

Next-Generation Compact and High-Performance Inverter “FREQROL – E800 Series”

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1. Introduction

The FR-E800 series with higher functionality and performance satisfies new needs such as compatibility with the IoT, easier maintenance, functional safety, compatibility with systems, and environmental adaptability in order to increase the application of general-purpose inverters.⁽¹⁾ This paper describes the latest technologies and functions of the FR-E800 series.

2. FR-E800 Series

2.1 Models

Several FR-E800 series models with various specifications are available: standard specification,

Ethernet specification, and safety communication specification. Customers can select suitable ones flexibly based on the purpose of use (Table 1).

2.2 Increase in the number of product types

The capacity of three-phase 200-V/400-V classes was increased to 22 kW (that of the existing FR-E700 series is 15 kW at maximum). Compared to the FR-A800 series having the same capacity, the size was reduced by 20%, saving the space occupied by the devices. In addition, a 575-V class was added to improve the compatibility with systems for overseas power supply specifications (Table 2).

Table 1 Models and main specifications of the FR-E800 series

Model	Specification	Communication connector	Safety integrity level	Safety communication
FR-E800	Standard specification	RS485	SIL2, PLd	-
FR-E800-E	Ethernet specification	Ethernet (two ports)	SIL2, PLd	-
FR-E800-SCE	Safety communication specification (Ethernet + Safety communication)		SIL3, PLe	Supported

Table 2 Voltage class and rated capacity range of FR-E800 series

Power supply specification	Voltage class	Capacity [kW]
Three-phase	200 V	0.1–22
	400 V	0.4–22
	575 V	0.75–7.5
Single-phase	200 V	0.1–2.2
	100 V (sale planned)	0.1–0.75

3. The IoT Era

3.1 Provision of CC-Link IE TSN as a standard feature

The FR-E800 series comes with CC-Link IE Time Sensitive Networking (TSN) as a standard feature. High-speed, stable communications allow production site data to be collected in real time, contributing to higher productivity.

3.2 Support for multiple protocols

Some FR-E800 series models support the main industrial Ethernet protocols (Table 3). The protocol to be used can be switched by parameter setting, enabling inverters to be introduced as needed for networks in use without additional options.

3.3 Provision of two Ethernet ports as a standard feature

The new series has two Ethernet ports as a standard feature, enabling line wiring without switching hubs. When the specification is changed such as adding a device, it is possible to easily establish a network simply by connecting a cable to an available port.

4. Maintenance Functions

4.1 AI fault diagnosis

The FR-E800 series automatically stores data (e.g., time, current value, and parameter setting values) when an alarm is issued. An engineering tool, FR Configurator2, employing AI technologies can be used to perform AI analysis of such data like development engineers do (Fig. 1). This enables rapid troubleshooting without special skills.

Table 3 Supported Ethernet protocols

Model	CC-Link IE TSN (100Mbps)*1	CC-Link IE Field Network Basic*2	MODBUS /TCP*3	PROFINET*4	EtherNet/IP*5	BACnet/IP*6	EtherCAT*7
FR-E800-[]EPA	●	●	●	-	●	●	-
FR-E800-[]EPB	●	●	●	●	-	-	-
FR-E800-[]EPC	-	-	-	-	-	-	○

●: Supported, ○: To be supported in the future

¹ 1 Gbps will be supported in the future as an option.

² "CC-Link IE Field Network Basic" is a registered trademark of the CC-Link Partner Association.

³ "MODBUS" is a registered trademark of Schneider Automation Inc.

⁴ "PROFINET" is a trademark or registered trademark of PROFIBUS & PROFINET International.

⁵ "EtherNet/IP" is a registered trademark of Open DeviceNet Vendor Association, Inc. (ODVA).

⁶ "BACnet" is a registered trademark of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

⁷ "EtherCAT" is a trademark of Beckhoff Automation GmbH.

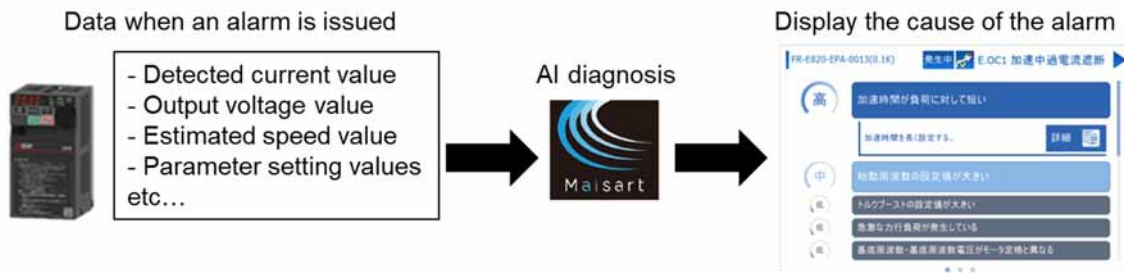


Fig. 1 Overview of AI fault diagnosis

4.2 Corrosion-Attack-Level Alert System (CALAS)

The world's first¹ Corrosion-Attack-Level Alert System (CALAS) can detect signs of damage to inverters caused by corrosive gas (Fig. 2). The system measures the combined resistance value from multiple metal corrosion sensors and senses the degree of corrosion of metal parts due to corrosive gas in the air in stages.

Through such detection of signs of damage, users are encouraged to improve the environment of the production equipment, which helps reduce equipment downtime (provided only on products having coated boards).

4.3 Power cycle life diagnosis

The technology used to estimate the temperature of semiconductor chips installed on inverter modules has been improved, making it possible to understand the difference in temperature between heating and cooling with high accuracy. This enables power cycle life diagnosis of modules (Fig. 3). If the life falls below the specified value, a warning signal is output, contributing to predictive maintenance of equipment and more stable operation.

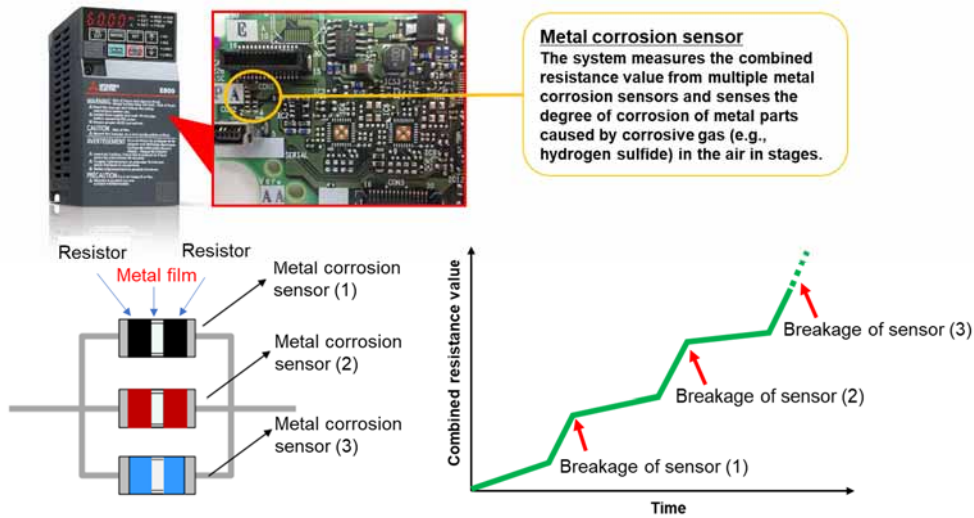


Fig. 2 Overview of Corrosion-Attack-Level Alert System

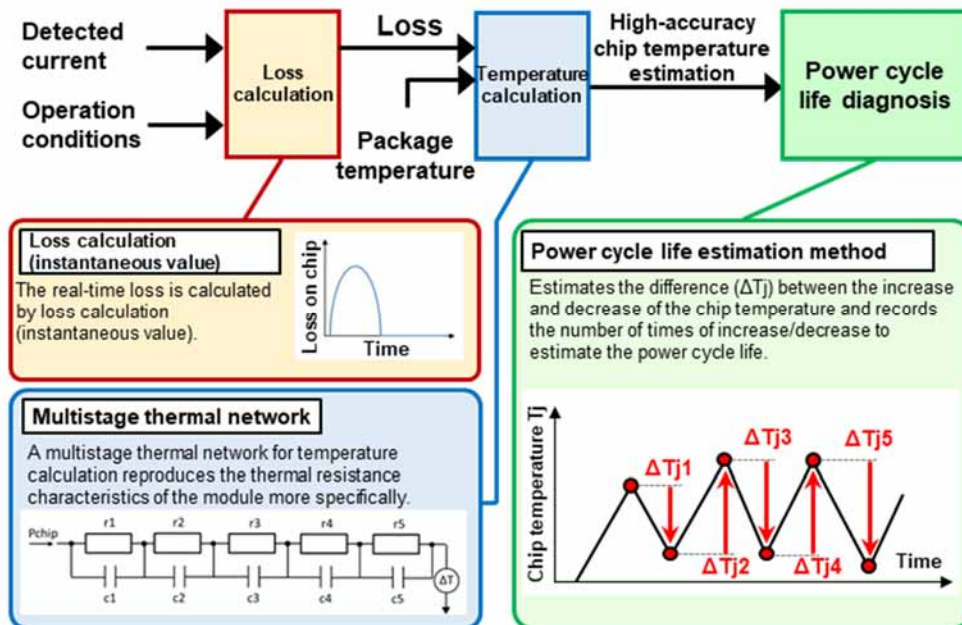


Fig. 3 Power cycle life diagnosis

¹ As of September 10, 2019, researched by Mitsubishi Electric Corporation

4.4 Maintenance through power supply from USB

Through power supply from a PC (USB bus powered), even when the main circuit is off, FR Configurator2 can be used to set parameters (Fig. 4), enabling quick and safe maintenance.

5. Functional Safety

5.1 Compliance with functional safety standards

The FR-E800 series satisfies functional safety standards (e.g., IEC61508 and SIL3) (Table 4), thus reducing the cost of introducing safety certifications. The series supports safety monitoring function standards (IEC61800-5-2), such as safe torque off (STO) and safely limited speed (SLS), contributing to reducing the number of external devices and maintenance time.

5.2 Safety communication functions

The FR-E800-SCE supports Ethernet-based safety

communication functions approved by international standards (Table 5). Safety signals can be input via networks, which can reduce the number of wires and I/O devices.

The FR-E800-SCE supports the CC-Link IE TSN safety communication function and many other safety communication protocols, which makes it easier to expand safety control systems that match the networks in use.

5.3 SLS function without encoders

The FR-E800-SCE employs a speed monitoring circuit that has been certified by functional safety standards and thereby supports the safely limited speed (SLS) function without encoders (Fig. 5). By eliminating the need for encoders, speed monitoring systems can be established with less wiring at lower cost.



Fig. 4 Power supply from USB port

Table 4 Safety standards compliance of the FR-E800 series

Model	Safety monitoring function	Safety integrity level
FR-E800 FR-E800-E	STO	SIL2, Cat.3, PLd
FR-E800-SCE	STO, SS1, SBC, SLS, SSM	SIL3, Cat.3, PLe

Table 5 Supported safety communication functions

Model	CC-Link IE TSN safety communication function	PROFIsafe*1	CIP Safety*2	FSoE (Safety over EtherCAT) *3
FR-E800-[]SCEPA	●	-	●	-
FR-E800-[]SCEPB	●	●	-	-
FR-E800-[]SCEPC	-	-	-	○

●: Supported, ○: To be supported in the future

*1 "PROFIsafe" is a registered trademark of Siemens Aktiengesellschaft.

*2 "CIP safety" is a registered trademark of ODVA.

*3 "Safety over EtherCAT" is a registered trademark of Beckhoff Automation GmbH.

6. Compatibility with Systems

6.1 Provision of two ratings (light duty and normal duty)

Thanks to improvements in the thermal design technologies, the models with the three-phase power input specification provide two ratings: light duty (LD) and normal duty (ND), for which the rated current and overcurrent capability vary (Table 6).

In an application in which no overload is required, smaller inverters can be selected based on the LD rating (for example, a 22-kW inverter can drive up to a 30-kW motor at the LD rating).

The rating can be switched simply by a parameter setting, which is useful when equipment specifications change, and also enables stock to be shared.

6.2 Model with highly protective structure (IP67) installable on outside panels

We are planning to add a new model with a highly protective structure (IP67) to our lineup, which can be used in severe environments (humid or dusty environments). The new model of inverter contains built-in peripheral devices (e.g., disconnect switch, electromagnetic compatibility (EMC) filter (class C2),

and communication options) and so can be installed outside a panel. This reduces the number of wires by systematic distribution of lines, saves space, and ensures safe communications for systems.

6.3 Excellent drive performance

For the first time in our compact inverters, the FR-E800 series supports vector control (vector control with encoders) and real sensorless vector control (vector control without encoders) (Tables 7 and 8). The series also supports premium efficiency motors and PM motors, and can be used in drive operations involving various solutions. In addition, the series supports high-speed operation for machining tools where precise machining (e.g., mirror planes) is required.

7. Environmental Adaptability

7.1 Model having coated boards (conforming to 3C2)

For use in corrosive environments, we have added a standard model having coated boards that conforms to environmental standards (IEC60721-3-3 3C2) to our lineup.

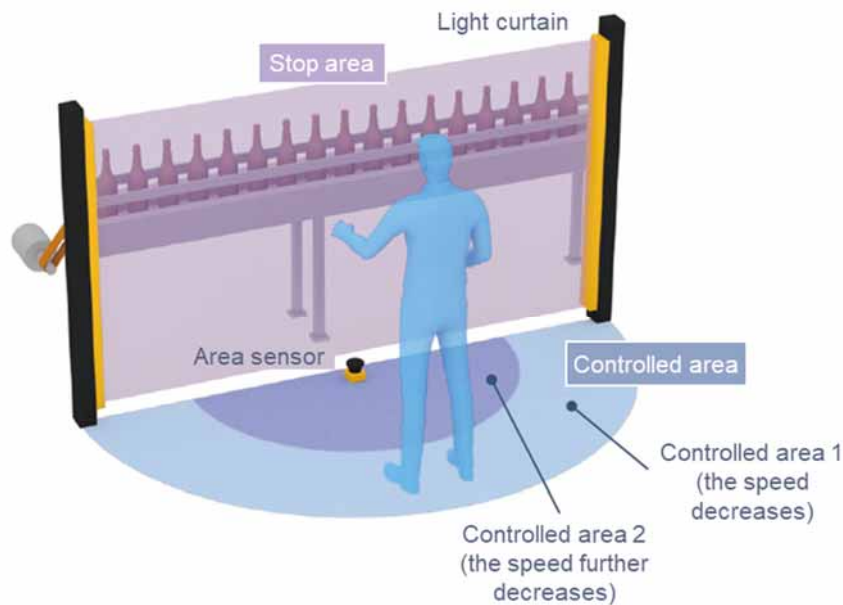


Fig. 5 Example of application of SLS function

Table 6 Multiple rating specification

Load	Rating	Rated overload current
Light load	LD	120% 60 s, 150% 3 s (inverse-time characteristic) Ambient temperature: 50°C
Normal load	ND	150% 60 s, 200% 3 s (inverse-time characteristic) Ambient temperature: 50°C

Table 7 Performance specifications of the FR-E800 series

Item		FR-E700	FR-E800
Control methods	V/F control	●	●
	Advanced magnetic flux vector control	●	●
	Real sensorless vector control	-	●
	Vector control	-	●
	PM sensorless vector control	-	●
Control modes	Speed control	●	●
	Torque control	-	●
	Position control	-	●
Output frequency	V/F control	0.2–400 Hz	0.2–590 Hz
	Other than V/F control		0.2–400 Hz

●: Supported, -: not supported

Table 8 Vector control specifications of the FR-E800 series

Item	Description	
Speed control	Speed control range	1:1500 (for both powering and regeneration) ^{*1}
	Speed variation	±0.01% (at 300 r/min)
	Velocity response	30 Hz
	Maximum speed	400 Hz (However, the number of PLG pulses is 102,400 pulses/s or smaller.)
Torque control	Torque control range	1:50
	Absolute torque accuracy	±10% ^{*2}
	Repeat torque accuracy	±5% ^{*2}
Position control	Repeat positioning accuracy	±1.5° (motor shaft end)
	Positioning feedback pulse	The number of PLG pulses per rotation of motor (Pr.369) × 4 multiplication
	Electronic gear setting	1/900–900
	Positioning completion width	0–32767 pulses
	Excessive error	0–400K pulses

PLG: PuLse Generator

¹ For regeneration, an optional regeneration unit is required.

² At the rated load of a vector control motor

7.2 Usable up to 3,000 meters above sea level

The insulation distance design conforming to IEC61800-5-1 (overvoltage category III) allows the FR-E800 series to be installed up to 3,000 meters above sea level² (the FR-E700 series can be used up to 1,000 meters).

7.3 Expansion of the ambient temperature range (-20 to +60°C)

Thanks to improvements in the controlled power source and thermal design technologies, the adaptable ambient temperature range was expanded to -20 to +60°C³, allowing the FR-E800 series to be used in more diverse environments than existing models (the FR-E700 series can be used at -10 to +50°C).

² The three-phase 575-V class can be installed up to 2,000 meters above sea level. When installing the products more than 1,000 meters above sea level, the current needs to be reduced.

8. Conclusion

This paper described the latest technologies applied to the next-generation compact high-functionality inverter FR-E800 series and the specifications. We will continue developing products with higher functionality and added value.

References

- (1) Tetsuo T., et al.: Next-Generation High Performance Inverter "FREQROL-A800 Series," Mitsubishi Denki Giho, 88, No.4, 245–248 (2014)

³ The three-phase 575-V class can be used at -10 to +60°C. When the ambient temperature is 50°C or higher, the current needs to be reduced.