Medium-Capacity Uninterruptible Power Systems with Improved Replaceability and Stable Operation

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ABSTRACT

The need to continue to supply electricity even in a power outage or power supply malfunction has been increasing the demand for medium-capacity uninterruptible power systems (UPSs) in factories and broadcasting facilities. The product line of medium-capacity UPSs need to include varied types to meet the specifications of individual load equipment. Also required are flexibly meeting the need for equipment replacement and predictive maintenance for stable operation. Fuji Electric has newly developed its "FX Series" medium-capacity UPSs to meet various needs for replacement by reducing their footprint and expanding the range of the battery voltage. A component failure diagnosis with abnormality symptom detection functions has allowed degraded parts to be replaced before failure, improving operational stability.

1. Introduction

Many factories, broadcasting facilities and communication facilities are often configured with 200-V equipment with medium power consumption (10 to 100 kVA). These facilities have small-scale power supply systems of various capacities, and the demand for uninterruptible power systems (UPSs) has been increasing to supply electricity continuously even during a power outage or power supply malfunction.

Fuji Electric has newly developed the "FX Series" medium-capacity UPS. While maintaining the specifications same as those of existing products, we have minimized the footprint, expanded the applicable battery voltage range to meet the need for replacement flexibly. It is equipped with Fuji Electric's unique abnormal sign detection to diagnose component failure. This paper describes this medium-capacity uninterruptible power system that features enhanced replacement support and stable operation.

2. Conventional Medium-Capacity UPSs

2.1 Overview

The UPS supplies stable power with a constant voltage and constant frequency to load equipment using energy stored in batteries even in the event of power failure, such as voltage fluctuation or power outage.

Figure 1 shows current and voltage waveform data during power failure and recovery. Even when a power outage occurs and the input voltage is interrupted, a continuous stable voltage is supplied. In addition, the output voltage fluctuation is less than 2% during power outages and recovery of power, and inrush current generation due to voltage variance is suppressed, thus enabling stable system operation without affecting the load equipment.

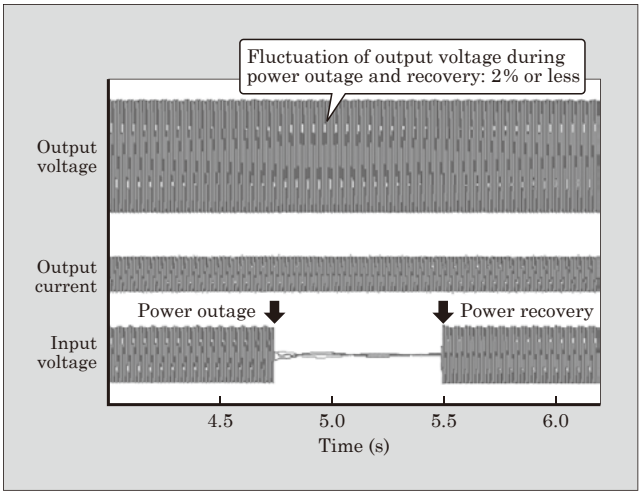

Fig.1 Waveform data of current and voltages in power outage and power recovery

2.2 Product line-up

Table 1 shows the product line-up of Fuji Electric's 200-V UPSs (conventional products) To meet a wide

Table 1 Product line-up of Fuji Electric's 200-V UPSs (conventional products)

Series	Insulation system	Number of phases	Voltage (V)	Capacity (kVA)
UPS6000D-1	Insulated	Single-phase	200/100	10 to 100
UPS6100D-3		Three-phase	200	
UPS7100MX-3	Non-insulated			

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variety of customer specifications, we offered three series of products: the "UPS6000D-1," "UPS6100D-3" and "UPS7100MX-3." They are available in insulated or non-insulated types, three-phase or single-phase types, and capacities ranging from 10 to 100 kVA.

2.3 Issues with conventional models

(1) Size reduction

The installation area varied from model to model, and it was difficult to respond flexibly to replacement. The size also needed to be further reduced to meet the requirement of customers with footprint constraints.

(2) Expansion of applicable battery voltage range

Medium-capacity UPSs are mainly configured to combine battery panels, but the battery voltage of conventional products was only 360 V (180 cells) or 384 V (192 cells). As a result, it was not always possible to satisfy customers who intend to replace only a UPS and leave a battery panel without replacing it.

(3) Power factor correction

Although a rated load power factor of 0.8 has been the norm for conventional medium-capacity UPSs, an increasing number of facilities are now requiring an input power factor of 0.9. To meet the needs of such customers who require more power, UPSs with a capacity of one rank higher were conventionally selected, but in some cases, they were unable to meet the customer's requirements in terms of cost and size.

(4) Shortened installation period

Conventional UPS panels and input and output panels were transported separately, and wiring work was performed locally, causing prolonged installation periods.

(5) Improved maintainability

We provide 24-hour maintenance system for medium-capacity UPS to ensure the continuity of power supply. In addition to this meticulous maintenance service system, it was necessary to further improve the stable operation of UPSs by applying new technologies to improve maintainability, such as component failure diagnosis using an abnormal sign detection function.

3. "FX Series" Medium-Capacity UPSs

3.1 Overview

The specification range of the conventional products have been maintained and integrated into the newly developed FX Series of medium-capacity UPS. Table 2 shows the product line-up of the FX Series. While expanding the series, we plan to adopt a platform design and ultimately reduce the overall series' external dimensions to two types. Furthermore, the standardization of parts makes it easier to replace parts in the event of failure, improving maintainability compared to conventional products.

Figure 2 shows the appearance of the newly developed "UPS6600FX" (insulated, three-phase, 200-V type 50-kVA model), and Table 3 shows the specifications.

Table 2 Product lineup of the "FX Series"

Series	Insulation system	Number of phases	Voltage (V)	Capacity (kVA)
UPS6600FX	Insulated	Single-phase	200/100	10 to 100
UPS7600FX	Non-insulated	Three-phase	200	

Fig.2 "UPS6600FX" (insulated, three-phase, 200-V type 50-kVA model)

Table 3 Specifications of the "UPS6600FX" (insulated, three-phase, 200-V type 50-kVA model)

Item		Performance and specifications
UPS system		Normal inverter feeding
Rated output capacity		50 kVA
AC input	Number of phases (Number of lines)	Three-phase, three-line
	Voltage	200/210 V ± 15% (220 V is available as an option)
	Frequency	50/60 Hz ± 5%
	Power factor	0.98 or more
	Current harmonic distortion rate	5% or less
AC output	Number of phases (Number of lines)	Three-phase, three-line
	Voltage	200/210 V ± 1% (220 V is available as an option)
	Load power factor	0.9 (delay)
	Transient voltage fluctuation	5% or less (load 0 ⇔ 100%)
	Output voltage distortion factor	2% or less (linear load) 5% or less (rectifier load)
	External synchronization frequency range	±5% or less
	Overload capability	125%: 10 min 150%: 1 min

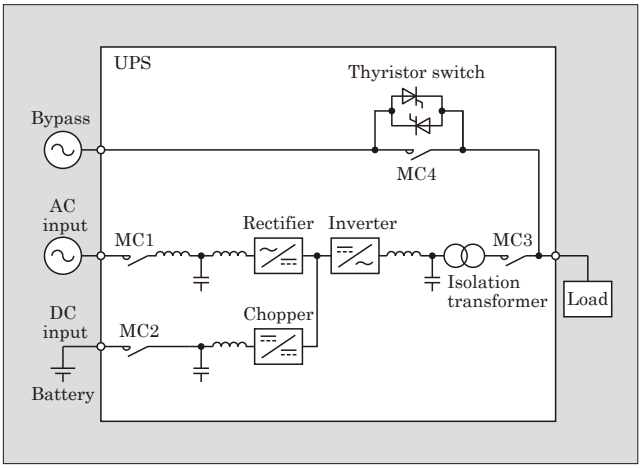

Fig.3 Main circuit block diagram of the "FX Series"

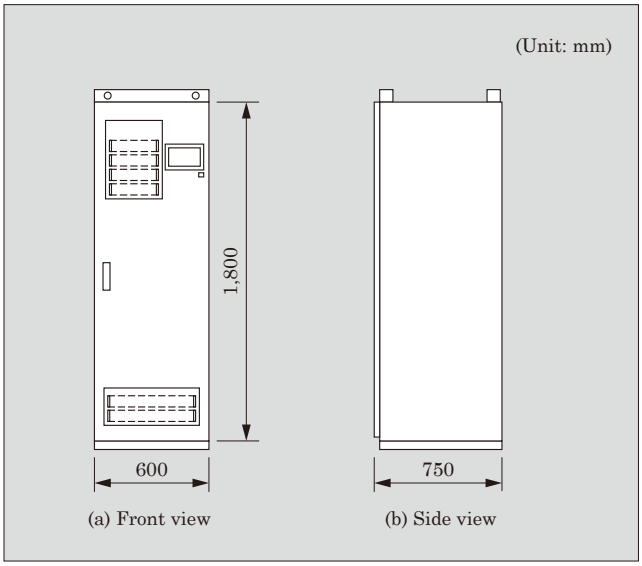

Fig.4 Outer view of "UPS6600FX" (insulated, three-phase, 200-V type 50-kVA model)

3.2 Operation

Figure 3 shows the main circuit block diagram of the FX Series. This series uses a normal inverter feeding system consisting of a rectifier, which converts AC to DC, and an inverter, which converts DC to AC. A chopper is also connected to the DC input to perform charge and discharge control of the battery.

In the normal operating state, in which the AC input is within the normal range, the inverter supplies stable power with a constant voltage and constant frequency to loads. The rectifier controls the AC input current of the UPS to be a sine wave with a power factor of approximately 1, while the chopper charges the storage battery. If the AC input is cut off, the chopper raises the voltage of the battery to an appropriate DC voltage, and the inverter then converts the DC into stable AC power and supplies it.

In addition to the above mentioned operations, the chopper also control battery discharge when power is supplied to a load from both the AC input and the battery, such as during overload, input voltage drops, and power walk-ins, in which power supply is gradually switched from the battery to the grid during power recovery.

When the inverter is unable to supply power due to failure, it switches the power supply from the inverter to the bypass.

3.3 Features

(1) Size reduction

We optimized component selection, component placement, and cooling structure while taking into account the diverse product groups that comprise the FX Series. As a result, compared with the previous product model with the largest footprint, the width was reduced from 700 mm to 600 mm, and the footprint was reduced by 14%. Figure 4 shows the outer view of the UPS6600FX (insulated, three-phase, 200-V type 50-kVA model).

(2) Expansion of applicable battery voltage range

The FX Series is equipped with a chopper to control the DC voltage, enabling it to handle battery voltages from 288 to 384 V (144 to 192 cells).

As a result, the battery panels for the combination of UPSs now can be used for products of other manufacturers other than Fuji Electric. It is now possible to select an optimum battery voltage suited to the UPS output capacity.

(3) Measures to improve the rated load power factor to 0.9

Improving the output performance of UPSs to increase power factor will increase the amount of heat generated by the equipment, requiring larger cooling structures. The FX Series has improved cooling performance by increasing the efficiency of the cooling structure. It is thereby the first in the industry to achieve a rated load power factor of 0.9 as a medium-capacity UPS without increasing the external dimensions.

(4) Shortened installation period

The UPS panel for the UPS6600FX products of 50 kVA or less is designed to combine the input and output panel to be wired between them in advance, allowing the panels to be integrated and transported. Thanks to this, on-site wiring work between panels is no longer necessary, and the installation period has been shortened.

(5) Maintainability improvement technologies

(a) Component failure diagnosis with abnormality symptom detection functions

The FX Series is equipped with component failure diagnosis (patent pending) based on Fuji Electric's unique abnormal sign detection function, which performs numerical analysis-based presumption of component performance degradation and the location of the failure that has caused shutdown.

The function uses multivariate analysis technology to analyze the amplitude and derivative values

(time variation) of UPS current and voltage waveforms to calculate estimated degradation values, which are indicators of the degree of degradation. Those values and the deviation from the threshold values are used to diagnose component degradation and predict replacement timing.

Figure 5 shows an example of the deterioration estimate obtained by the multivariate analysis from the waveforms of the output voltage and current and related data obtained when the cutoff frequency of the output filter is increased in a simulated manner to reproduce the state of the filter performance deteriorated. As the performance of the output filter degrades, the output waveform distortion increases due to leakage of UPS switching ripple into the output power and output current, but there is no apparent noticeable change in the output voltage or output current waveforms in Fig. 5. However, the deterioration estimate changes according to the performance deterioration of the output filter.

Figure 6 shows an overview of the value analysis. This analysis analyzes the voltage and current waveforms detected in the control system in real time to detect abnormalities on the basis of the calculated deterioration estimate. These data are saved in the memory in the control system.

During periodic maintenance, maintenance service personnel obtain the stored deterioration estimates and compare how much these deviate from the values at the time of delivery to determine the current deterioration status of the components and predict when they should be replaced. Figure 7 shows a conceptual diagram of replacement timing prediction using degradation estimates. By finding deteriorated parts before a failure and replacing them, failures can be prevented from occurring.

In the event of a UPS failure or other malfunction, maintenance service personnel can retrieve data from the target model on-site and rapidly presume the part that needs to be replaced. This presumption result facilitates the reduction of time for replacing parts in restoration work (see Fig. 8).

(b) Use of a wide color liquid crystal touch panel

The FX Series is equipped with a 7-inch wide color liquid crystal touch panel larger than the con-

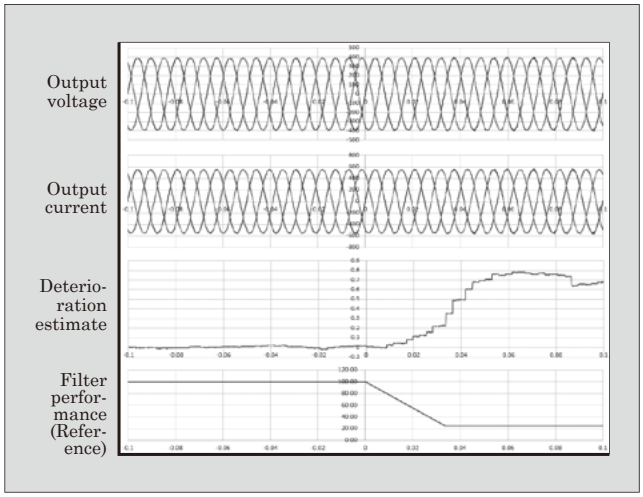

Fig.5 Operation waveform and deterioration estimate at time of output filter deterioration

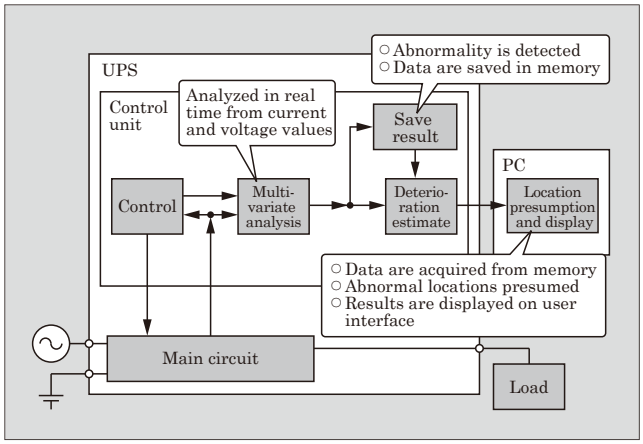

Fig.6 Overview of value analysis

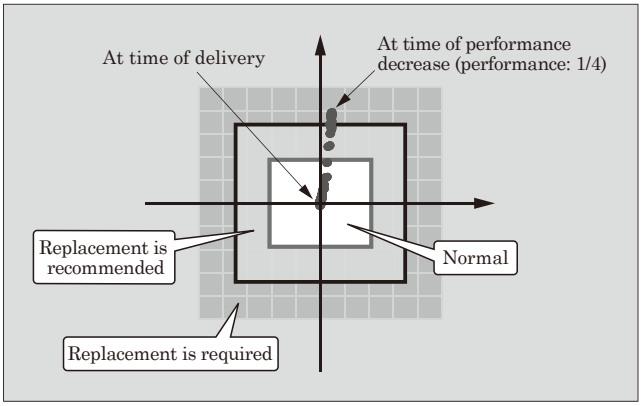

Fig.7 Conceptual diagram of replacement timing prediction using deterioration estimate

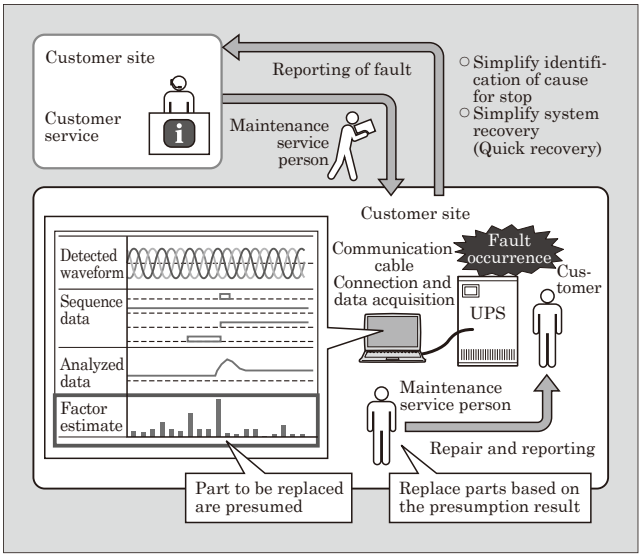

Fig.8 Response at time of failure occurrence

ventional product on its front panel. The operation screen with a simple, sophisticated design displays operating state, failure history and operation guidance to improve maintainability.

(c) Network connection and operating state monitoring

As a standard feature, the FX Series is equipped with a communication card compliant with the Modbus*1 specifications, which are widely used as a connection method for industrial equipment. By connecting to a customer facility network using Modbus, the FX Series can be constantly monitored (operating state monitoring and failure information notification) on the network.

Furthermore, adding the Web/SNMP communication card on the UPS to connect the network, users can monitor the operating state from a standard web browser and receive failure information by email.

The operating state of the UPS can be monitored, such as output power trends, operation history, and failure history through dedicated monitoring software.

3.4 Efforts for quality improvement in development design

The development phase of the FX Series evaluated software with a simulator (HILS: Hardware-in-the-Loop Simulator). Figure 9 shows an illustrative diagram of the evaluation system. We used the system to find and correct bugs and errors, ensuring stable operation of the product.

Furthermore, by simulating the behavior of equipment under input and load conditions that are difficult to achieve in actual equipment verification, we detected and corrected defects that had been difficult to detect in advance and accumulated knowledge that will lead to early recovery and minimize downtime in the event of a defect.

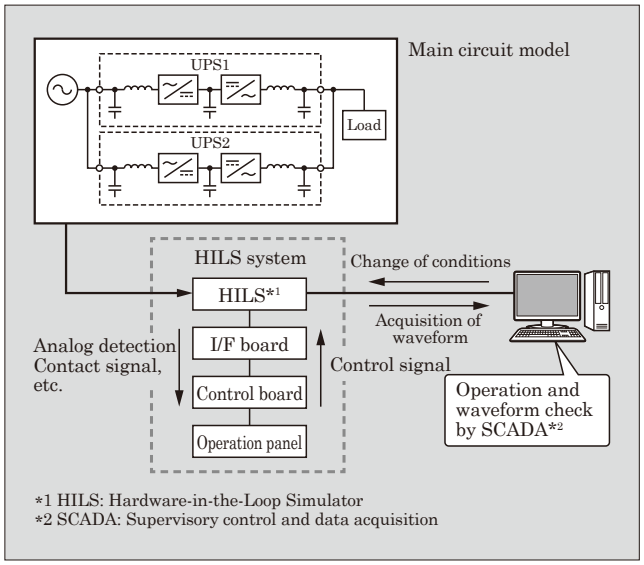

Fig.9 Illustrative diagram of the evaluation system

4. Postscript

This paper described medium-capacity uninterruptible power systems with enhanced replacement support and improved stability of operation. While improving the output performance with a rated load power factor of 0.9, the new series also features a reduced footprint to enhance its replacement capability, as well as improved stabilization of operation by incorporating Fuji Electric's unique predictive maintenance function for detecting abnormal conditions.

We will continue to improve this line-up going forward, and we plan to complete the product release of all models by FY2023. Moreover, we will further improve reliability and meet customers' expectations by enhancing component failure diagnosis with the abnormal sign detection function.

*1 Modbus: Trademark or registered trademark of Schneider Automation, Inc.

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