"UPS 7000HX Series" of High-Efficiency, Large-Capacity UPS Products Using AT-NPC 3-Level for Data Centers

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ABSTRACT

In recent years, as ICT expands, the building market exemplified by data centers has focused on environmental performance and economy, and the demands for high efficiency, high reliability, and compactness from power supply equipment are increasing. Fuji Electric developed a large capacity high efficiency UPS, "UPS 7000HX Series" (400 V 500 kVA) to meet these needs. Maximum efficiency is as high as 97% and the installation area is 30% less than conventional models. In addition, the parallel operation provides a stable power supply. To achieve this, we set the power conversion circuit construction to three levels and used a three-level dedicated module equipped with the RB-IGBT that we developed in the switching element.

1. Introduction

Networks and communications infrastructure making use of the rapid development of information and communications technology (ICT) are not only used in businesses, but are also improving the convenience of civic life, into which they have penetrated deeply and become an essential feature in the same way as utilities such as electricity and waterworks.

The volume of data handled by information processing systems is also growing each year, and the electricity those systems consume is increasing. Information processing systems were conventionally managed separately at each company, but there is now an increasing trend towards outsourcing the system construction and operation. This is based on efforts to reduce installation and operating costs, high level ICT introduction plans and business continuity plans for disasters or other unforeseeable situations. The data centers that this work is outsourced manage everything from the construction to the operation and maintenance of information processing systems, air-conditioning systems, power management systems, etc.

As a result, the amount of power consumption becomes huge in the data centers where the information processing systems are concentrated. There are therefore strong demands for improved machine efficiency of the uninterruptible power supplies (UPS) which supply stable electric power to the systems.

In this paper, we present the 400 V 500 kVA model of a large capacity, high efficiency UPS product, "UPS 7000HX Series," which features the AT-NPC 3-level conversion technology. This UPS for data centers has reduced power loss by using the advanced t-type neutral-point-clamped (AT-NPC) 3-level conversion circuit and Fuji Electric's original new devices.

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2. Characteristics

Figure 1 shows the external appearance of the UPS 7000HX Series 400 V 500 kVA model.

2.1 High Efficiency

The equipment efficiency has been improved by 2% from the conventional model, achieving an industry-leading level of 97%. The improvement in the equipment efficiency also reduces the heat generation due to UPS power loss, and there is also the merit that the electricity consumption of the air conditioner used for the UPS system can also be reduced.

Equipment duplication and redundancy are used at data centers to improve the reliability of individual system. This means that in some cases the load factor during normal operation is low, and this equipment also reduces power loss in the low load range (20 to

Fig.1 "UPS 7000HX Series" (400 V 500 kVA)

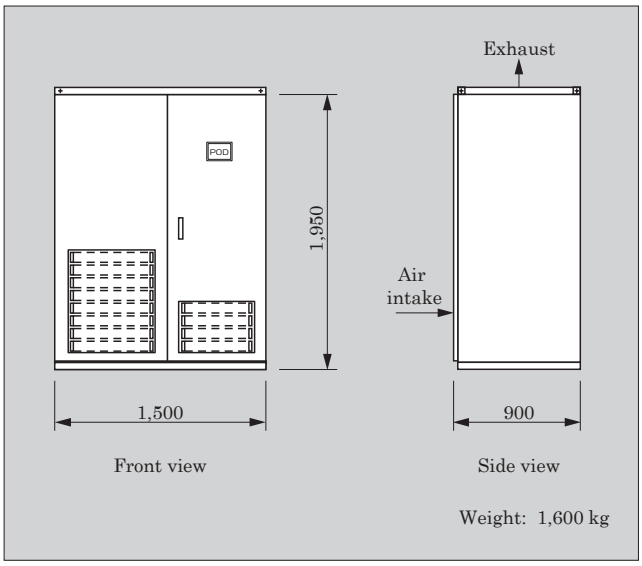

Fig.2 External appearance and weight

50%).

2.2 Miniaturization and Space-saving

Compared with conventional models, the size of the equipment has been reduced by approximately 30% and the weight is also approximately 30% lighter, to 1,600 kg (see Fig. 2). The merit of any space-saving done with equipment and devices such as UPS etc. is that there can be more space for installing servers and other equipment.

2.3 High Reliability

Data centers need a power supply which continues 24 hours a day for 365 days a year. Even during maintenance and any failures that may occur unexpectedly, this is supported with systems such as parallel redundant systems and stand-by redundancy systems, with a continued electricity supply from a UPS. Representative system configurations are shown in Figs. 3 and 4.

2.4 High Performance and High Functionality

(1) Support for high power factor load

In the conventional 500 kVA equipment, support range was only up to a load power factor of 0.9 (450 kW), but the UPS 7000HX Series achieves an output up to a load power factor of 1.0 (500 kW). Therefore, for high power factor loads such as information pro-

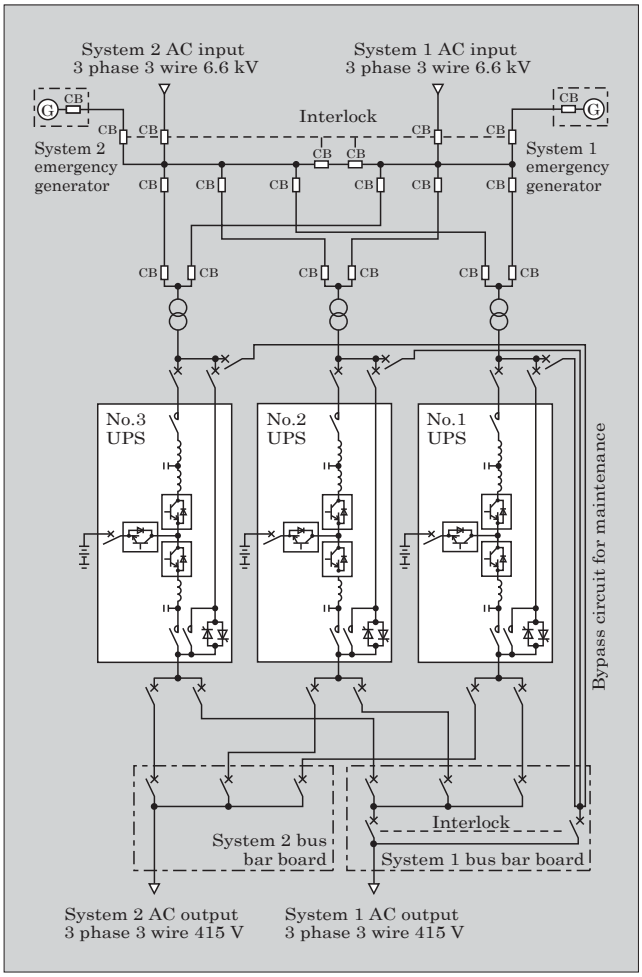

Fig.3 Parallel redundant system
(Completely independent double bus method)

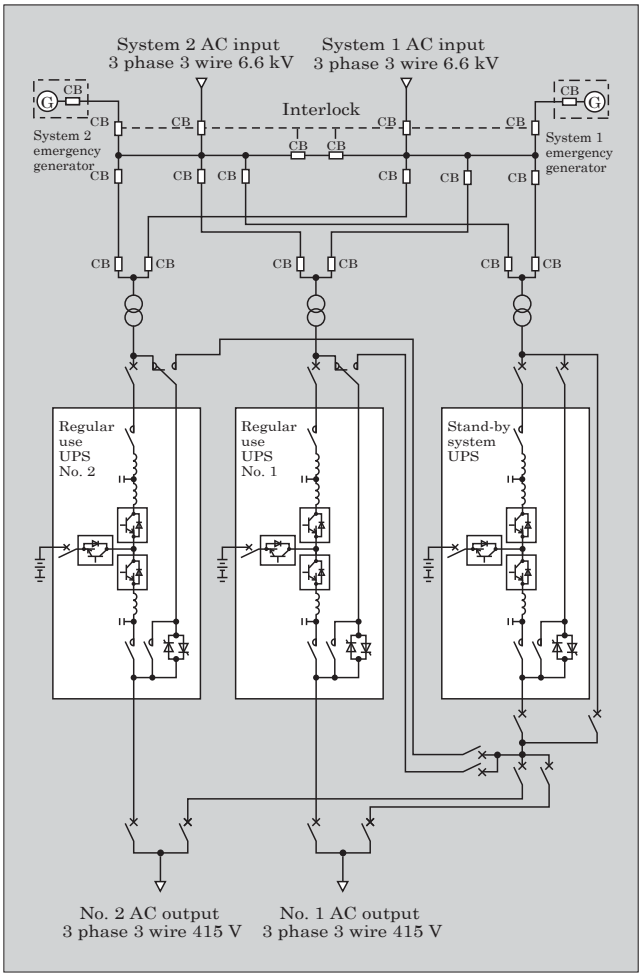

Fig.4 Stand-by redundancy system

cessing systems using power-factor correction circuits (PFC) on their power supply inputs, the product supplies 11% more electric power compared with conventional models.

(2) Power walk-in function

When the UPS switches over from the power supply from the battery (in operation at blackout) to the power supply from the emergency generator, by employing a function to gradually transfer from the battery discharge power to the emergency generator power (a power walk-in), voltage fluctuation or hunting on the emergency generator due to a rapid change in load can be suppressed.

(3) Network function

By connecting to a network using the "Web/SNMP card" the operating status of the UPS can be monitored using a standard browser and notification of failure information can be sent by e-mail. In addition, by using the dedicated monitoring software, it is possible to monitor items such as trends in the output power and the operation history and failure history of the UPS.

Table 1 Performance and specifications of the "UPS 7000HX Series"

Item		Performance and specifications
UPS method		Normally inverter feeding
Rated output apparent power		500 kVA/500 kW
Equipment maximum efficiency		97%
Switch-over time at power failure		Uninterrupted
AC input	Number of phases	3 phase 3 wire
	Voltage	415/420 V ±10%
	Frequency	50/60 Hz ±5%
	Power factor	0.98 or more
	Current harmonic distortion factor	5% or less
Bypass input	Number of phases	3 phase 3 wire
	Voltage	415/420 V ±10%
DC input	Nominal voltage	480 to 528 V (Equivalent to 240 to 264 lead storage battery cells)
AC output	Number of phases	3 phase 3 wire
	Voltage	415/420 V
	Frequency	50/60 Hz
	Load power factor	0.7 (delay) to 1.0
	Voltage tolerance (at steady state)	Within ±1%
	Transient voltage regulation	Within ±3% (Load: 0 to 100%)
	Settling time	50 ms or less
	Voltage waveform distortion	2% or less (linear load), 5% or less (rectifier load)
	Frequency precision	0.01% or lower (when internal oscillation)
	Range of external synchronization	Within ±5%
	Overload capability	125%: 10 minutes, 150%: 1 minute, 200%: 2 seconds

3. Specifications

Reduced losses and miniaturization of the filter circuits were realized with the use of a 3-level conversion circuit. As a result, the equipment as a whole was made smaller and lighter. Table 1 shows the performance and specifications of the UPS 7000HX Series.

4. Circuit Structure and Operation

4.1 Outline of the Configuration and Operation of Main Circuit

Figure 5 shows the main circuit block diagrams. We adopted a normal inverter feeding method, made up of an inverter which converts direct current to alternating current and a rectifier which converts alternating current to direct current. There is also a chopper connected on the DC input, which performs charge/discharge control for the storage battery.

In the normal operating state, where the AC input is within the normal range, a stable power supply with a constant voltage and constant frequency is supplied to the load using the inverter. The rectifier controls the UPS AC input current to be a sine wave with power factor ≈ 1.0, and the chopper charges the storage battery. When a power failure occurs in the AC input, the chopper boosts up the storage battery voltage to the appropriate DC voltage and the inverter converts it

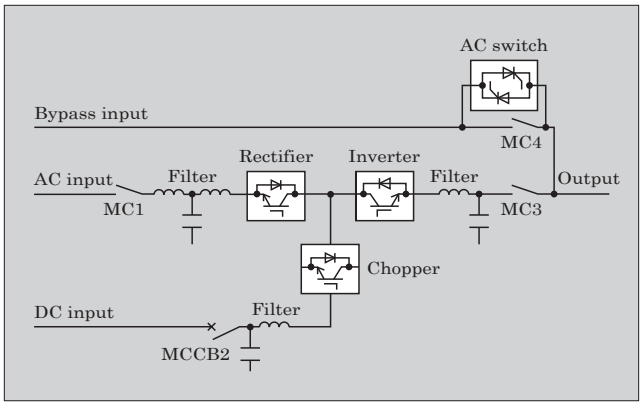

Fig.5 Main circuit block diagram

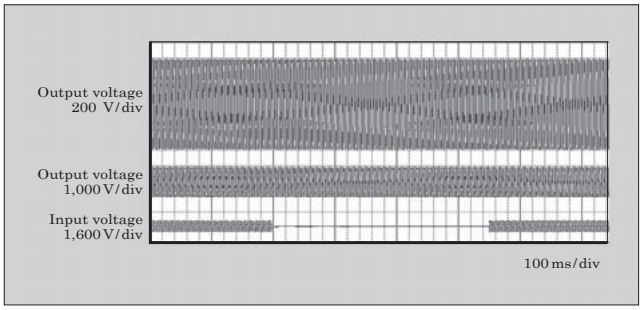

Fig.6 Waveforms at the time of power failure and recovery

to a stable alternating current and supplies it. Figure 6 shows the waveform data at the time of a power failure and power recovery. Even if power failure occurs in the input voltage, the output continues to supply a stable voltage.

4.2 Application of AT-NPC 3-level Conversion Circuit

AT-NPC 3-level conversion circuit as shown in Fig. 7 was adopted for the rectifier and inverter part. The characteristics of an AT-NPC 3-level conversion circuit are as below.

(1) As the switching voltage is half that in a 2-level conversion circuit, the switching loss in the converter is reduced and it is possible to improve the power conversion efficiency, to achieve energy conservation, and to achieve miniaturization of the converter.
(2) As the switching waveform is a staircase waveform as shown in Fig. 8, the harmonic voltage is reduced compared to that in a 2-level conversion circuit. In addition, because the losses are also reduced from the filter circuits accounting for a high proportion of the volume and mass, such as the reactor and capacitors, miniaturization of the equipment is possible.
(3) The noise generation from the switching can be reduced comparing 2-level conversion circuits.

4.3 Application of AT-NPC 3-level IGBT Module

The AT-NPC 3-level insulated gate bipolar transistor (IGBT) module developed by Fuji Electric is used in the 3-level conversion circuit (see Fig. 9). This module

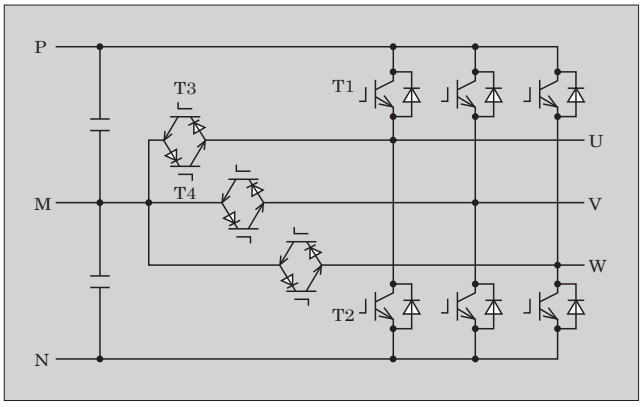

Fig.7 AT-NPC 3-level conversion circuit

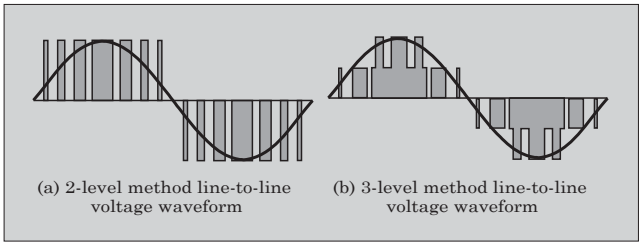

Fig.8 Comparison of switching waveforms between 2-level and 3-level conversion circuits

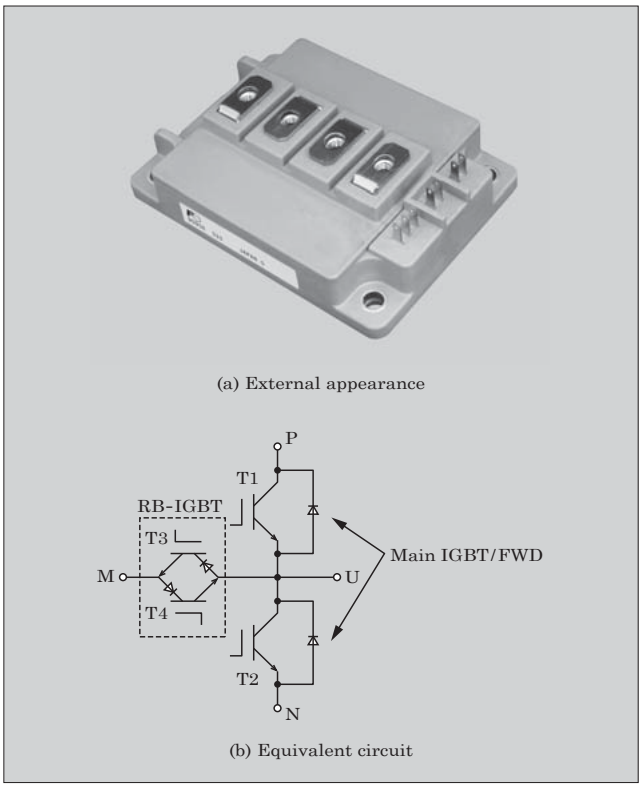

Fig.9 AT-NPC 3-level IGBT module

uses a reverse-blocking IGBT (RB-IGBT) as the neutral point clamped element and the four semiconductor switching elements required for a single 3-level arm are packaged in one device.

The merits for the use of this module are as described below.

(1) Compared with a generally available diode clamped NPC, the number of conducting elements are reduced by half, and the conduction loss can be suppressed.
(2) The use of a single package module makes it possible to use 3 sheet conductors corresponding to P, M and N as shown in Fig. 7 for the connections between elements. This reduces the inductance of the switching circuit and the surge voltage can be suppressed, and it becomes possible to suppress noise and to streamline circuits through a reduction in the devices needed as countermeasures to surge voltage.

4.4 Efficiency and Losses

Figure 10 shows the efficiency characteristics of this machine during AC-AC operation. In the range where the load factor is between 20% and 100%, the maximum efficiency is 97.1% and the minimum efficiency is 95.9%. Since the efficiency is also good even when the actual operation load is low, a large energy conservation effect can be obtained.

Figure 11 shows a comparison of losses for the conventional 2-level conversion equipment and for the AT-NPC 3-level conversion equipment. For the AT-NPC

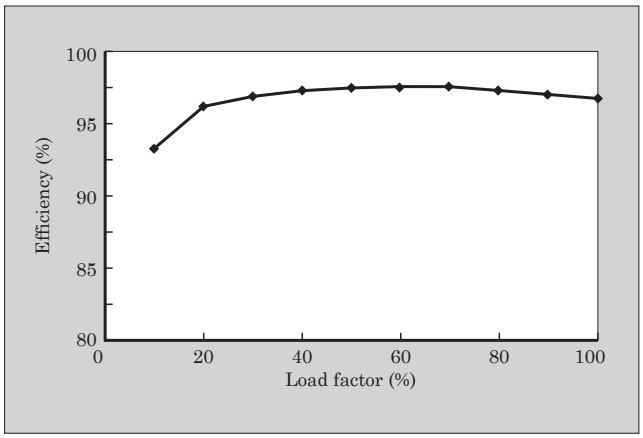

Fig.10 Efficiency characteristics

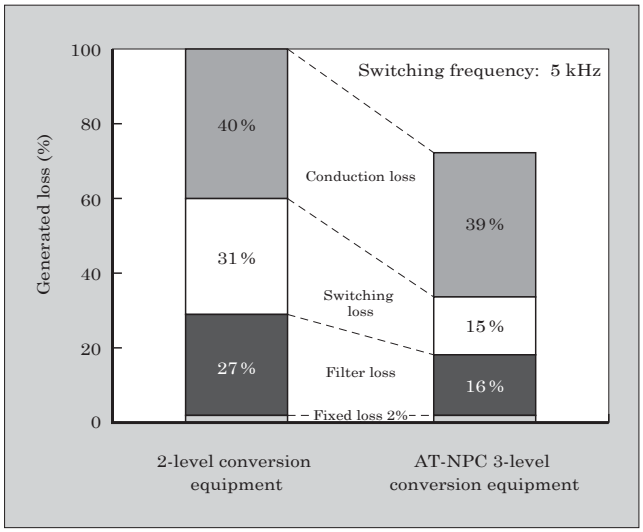

Fig.11 Comparison of loss between 2-level conversion equipment and AT-NPC 3-level conversion equipment

3-level conversion equipment, losses are reduced by about 30% compared with those for the conventional 2-level conversion equipment. The figure clearly shows that there is a great reduction in switching loss and filtering loss. As written above, this is because the switching voltage is reduced by half.

4.5 Control Technology

The control equipment carries out PWM waveform control, sequence control, communication reliability, availability, serviceability (RAS) management and man-machine control.

In addition to the instantaneous voltage waveform control in the inverter, this control equipment also performs instantaneous current control. This makes it possible to perform shock-less changeovers between the inverter power supply and bypass power supply and also parallel operation of the UPS. It realizes a steady and high-quality supply of electric power, both in normal and transient states.

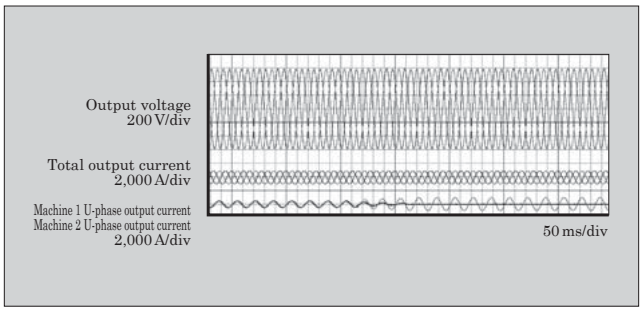

Fig.12 Waveform at one unit stopped during two unit operation

In parallel operation, the current is balanced by control so that the current in each UPS is equal. Furthermore, when one of the units in parallel operation is stopped and removed, for example, for maintenance work, and when a UPS that has been stopped is started up and connected in parallel with an operating UPS, the share of the current is controlled so as to change slowly, so that there is no disturbance in the output voltage and it is possible to supply a stable voltage to the load.

Figure 12 shows the waveforms when one of two units in parallel operation is stopped and separated off. There is no disturbance in the output voltage and the current from the UPS which is to be stopped gradually decreases to zero and the current from the UPS to be continued operation gradually increases.

5. Postscript

We presented a large capacity, high-efficiency UPS product, “UPS 7000HX Series” which is intended for data centers and features AT-NPC 3-level conversion technology. By using the AT-NPC 3-level conversion circuit and Fuji Electric's proprietary IGBT module dedicated for 3-level circuits, high efficiency of maximum 97% and miniaturization by 30% can be achieved compared to conventional models. Furthermore, the equipment also supports various power management systems, and it is expected that it will be used for a wide range of power supply equipment in addition to data centers, in applications where a reduced environmental burden and high reliability are demanded.

We will continue to incorporate new technologies and to work to develop and commercialize power supply equipment which meets the expectation of customers.