagram



having large load inertia (at the motor shaft).

Figure 2 shows speed vs. torque characteristics at low speed. Compared to FRENIC5000G11UD, it can be seen that FRENIC-Lift has larger torque and lower speed ripple, and is thereby capable of powerful and stable operation.

2.1.2 Internal encoder interface and braking circuit

Encoder interface and braking circuit are provided as standard equipment. As a result, it is attachable to the small space compared with previous models.

2.1.3 Safety function

Safety function is provided whereby, regardless of operating state, when dedicated control input (EN terminal) is turned OFF, inverter output is cutoff immediately and motor drive is stopped reliably. The process by which drive output is cutoff in response to this function is implemented by hardware, which operates much faster than software processing. Additionally, since output cutoff circuit is equipped with functions for stopping the motor drive reliably even in the case of partial malfunction and for delivering information outside about the malfunction, it realized enhanced safety feature.

2.2 High-level control performance

2.2.1 Greater riding comfort by improved control response

With FRENIC-Lift, control response has been improved significantly with use of higher-speed automatic current regulator (ACR). Figure 3 shows a block diagram of FRENIC-Lift control system, and Fig. 4 shows speed response characteristics of FRENIC-Lift and the FRENIC5000G11UD.

With improved control response of FRENIC-Lift, elevator car vibration (vertical) has been reduced compared to previous models, and a vibration characteristic less than 0.10 m/s^2 (p-p) was achieved in actual gearless elevator (See Fig. 5).

Fig.4 Speed response characteristics

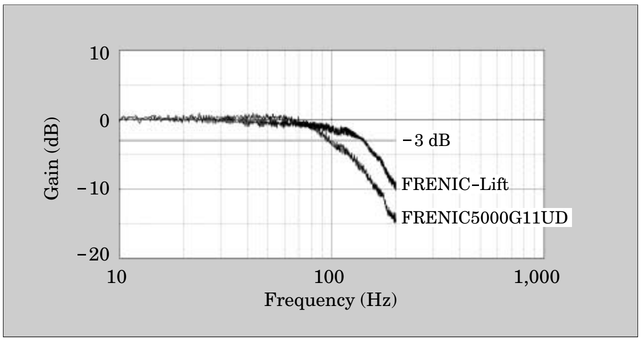
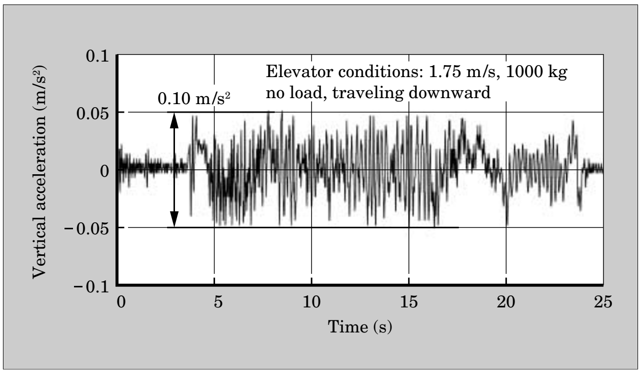


Fig.5 Car vibration (vertical)



2.2.2 Reduced rollback when brake is released

Unless elevator provides torque compensation in response to load imbalance between weight of car (with load) and counterweight, rollback will occur when mechanical brake is released.

Typically, a signal from load detector attached to elevator car has been used to calculate necessary amount of torque to inverter so as to reduce the occurrence of rollback when the mechanical brake is released. FRENIC-Lift, however, is equipped with imbalanced load compensator to calculate and provide

Fig.6 Reduced rollback when mechanical brake is release

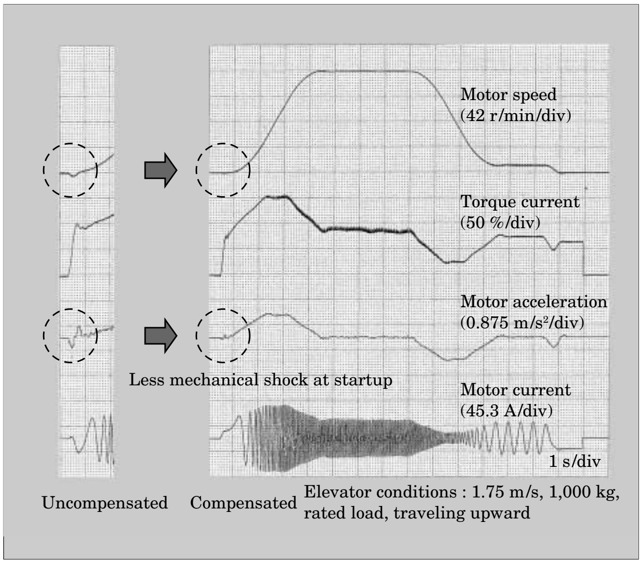
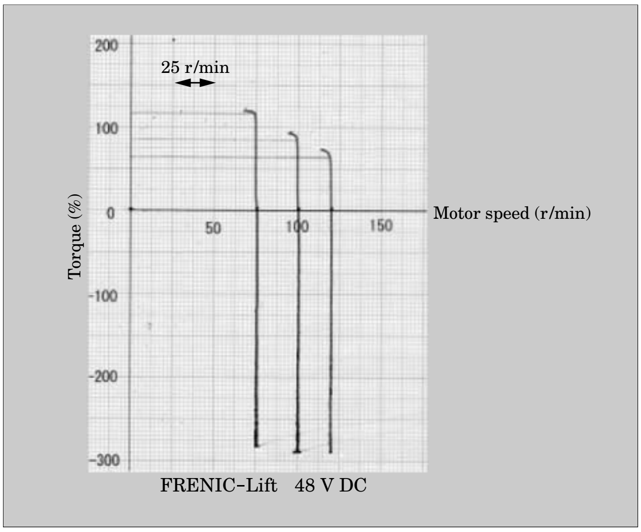


Fig.7 Torque characteristics during battery operation



necessary amount of torque compensation.

Figure 6 shows characteristic data of imbalanced load compensator. Data on the left is "uncompensated" and data on the right is "compensated." The phenomenon of rollback when mechanical brake is released can be checked with vibration of motor acceleration. Compensated data shows no fluctuation in motor acceleration, and it can be seen that the imbalanced load compensator mitigates the phenomenon of rollback.

Because load detector is unnecessary with this function, elevator system can be simplified and reduce its cost. When renewing an elevator, for example, imbalanced load compensator is very effective to realize smooth operation even in elevators not equipped with load detector.

2.2.3 Application for gearless elevators (option)

For synchronous motors, an optional interface is available that supports "EnDat 2.1 serial interface encoder" and "4-bit gray code and U V W 3-bit code parallel interface encoders," which are used often in elevator industry. Additionally, offset tuning function of magnetic pole position is also provided to adjust the magnet pole position offset values automatically.

As a result, set-up work for gearless elevator is simplified.

2.3 Functions suited for elevator applications

2.3.1 Standard CAN bus interface

Controller area network (CAN) bus is a highly reliable network having a track record of many successful applications. Moreover, due to low protocol overhead and high-speed communication capability of CAN bus, high-speed response can be achieved that is approximately 10 times RS-485 communication performance used in conventional general-purpose inverter.

Because CAN bus is provided as standard interface, inverter control can be realized via communication lines, and as a result, less wiring is possible.

2.3.2 Optimization of operating cycle

Generally, just prior to landing elevator (the car is approaching loading position), it travels at a low-speed known as creep speed to reach the landing position accurately. However, FRENIC-Lift is equipped with creepless operation function that operates when the elevator is landing. When receives a positioning signal as an external command, this creepless operation function generates speed command pattern to move the elevator from that time to just the specified distance, and then to stop the elevator. Therefor it can eliminate the need for creep speed operation.

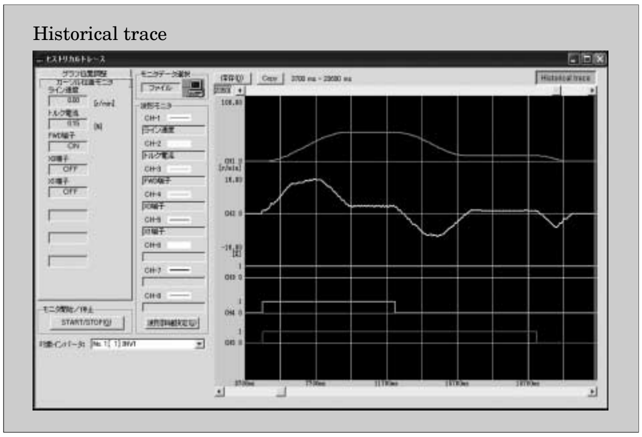
This function enables optimized operating cycle of an elevator.

2.3.3 Battery operation characteristics

Figure 7 shows speed vs. torque characteristics during battery operation. The battery voltage is 48 V DC. When in the braking mode, even during battery operation, stable operation with at least 200 % torque is possible.

Additionally, during battery operation, an uninterruptible power supply (UPS) or the like may be used as an auxiliary power input to inverter control circuit. Since UPS output voltage matches the voltage of the power distribution system, it often differs from the voltage at the motor power inputs (3-phase power supply). For example, in the case where 3-phase power supply is 380 V and the power distribution system voltage is single-phase 220 V, a voltage drop of more than 40 % will occur at time of changeover to the UPS. Fuji Electric's general-purpose inverters only guarantee proper operation for up to 15 % drop in power supply voltage. However with FRENIC-Lift, design of the DC-DC converter load has been optimized to guarantee proper operation during this type of wide voltage variation. By reducing DC-DC converter load during battery-powered operation, 400 V series inverter can allow 200 V control power input during a power failure.

Fig.8 Trace function



2.4 Ease of use

2.4.1 Trace function

Windows[*1]-compatible FRENIC loader enables trace function that is capable of monitoring such waveforms as inverter's internal reference speed and reference torque, etc.

Trace function allows for real-time traces, which display the current state as a continuous waveform, and historical traces, which display waveforms before and after when trigger conditions are met (See Fig. 8).

Because this function allows parameters to be adjusted during test runs, maintenance, waveform monitoring, and the like, operation efficiency is improved and set-up time is reduced.

2.4.2 Environment-friendly functions

Since elevators are public facility, the level of acoustic noise emitted from an inverter's cooling fan when elevator is stopped, may be undesired in some cases. With FRENIC-Lift, the conventional cooling fan control has been improved such that, as long as the inverter's heat sink temperature does not rise, the cooling fan will not operate. As a result, not only reduction of acoustic noise from the cooling fan, but also extension of service life of cooling fan is performed.

Additionally, since inverters are installed in relatively severe environments such as inside an elevator control console, machine room, or the like, a dust-protecting fan is used to improve the capability of the inverter against such environments.

2.4.3 Other functions

An elevator control system consists of user controller, inverter and peripheral circuitry. FRENIC-Lift series is system-oriented, and is equipped with many convenient functions.

One of such function is providing door open-close control signal. This signal equipped on inverter side make it easy to control the elevator door when the elevator has landed.

Another convenient function is selection of positive or negative logic for each I/O signal. The decision of whether each signal is normal ON, or abnormal ON, depends on the type of control signal and the system design. With FRENIC-Lift, all I/O signal active logic can be switched easily with the parameter settings.

3. Future Outlook

3.1 Global standard conformance

Fuji Electric intends to conform with EC directive (CE mark) required in the European markets, and the UL standards and cUL certification required in the North American markets. Furthermore, although inverters are presently exempt, in consideration of the growing sense of environmental awareness in the market, Fuji Electric is also making preparations to facilitate conformance with RoHS directive[*2].

3.2 Product series expansion

In the future, Fuji Electric plans to develop a large-capacity 400 V series and a 200 V series.

4. Conclusion

Features of FRENIC-Lift series inverters for elevator machinery have been presented. Fuji Electric intends to continue to develop inverters that meet the needs of the market and to incorporate insights from end users to create even better products in the future.

*1: Windows is a registered trademark of Microsoft Corp. in the US and other countries.

*2: RoHS directive is restriction on the use of certain hazardous substances in electric and electronic devices.