“FRENIC-RHC Series” High Power Factor PWM Converters with Power Regeneration Function

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ABSTRACT

Controlling a motor with a general-purpose inverter occasionally needs to suppress input current harmonics and to process motor braking energy. Fuji Electric has developed the “FRENIC-RHC Series” of high power factor PWM converters with power regeneration function as a line-up of products that offer better features and operability than conventional PWM converters. The series has the following features: Capable of controlling large capacity equipment through the extended number of parallel connections, up to four, without isolation transformers, standardized traceback function for analyzing the causes of alarms; highly detailed monitoring of the operating conditions of the upper layer system via high-speed E-SX bus communications.

1. Introduction

One of the main solutions to prevent variable-speed drive systems, such as a general-purpose inverters, from causing disturbance to other devices connected to the same system is to shape their input current waveform into a sine wave in compliance with the guidelines established by the Ministry of Economy, Trade and Industry. Meanwhile, regenerating energy back to the power supply can help save energy. In addition to these measures against harmonics, we have provided the market with the “RHC-C Series” pulse width modulation (PWM) converters with energy-saving measures taken.

We have newly developed the “FRENIC-RHC Series” PWM converters with the function and operability further improved from this existing PWM converter series. This paper describes the features and specifications of the FRENIC-RHC Series.

2. Features of “FRENIC-RHC Series”

Figure 1 shows the external appearance of the FRENIC-RHC Series. Table 1 shows the standard capacity line and standard specifications. The FRENIC-RHC Series, which maintains compatibility with conventional models, has features such as expansion of the number of connections in a multiple-unit parallel system, standard traceback function and support for high-speed communication bus “E-SX bus” and is capable of being applied in a wide-variety of factory automation (FA) systems.

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Fig.1 “FRENIC- RHC Series”

2.1 Capacity line-up enhancement and capacity expansion

The FRENIC-RHC Series has a standard capacity line-up of a total of 21 models including 6 models of 200 V/30 to 90 kW and 15 models of 400 V/45 to 630 kW. Explanation is omitted here but we also have the “FRENIC-eRHC Series compact PWM converters for smaller capacities 200 V/5.5 to 22 kW and 400 V/5.5 to 75 kW.

The FRENIC-RHC Series has two ratings MD*1 (CT*2) specification for medium overload and LD*3 (VT*4) specification for light overload, from which users can select according to load capacity. The MD (CT) specification, which has a 1-minute overload rating equal to 150% of continuous capacity, is mainly used for applications such as general industrial machines,

*1 MD: Medium overload (medium duty)
*2 CT: Low torque application (constant torque)
*3 LD: Light overload (low duty)
*4 VT: Square reduction torque application (variable torque)

Table 1 Standard capacity line and standard specifications

(a) Three-phase 200-V series

Item			Specification					
Type RHC□□□-2E□			30	37	45	55	75	90
MD (CT) specification	Applicable inverter capacity (kW)		30	37	45	55	75	90
	Output	Continuous capacity (kW)	36	44	53	65	88	103
		Overload rating	150% of continuous rating – 1 min					
		Voltage	320 to 355 V DC (Varies according to the input voltage)					
LD (VT) specification	Applicable inverter capacity (kW)		37	45	55	75	90	110
	Output	Continuous capacity (kW)	44	53	65	88	103	126
		Overload rating	120% of continuous rating – 1 min					
		Voltage	320 to 355 V DC (Varies according to the input voltage)					
Input power	Number of phases, voltage and frequency		3-phase, 3-wire type, 200 to 220 V, 50 Hz / 200 to 230 V, 60 Hz					
	Allowable fluctuation of voltage and frequency		Voltage: −15% to +10%, Frequency: −5% to +5%, Voltage phase unbalance rate: within 2%					

(b) Three-phase 400-V series

Item			Specification														
Type RHC□□□-4E□			45	55	75	90	110	132	160	200	220	280	315	355	400	500	630
MD (CT) specification	Applicable inverter capacity (kW)		45	55	75	90	110	132	160	200	220	280	315	355	400	500	630
	Output	Continuous capacity (kW)	53	65	88	103	126	150	182	227	247	314	353	400	448	560	705
		Overload rating	150% of continuous rating – 1 min														
		Voltage	640 to 710 V DC (Varies according to the input voltage)														
LD (VT) specification	Applicable inverter capacity (kW)		55	75	90	110	132	160	200	220	280	315	355	400	500	-	-
	Output	Continuous capacity (kW)	65	88	103	126	150	182	227	247	314	353	400	448	560	-	-
		Overload rating	120% of continuous rating – 1 min														
		Voltage	640 to 710 V DC (Varies according to the input voltage)														
Input power	Number of phases, voltage and frequency		3-phase, 3-wire type, 380 to 440 V, 50 Hz / 380 to 460 V, 60 Hz														
	Allowable fluctuation of voltage and frequency		Voltage: −15% to +10%, Frequency: −5% to +5%, Voltage phase unbalance rate: within 2%														

which have a constant torque load. Meanwhile, the main applications of the LD (VT) specification, which has a 1-minute overload rating equal to 120%, include fans, pumps, and other square reduction torque loads*5. The LD (VT) specification is economical because it allows use of PWM converters with a small capacity corresponding to the load capacity. In this way, we provide a rich capacity line-up, from which a PWM converter best suited for each application can be selected.

2.2 Capacity expansion by multiple connections

Applications exceeding 630 kW can be accommodated by connecting PWM converter units in parallel to increase capacity. With the control option card "OPC-RHCE-TBSI," high speed serial communication terminal block installed, all PWM converters in parallel system can be connected via a fiber optical cable. This allows converter's internal control to synchronize current of all converters connected; therefore a parallel system is achieved.

Parallel connection includes two methods depending on whether an input isolation transformer is used or not. In a transformerless system without an isolation transformer on the input side, the conventional RHC-C Series allowed up to three parallel connections. As shown in Fig. 2(a), the maximum number of parallel connections has been increased to four with the FRENIC-RHC Series. This has been achieved by improving the speed of serial communications via optical fiber from 1 Mbps to 2.5 Mbps. In a transformer-isolated parallel system with an isolation transformer provided on the input side, up to six parallel connections are allowed as shown in Fig. 2(b). With parallel connections like these, the 400-V MD specification

*5 Square reduction torque load: A load in which the load torque varies in proportion to the square of the rotational speed

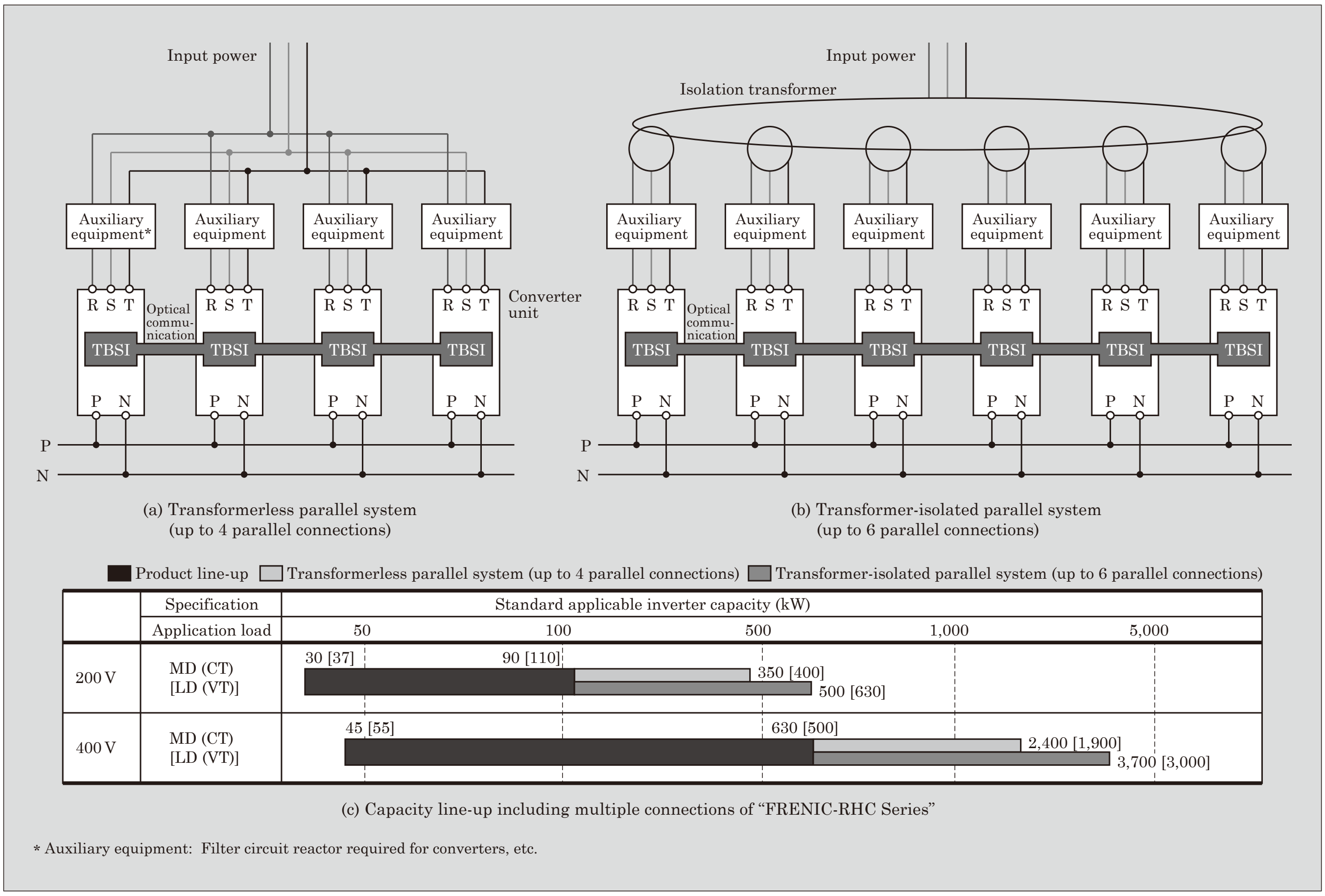

Fig.2 "FRENIC- RHC Series" parallel connection configuration

allows the capacity to be expanded to 2,400 kW for transformerless parallel systems and to 3,700 kW for transformer-isolated parallel systems, which is shown in Fig. 2(c).

2.3 Traceback function

The traceback function provided in the high-performance vector controlled inverter "FRENIC-VG Series" has been added to the FRENIC-RHC series as a standard feature. The function records the internal data and the date and time of the PWM converter immediately before and after the occurrence of an alarm and uses the battery to make a backup. The input voltage and current can be measured in a minimum sampling period of 62.5 µs. As shown in Fig. 3, these can be shown as time series waveform data on the PC screen by using PWM converter support software "FRENIC-RHC Loader" (downloadable for free from Fuji Electric website*6), which facilitates analysis of alarm generating factors.

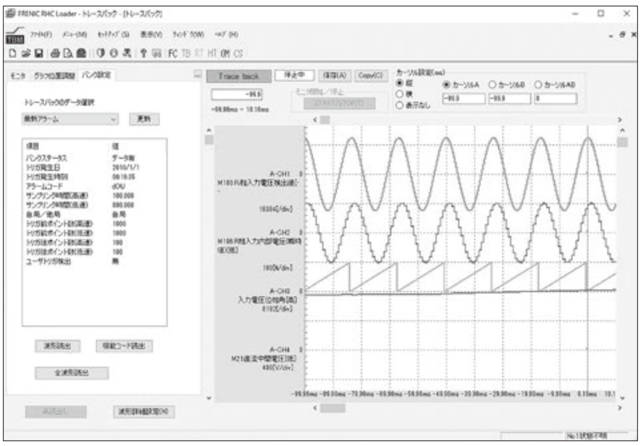

Fig.3 Traceback screen provided by "FRENIC-RHC Loader"

2.4 Control options

Table 2(a) lists the control options including communication options supported by the FRENIC-RHC Series and Table 2(b) restrictions on control option installation.

High-speed, large-capacity E-SX bus communications, which is already supported by the FRENIC-VG Series in Table 2, is supported by the FRENIC-RHC Series as well. With the conventional SX bus, the maximum number of data that can be transmitted and received in a minimum period of 500 µs was 16 words. The E-SX bus is capable of transmitting and receiving

*6 "FRENIC-RHC Loader" free download link on Fuji Electric website
https://felib.fujielectric.co.jp/download/index.htm?site=global&lang=en

Table 2 Control options

(a) Control option list

Category	Name	Type	Specification
Analog card (for A port only)	AIO extension card	OPC-VG1-AIO	AO 2-points extension card
Analog card (for B port only)	AC fuse blown detection card	OPC-RHCE-ACF	Card for detecting AC fuse blown
Digital card (for A or B port only)	DIO extension card	OPC-VG1-DIO	When DIOA is set: DO 8-points extension card
	T-Link interface card	OPC-VG1-TL	T Link interface card
	CC-Link interface card	OPC-VG1-CCL	CC-Link interface card
Digital card (for D port only)	SX bus interface card	OPC-VG1-SX	SX bus interface card
	E-SX bus interface card	OPC-VG1-ESX	E-SX bus interface card
Control circuit terminal (for F port only)	High-speed serial communication supported terminal board	OPC-RHCE-TBSI-□	Used for parallel systems Type dependent on voltage series

(b) Restrictions on mounting control options

OK: Can be mounted together, NG: Cannot be mounted together

OPC-□□□-□□□□	AIO	ACF	DIO	TL	CCL	SX	ESX	TBSI
VG1-AIO	NG	–	–	–	–	–	–	–
RHCE-ACF	OK	NG	–	–	–	–	–	–
VG1-DIO	OK	OK	NG	–	–	–	–	–
VG1-TL	OK	OK	OK	NG	–	–	–	–
VG1-CCL	OK	OK	OK	NG	NG	–	–	–
VG1-SX	OK	OK	OK	OK	NG	NG	–	–
VG1-ESX	OK	OK	OK	NG	NG	NG	NG	–
RHCE-TBSI-□	OK	OK	OK	OK	OK	OK	OK	NG

up to 32 words of data in a minimum period of 250 μs, which has allowed detailed operation status of the FRENIC-RHC Series to be monitored on the host side.

3. Operation Characteristics

3.1 Input current and harmonic characteristics

Figure 4 shows the PWM converter input current and phase voltage waveforms for driving and braking with 400-V, 315-kW FRENIC-RHC (type: RHC315-4E) at a load factor of 150%. They show a sine wave. During driving, a current was controlled having the same phase as the voltage and the power factor being to 1.

Figure 5 shows the content rate of the input harmonic current of the PWM converter when driving this model at a load factor of 100%. The measurement has been made for up to the 50th order and the harmonic content for each order is shown with the fundamental wave component (1st order: 60 Hz) as 100%. The second-order component show the highest content at 1.04% and the total harmonic distortion factor *THD**[7] is 1.85%.

With general inverters that perform three-phase full-wave rectification without any measures taken against harmonics, the harmonic content of the seventh-order component is approximately 40%, which indicates that the employment of the PWM converter significantly reduces harmonic current.

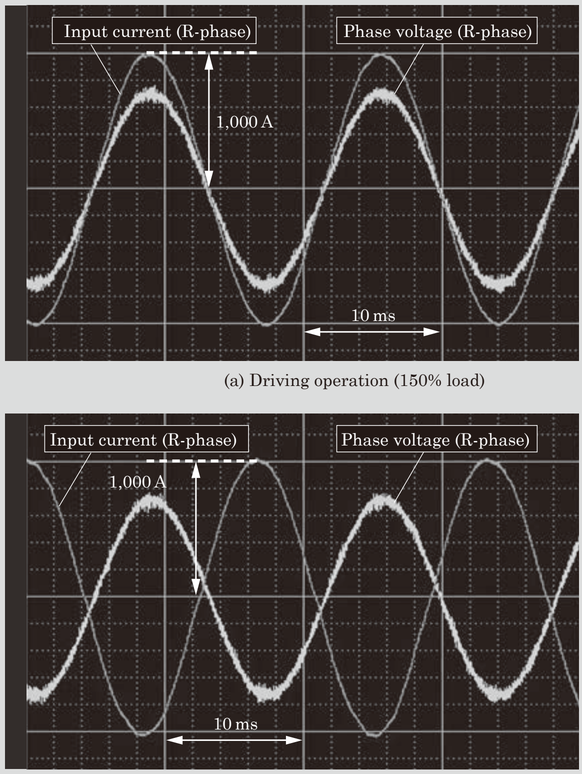

Fig.4 "FRENIC-RHC" (RHC315-4E) input current and phase voltage waveforms

*7 $THD = \frac{\sqrt{(\Sigma I_n^2)}}{I_1} \times 100$

I_1: Fundamental wave current

I_n: nth-order harmonic current

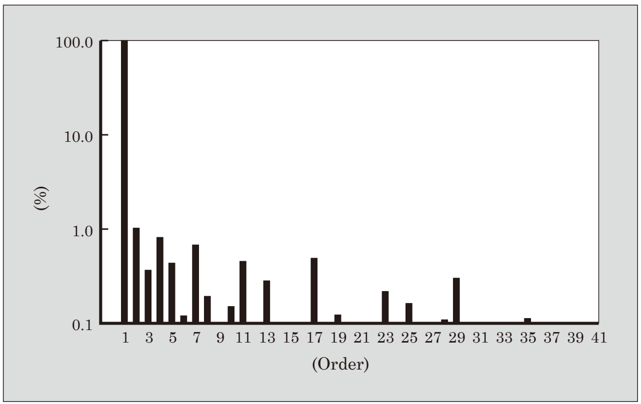

Fig.5 “FRENIC-RHC” (RHC315-4E) input current harmonic characteristics

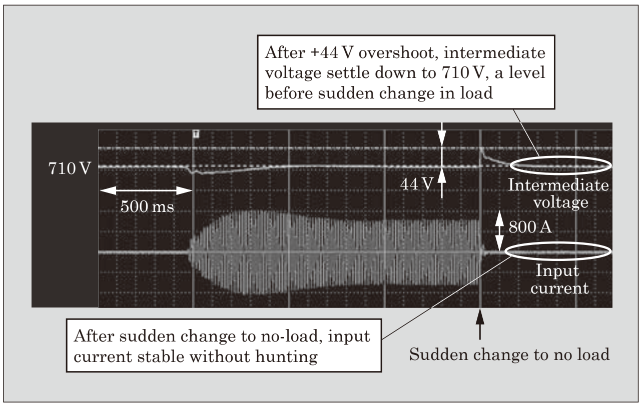

Fig.6 “FRENIC-RHC” (RHC315-4E) impact load characteristics

3.2 Impact load characteristics

Figure 6 shows the impact load characteristics with the load suddenly changed in this model RHC315-4E. The overshoot of DC bus voltage when the load is instantaneously reduced from 100% to 0% is controlled lower than 44 V, which means there is still enough margin to overvoltage level. This guarantees the stable operation of the equipment.

3.3 Operation characteristics of transformerless parallel system

Figure 7 shows input current waveforms in a transformerless parallel system operated with four parallel connections. As the PWM converters, four units of 400-V, 75-kW RHC75-4E were connected and driven with a load factor of 100% for each PWM converter.

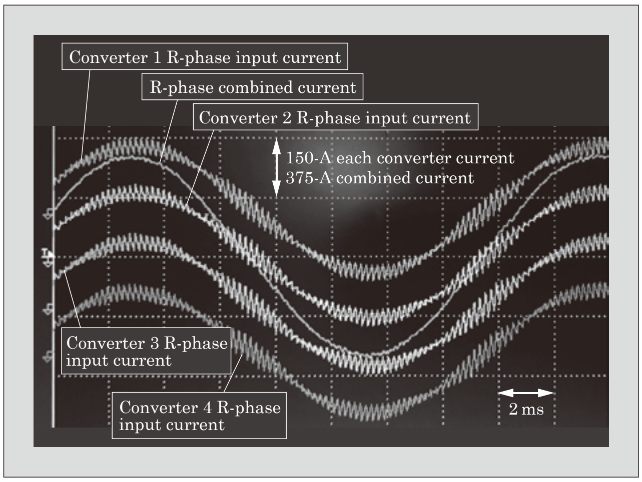

Fig.7 “FRENIC-RHC” (RHC75-4E) transformerless parallel system (four parallel connections) input current waveforms

The figure shows the waveforms of the R-phase input current and the combined current of the four PWM converters. The R-phase current waveform of each converter is sinusoidal and the peak value and phase of the individual waves coincide with each other, indicating that the current control of the parallel system is operating correctly. The *THD* of the combined current here is 2.31%, showing good harmonic characteristics.

4. Postscript

This paper has described the “FRENIC-RHC Series” high power factor PWM converters with a power regeneration function. In the future, we will promote the development of a stack type and compliance with standards for industrial plants and harbor cranes, which require a large number of inverters. We have made the FRENIC-RHC Series applicable to a wide range of fields by expanding capacities through the improved capacity line-up and use of parallel systems, enhancing functions and providing support for E-SX bus communication, which features high speed and large capacity. We will further strive for product development to make PWM converters capable not only of providing measures against harmonics when an inverter is applied or used for applications such as power regeneration but also of meeting new market demands as a system combined with an inverter.

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