Traction Machines and Inverters for High-Speed Elevators

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Keywords Traction machine, Inverter, Elevator, Safety, Energy saving

Abstract

Traction machines (PM6T·PM13T) and inverters (THYFREC VT850H) for high-speed elevators have been developed and released in the market. Features of the developed traction machines are that a one-end sheave construction is adopted and torque ripples are low. These products conform to the latest Safety Standards of Ministry of Land, Infrastructure, Transport and Tourism of Japan and GB Standards of China (GB/T24478-2009). Our traction machines have already acquired the GB type test certificate in accordance with relevant Chinese national standard. Standard inverter products are equipped with power regenerative converters of the PWM control system with features of energy saving, restriction of harmonics in power source, and high power factor. Important functions of protection, trace-back, and elevator position control are duly secured. We have pursued performance features of safety and convenience.

1 Preface

Reflecting on Chinese economic growth, a number of high-rise buildings and apartments have been on the rise recently and the demand for high-speed elevators is expanding in relation to this rise. Responding to such requirements, we developed a traction machine of the PM15T which was released in 2011. This traction machine assures the rated load of 2000kg and the rated speed of 4.0m/s.

We recently developed an inverter THYFREC VT850H (VT850H hereafter) which is intended to drive the PM13T with the rated load of 1600kg and the rated speed of 4.0m/s, the PM6T with the rated speed of 2.5m/s, and traction machines for high-speed elevators. This paper introduces the specifications and features of the PM6T, the PM13T, and the VT850H.

2 Product Outline of PM6T and PM13T

2.1 Product Specifications

Fig. 1 shows an external appearance of the PM13T and Table 1 shows the major specifications of the PM6T and the PM13T. Like the PM15T machine, these traction machines have a one-end sheave construction due to our focus on maintainability.

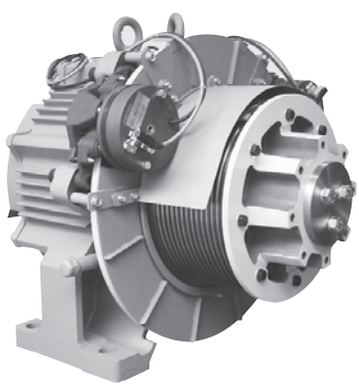

Fig. 1 Traction Machine PM13T

Like the PM15T machine, these traction machines have a one-end sheave construction

2.2 Features

This traction machine design focuses on a comfortable ride, easy maintenance, high reliability, and safety. The major features are as follows:

2.2.1 One-End Sheave Construction

This traction machine has a construction where the load-side bearing creeps into the inner side of the sheave so that the machine can withstand a large shaft load required for a high-speed elevator. In addition, tilting of the sheave and the shaft deflection are reduced by adopting the integration of the frame and the load-side bracket of the sheave and

Table 1 Major Specifications of PM6T and PM13T

The table below shows major specifications of our traction machines for high-speed elevators.

Item	PM6T	PM13T
Load (kg)	1600	1600
Speed (m/s)	2.5	4.0
Rated output (kW)	25	40
No. of poles	20	20
Rated rotational speed (min^{-1})	119	319
Sheave shaft load (N)	58,800	127,400
Sheave diameter (mm)	480	480
Brake torque (N·m)	3000	3000
Protective construction	IP41	IP41
Dimensions (mm)	W880 × H882 × D787	W880 × H882 × D904
Mass (kg)	Approx. 1050	Approx. 1180

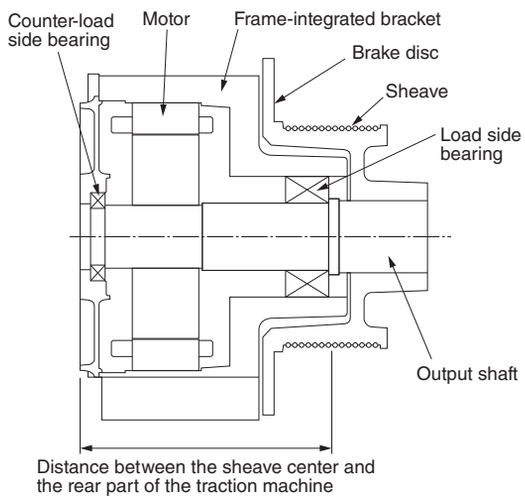

Fig. 2 One-End Sheave Construction Drawing

A construction drawing of the PM13T is shown. The sheave and the brake disc are assembled in an integrated configuration.

the brake disc. Compared with ordinary both-end sheave construction, replacement of the sheave can be easily made. Fig. 2 shows the construction drawing.

2.2.2 Low Torque Ripples

Torque ripples of elevator motors can adversely affect the riding comfort. Therefore, it is necessary to reduce the torque ripples as low as possible. For this type of traction machine, a method of electromagnetic analysis has been adopted for the optimization of motor shapes. As a result, the rate of torque ripples to the rated load has been lowered to a level that is less than half the rate of conventional machines.

2.2.3 Compact Design and Small Footprint

Because of elevator layout, the sheave is required to be placed in the center of the hoistway space. The distance between the sheave center and the rear part of the traction machine shown is Fig. 2 should be as short as possible in order to have a better configuration. Since the concentrated winding is adopted for this traction machine, the total length of the elevator motor has been made shorter by reducing the distance between bearings. For this result, we made CAE analysis on the frame-bearing structure to shorten the distance between the sheave center and the rear part of the traction machine; we can reduce it by 20% compared with the conventional design.

2.2.4 Totally Enclosed Type

During the construction of a building, an elevator is often used for the transportation of construction materials. Therefore, the elevator is required to have a dustproof construction in order to withstand dust generated during construction work.

Conventionally, a traction machine for a high-speed elevator was installed in a machine room. In the case of this traction machine, however, high efficiency has been attained for the elevator motor. In addition, shapes of the fins distributed over the machine surface have been effectively designed to create a completely enclosed construction where temperature rise in the motor is contained. It has a high protection level against dust.

2.2.5 Related Standards-Compliant

The performance features of this traction machine conform to the GB Standards of China (GB/T24478-2009). The traction machine itself has already acquired the GB type test certificate. The mechanical configuration explained below conforms to the latest safety standard (New Safety Standard) of the Ministry of Land, Infrastructure, Transport and Tourism of Japan based on the Revisions of the Building Standards Law effective since September 30, 2009.

(1) Redundancy of the brake

The New Safety Standard calls for provisions of the two essential points specified below.

(a) Two brake units shall be provided.

(b) Each brake unit shall be capable of clamping, holding, and braking a 100% load at the rated load.

This traction machine is provided with two electromagnetic brakes and large-diameter brake

discs to meet the requirements of the standard. In addition, the integration of the sheave and brake discs has increased the torus strength of the discs and the displacement on the brake disc surface has been reduced.

(2) Redundant measures against bearing oil leakage

According to the New Safety Standard, oil contamination is prohibited in a place where such contamination can affect the braking force. The structure should be visible in order to enable the identification of oil leakage location from the outside during maintenance and inspection. Regarding countermeasures against oil leakage for this traction machine, a construction of an oil seal and labyrinth seal is adopted to realize the redundancy. Even in the case of oil leakage due to deterioration of an oil seal, the adopted construction is made to prevent oil leakage from reaching the braking surface because such leaking oil is ejected from a drain (oil relief hole) located beneath the motor.

2.2.6 Hand-Powered Emergency Operation System

In the case of a power outage or accidental confinement in an elevator cage due to a problem, it is necessary to move the cage to the closest floor as soon as possible. As shown in **Fig. 3**, this traction machine is made to perform manual release of a brake by means of a lever. After that, a hand wheel is mounted on a rear part of the traction machine. When the hand wheel is turned, the elevator car with the rated load cage can be moved manually.

2.2.7 SIN/COS Line Driver Encoder

Instead of load sensors, recent elevators have tended to use output signals (sine waves) of analog encoders. These signals are used to restrain shocks (rollbacks) that may occur when the brake is released. In order to cope with this type of control, our standard traction machine is equipped with an encoder of 1Vp-p sinusoidal differential output.

3 Outlined Description of VT850H Products

3.1 Product Specifications

We have developed an inverter series of VT850H for high-speed elevator driving applicable to a load of 1350～2000kg and a speed of 2.0～4.0m/s. **Fig. 4** shows an external appearance.

Each standard unit of the VT850H Series is provided with a function of energy regeneration. This product contributes greatly to the reduction of energy to be consumed by elevators. Since the PWM control system is adopted, harmonics in electric power are effectively suppressed. **Table 2** shows the major specifications of the VT850H.

The design concept for this product is that the output voltage is boosted up to 513V in order to minimize the inverter size and suppress the output current so that ratings can be reduced for inverter-side switchgear and cabling. Anticipating possible applications to high-storied buildings and hospitals, the product has been designed for the attainment of duty cycle 60%ED, 12 hours of operation a day, 240 times of starting per hour, and a maximum of one-million operating frequencies on annual average.

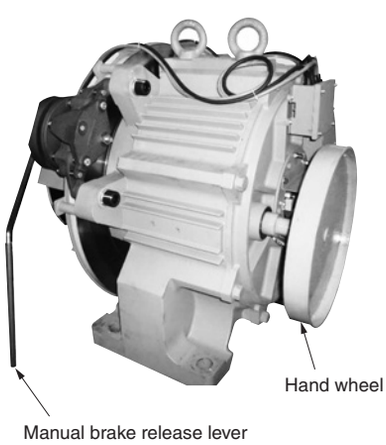

Fig. 3 Hand-Powered Emergency Operation System

The brake is manually released by means of a lever. A hand wheel is turned to take rescue actions.

Fig. 4 VT850H

Standard equipment of the VT850H Series is provided with the power regenerative converter function that contributes to energy saving.

Table 2 Major Specifications of PM6T and PM13T

The table below shows major specifications of our traction machines for high-speed elevators.

Type VT850H-□□□□			5100	5130	5160
Traction machine	Max. applicable motor (kW)		30	40	49
	Rated torque (%)		100	100	100
	Acceleration torque (%)		220	220	220
Equipment ratings	Max. continuous rated current (A)		100	130	160
	Max. accelerating current (A)		37	62	75
	Carrier frequency		8kHz for standard (Variable in 2～10kHz)		
	Duty cycle		60%ED		
	Starting frequency		240 times/hour		
	Operating time		12 hours/day 365 days/year		
Power source	Rated input voltage		380～440V±10%		
	Rated input frequency		50, 60Hz±5%		
Output	Rated output voltage		513V		
Control system	Input control system		Sinusoidal approximated PWM control		
	Output control system		Sinusoidal approximated PWM control		
Construction	Installation system		Wall-hung type		
	Cooling system		Forced-air cooled		
	Protective construction		IP20		
	Dimensions (mm) W × H × D	Converter	W650 × H600 × D250	W380 × H590 × D260	
		Inverter		W380 × H590 × D260	
	Approx. mass (kg)	Converter	45	27	
		Inverter		27	

3.2 Features

3.2.1 Safety and Reliability

In order to maintain safe elevator operation, the VT850H Series is provided with the control and protective functions related with elevator operation. The typical control and protective functions assured for the VT850H Series are as follows:

(1) Functions of brake control and operation supervision

Interlocked with inverter torque control, brake ON-OFF control is carried out. At the same time, supervision is carried out of brake operation and that of the brake ON-OFF status in relation to speed reference and feedback.

(2) Anti-rollback function

Even when the load sensor is not installed or not adjusted, this function prevents the elevator car from rollback. Thanks to this function, safety can be improved at the time of installation and adjustment of load sensors can be simplified.

(3) Overloading detection function

Each elevator is provided with a function of detecting overloading; however, there is no backup feature in the case of equipment error and problem of a cable disconnection. As a remedial feature, the VT850H is provided with a protective function that stops elevator operation based on the amount of overloading computed from the current value measured when the anti-rollback function is turned on.

(4) Safe Torque Off (STO) function

This function is intended to turn off the power supply of the inverter switching circuit upon reception of a command from external circuit. If there is an external failure, this STO function is used to cut off the inverter output assuredly.

(5) Rescue function

In the case of a service interruption, rescue operation is needed with the use of an emergency power supply such as the Uninterruptible Power System (UPS) or a battery bank. When an emergency power supply is used, regeneration of power cannot be performed. For the VT850H, standard equipment is provided with transistors to compose a discharge rheostat in order to prevent a DC overvoltage during rescue operation. In addition, auto-discrimination of light load direction is possible based on the current carried when the anti-rollback function is turned on. Based on the result of afore-mentioned discrimination, the direction of rescue operation can be determined so that power consumption in emergency power source can be reduced.

3.2.2 Energy Saving

Standard equipment of the VT850 Series is provided with a power regenerative converter that controls the approximated PWM current of the sine wave. We can effectively use regenerative energy with this function, though in the past, heat generation from resistors was wasted without using it. In addition, since the PWM control system is adopted, it is possible to restrain harmonic currents and

reduce the capacity of a power facility because we can secure a high power factor.

In order to reduce the standby power, there are provisions of functions such as converter ON-OFF function in standby mode or a cooling fan OFF function.

3.2.3 Fault Diagnostic Support

If there is any problem in the middle of elevator operation, a variety of information is needed to promptly identify the possible cause. In the VT850H Series, a traceback function is available in addition to conventional fault hysteresis recording. The traceback function is used to save various data automatically, such as output voltages, output currents, output frequencies, speed reference, speed feedback, etc., observed before and after the occurrence of a fault. This information is read out by an appropriative tool of a personal computer. As a result, analysis of conditions at the time of fault occurrence can be carried out with the use of a waveform display function.

3.2.4 Better Maintenance

An elevator can give rise to a serious problem when it stops due to a control unit malfunction. Therefore, it is absolutely indispensable to carry out maintenance and inspection of products so that faults cannot be caused as a result of deterioration. The VT850H Series is provided with a life assessment function that tells a guideline for the replacement of life-limited parts (main-circuit IGBT, AC fuse, cooling fan, etc.).

3.2.5 Convenient Feature

(1) Operation panel

The operation panel has a large screen that is capable of 5-line indications. A parameter setup system by means of ten-key is adopted to improve user interface. **Fig. 5** shows its external appearance.

(2) Operation mode with irregular power supply

During construction of a building, elevators may be used for materials transportation. In such a case, electric power is mostly fed from a temporary power source. The VT850H is provided with a mode where operation is possible at a voltage down to 3-phase 380V minus 30% or even at a single-phase of 220V. This feature is applicable to a temporary power source for building construction.

Fig. 5 Operation Panel

The operation panel is equipped with a large screen capable of 5-line indication plus a ten-key. The operationability has been improved.

3.2.6 Position Control Function

The position control function which is used in Meiden thin-type inverters (THYFREC VT800) for elevators has been expanded and installed as a unit for high-speed elevators. This position control function is made so that inverters can learn the floor position of an elevator cage or the position of a safety limit switch. The position control function is intended for the elevator's run control. By simply selecting an operation mode (normal run, inspection run, rescue run, etc.) from an upper controller through serial communication, speed control and creepless floor identification control are possible in the selected operation mode. When this function is used, it is unnecessary to use complicated programming for applications such as establishment of a speed pattern formerly undertaken by the upper controller.

4 Postscript

This paper introduced some features of Meiden traction machines PM5T and PM13T for high-speed elevators and the VT850H inverters. Since these products are provided with high quality and safety performance, we are expecting that they will play major roles as products for high-speed elevators whose market is anticipated to expand in the future. We will continue to pursue high quality and safety and develop our products in a manner timely to meet the requirements of our customers.