Large-Capacity, High-Efficiency 3-Level UPS for North America “7000HX-T3U”

KAWASAKI, Daisuke*　HAMADA, Ippei*　SATO, Atsushi*

ABSTRACT

Due to the development of information and communications systems in the information society in recent years, the data center market is expanding both in Japan and abroad. At the same time, there are increasing needs for uninterruptible power systems (UPSs) to ensure stable system operation. “7000HX-T3U,” which has been developed for the North American market, is a large-capacity, high-efficiency UPS using a 3-level power conversion circuit with a rated voltage of 480 V. By using Fuji Electric’s original AT-NPC 3-level insulated gate bipolar transistor (IGBT) module, the UPS has achieved a maximum efficiency of as high as 97%. It provides high reliability, as with the conventional models, and also supports UL and NEC standards which must be complied with in North America.

1. Introduction

Information communication systems, such as those used in communication equipment and networks, have an indispensable role in today’s information-driven society. Social activities could be significantly impacted if these systems were to stop working, and stable operation is thus an absolute requirement.

An uninterruptible power system (UPS) plays a major role in information communication systems, and it is an essential piece of electrical equipment needed in supplying a stable source of power in data centers 24 hours a day, 365 days a year. In recent years, the market size and growth rate of data centers, while still comparatively small in Japan, has been growing in Asia and North America, and it is expected that considerable growth will be sustained into the future.

Fig.1 “7000HX-T3U” (400 V, 500 kVA)

* Power Electronics Business Group, Fuji Electric Co., Ltd.

Fuji Electric has developed UPSs for the Japanese, Asian and North American markets.

This paper describes the “7000HX-T3U,” a high-efficiency UPS with a high-capacity rated voltage of 480 V developed for use in the North American market (see Fig. 1).

2. Features

2.1 Compliance with North American standards

When developing products for use in North America, it is strictly required that they be compliant with the product safety standards of Underwriters Laboratories Inc. (UL standards), as well as the standards related to cable laying prescribed by the National Fire Protection Association (NEC standards). In order to make the UPS described in this paper compliant with these standards, we carried out the selection and development of new device components.

2.2 High efficiency

The current model maintains the world’s highest level of efficiency at 97%, being based on the exact same features as the “7000HX-T3,” a previous product developed for the Japanese market. The high equipment efficiency not only decreases the power loss of the UPS, but also reduces the power consumption of air conditioning equipment used to cool the UPS.

Since equipment in a data center adopts dual and redundant configurations to improve reliability of the system, it operates at a low load factor. Power loss is also reduced in the low load range (20% to 50%) during normal operation.

2.3 High reliability

In data centers, the UPS needs to continuously supply power 24 hours a day, 365 days a year. This

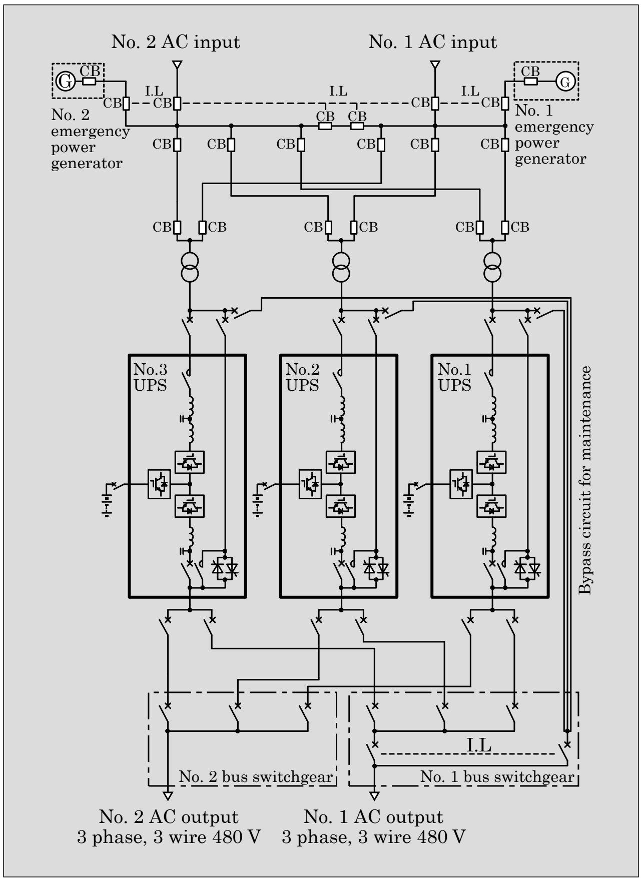

Fig.2 System configuration of parallel redundant operation system (completely independent double bus system)

model supports a parallel redundant operation system and a standby redundant operation system, which ensure continuous power supply during time of maintenance and equipment failure. The typical system configurations for each of these systems are shown in Fig. 2 and Fig. 3.

2.4 High performance and high functionality

(1) Support for high power factor load

In recent years, an improved power factor has been required by standards such as those enacted by the International Energy Star Program*1, and the number of electronic devices that adopt a PFC circuit for implementing power factor correction has been increasing. This product, therefore, supports to loads with a power factor of 1.0 (500 kW) in order to supply power to such equipment that uses the PFC circuit without reducing their power capacity.

*1: The International Energy Star Program (Energy Star) is an international environmental labeling system for ensuring energy savings in electrical equipment. It is being managed under the mutual recognition of the Ministry of Economy, Trade and Industry in Japan and the United States Environmental Protection Agency. The program includes a wide range of products such as home appliances, industrial machines and computers.

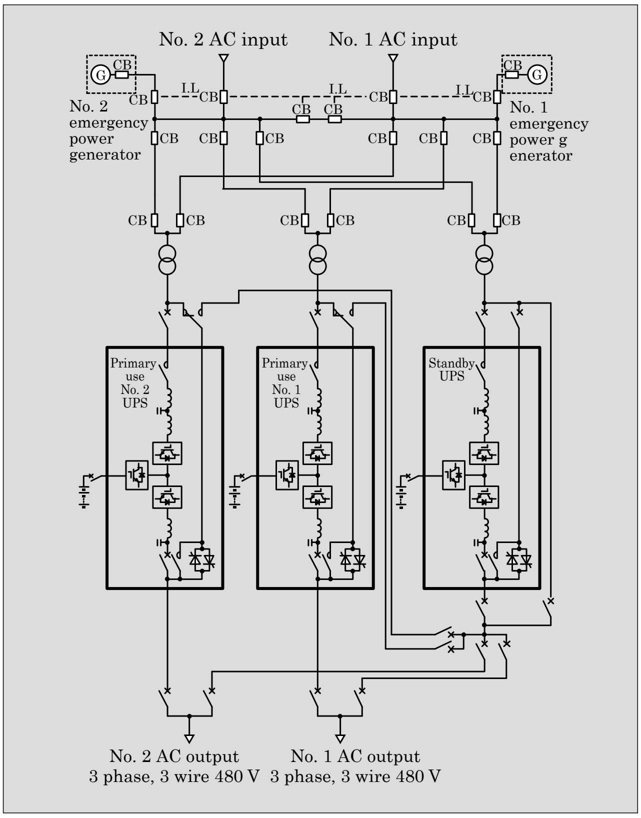

Fig.3 System configuration of standby redundant operation system

(2) Power walk-in function

When the UPS switches from battery based power supply (operation during power failure) to emergency generator based power supply, the power walk-in function gradually changes the power sources. This function allows emergency generators to prevent hunting and suppress voltage fluctuation due to sudden load changes.

(3) Web/SNMP card

Connecting to a network via the Web/SNMP card, users can monitor the operating state of the UPS from a standard web browser and receive failure information by email.

Moreover, using dedicated monitoring software, they can also monitor output power trends and operating history and failure history of the UPS.

(4) MODBUS*2 card

A newly developed option card supporting MODBUS makes it easy to monitor UPS data by connecting to the networks of customer equipment. By selecting either the MODBUS card or Web/SNMP card, wide-scale compatibility can be achieved with the communication systems of customer equipment.

*2: MODBUS is a trademark or registered trademark of Schneider Automation, Inc., France

3. Specifications

Figure 4 shows the outer dimensions of the 7000HX-T3U, and Table 1 lists the specifications. By adopting a 3-level power conversion circuit, we have been able to decrease loss while also reducing the size of the filter circuit. These enhancements have enabled us to achieve a reduced size and weight of equipment.

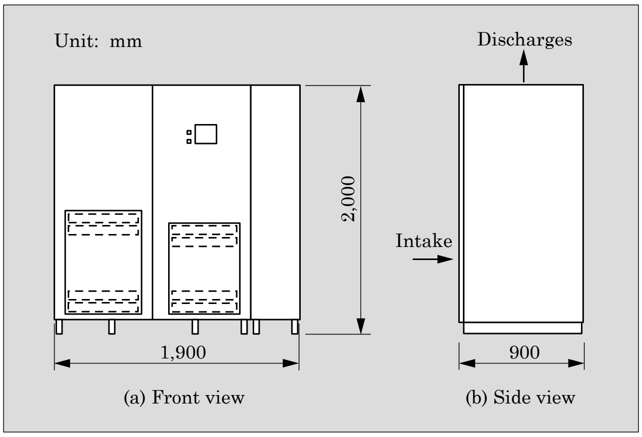

Fig.4 Outer drawing of the “7000HX-T3U”

Table 1 “7000HX-T3U” specifications

Item		Specification
Feeding method		Normal inverter feeding
Rated output capacity		500 kVA/500 kW
Equipment max. efficiency		97%
Power failure switching time		Uninterrupted
Mass		1,800 kg
AC input	Number of phases	3 phase, 3 wire
	Voltage	480 V+10%, – 20%
	Frequency	60 Hz±5%
	Power factor	0.99 (delay) to 1.0
	Current harmonic distortion rate	3% or less
Bypass input	Number of phases	3 phase, 3 wire
	Voltage	480 V±10%
DC input	Nominal voltage	480 to 528 V (Equivalent to 240 to 264 lead-acid batteries)
AC output	Number of phases	3 phase, 3 wire
	Voltage	480 V
	Frequency	60 Hz
	Load power factor	1.0
	Voltage precision (at steady state)	Within ±1%
	Transient voltage fluctuation	±3% or less (load 0 ⇔ 100%)
	Settling time	50 ms or less
	Voltage waveform distortion rate	2% or less (linear load) 5% or less (non-linear load)
	Frequency precision	Within ±0.01% (during internal oscillation)
	External synchronization range	±5% or less
	Overload capability	125%: 10 min 150%: 1 min

4. Circuit Configuration and Operation

4.1 Overview of main circuit configuration and operation

Figure 5 shows the main circuit block diagram. This model adopts a double conversion system consisting of a rectifier to convert AC to DC and an inverter to convert DC to AC. A chopper is connected to the DC input to carry out charge/discharge control of the storage battery.

In the normal operating state, in which the AC input is within the normal range, stable power with a constant voltage and constant frequency is supplied to the load via the inverter. The rectifier carries out control so that the AC input current of the UPS becomes a sine wave with a power factor approximately equal to 1, while the chopper charges the storage battery. If there is a power failure for the AC input, the chopper raises the voltage of the storage battery to an appropriate DC voltage, and the inverter supplies power after converting it to stable AC power. Figure 6 shows the waveform at power failure and power restoration. As a result, a continuous and stable output voltage can be supplied even during a power failure.

In addition to the above mentioned operations, the chopper also performs discharge control in a mode that simultaneously supplies power to a load from both the input and the battery during overload, input voltage

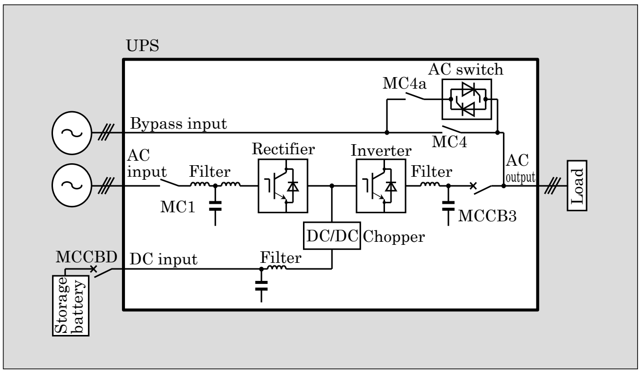

Fig.5 Main circuit block diagram

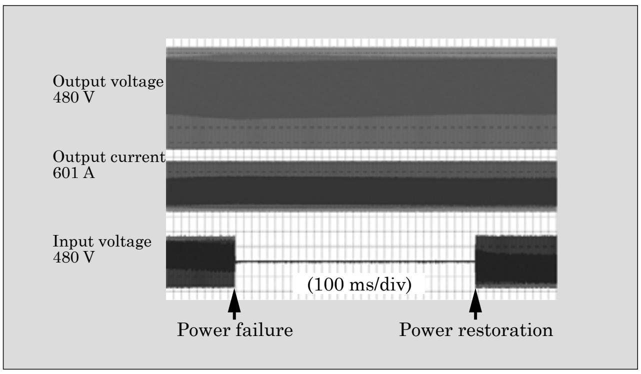

Fig.6 Waveform at power failure and restoration

drop and restoration power walk-in.

4.2 Application of AT-NPC 3-level power conversion circuit

The rectifier and inverter adopt an advanced T-type neutral-point-clamped (AT-NPC) 3-level power conversion circuit*3 as shown in Fig. 7. The semiconductor component used in the conversion circuit utilizes Fuji Electric developed AT-NPC 3-level insulated gate bipolar transistor (IGBT) modules.

The features of the AT-NPC 3-level power conversion circuit are indicated as follows:

(a) Switching voltage is half that of a 2-level power conversion circuit, and as a result, it is possible to reduce the switching loss of the converter, improve power conversion efficiency, save energy and reduce the size of the converter.

(b) Since the switching waveform is step-wise as shown in Fig. 8, it has reduced harmonic voltage compared with 2-level power conversion circuits. As a result, loss caused by filter circuit harmonics is reduced, and this reduces fixed loss (no-load loss) and improves efficiency in the low load range while also making it possible to reduce the size of the reactor and capacitor.

(c) Noise generated by switching can be reduced compared with 2-level power conversion circuits.

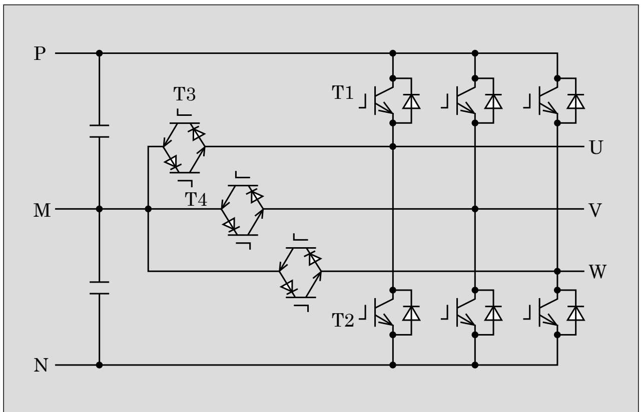

Fig.7 AT-NPC 3-level power conversion circuit

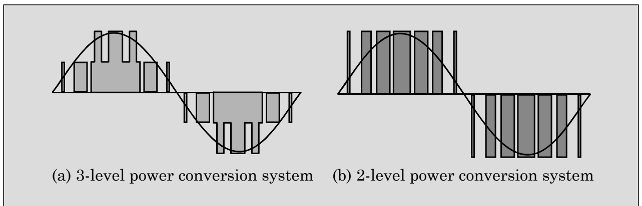

Fig.8 Comparison of switching waveforms

*3: For more details on the 3-level power conversion circuit, refer to “3-Level Power Conversion” on page71 [Supplemental explanation 6].

4.3 Applicable to 480 V AC rating

Since the rated line voltage of this model is 480 V, it needs to output a voltage higher than the typical 415 V output by converters manufactured for the Japanese market. To achieve this, it is generally necessary to change the withstand voltage of the component used in the semiconductor power converter, but this model allows the use of the same component used in products manufactured for the Japanese market by adopting a trapezoidal wave modulation system as the control system (see Fig. 9).

Trapezoidal wave modulation enables the output of a line voltage that is higher than sine wave modulation even when the peak of the phase voltage and the sine wave are the same. Since the withstand voltage of the semiconductor component is determined by the phase voltage, the utilization of trapezoidal wave modulation makes it possible to obtain a high line voltage even when using a component with a low withstand voltage. Furthermore, since DC voltage is low, the switching loss of the semiconductor can also be reduced.

4.4 Efficiency and loss

The efficiency characteristics during AC-AC op-

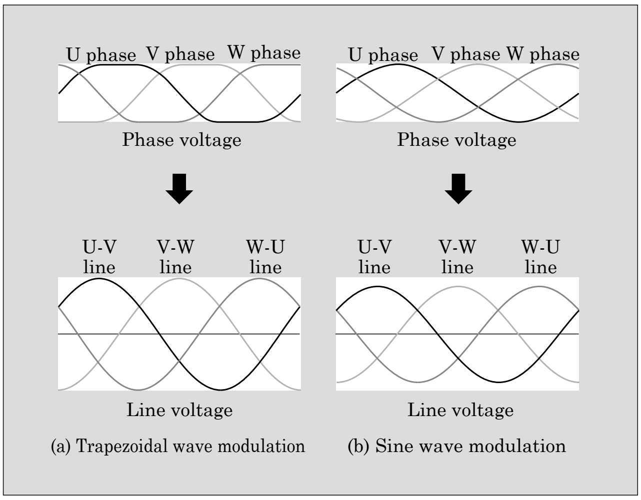

Fig.9 Voltage waveform of rectifier and inverter

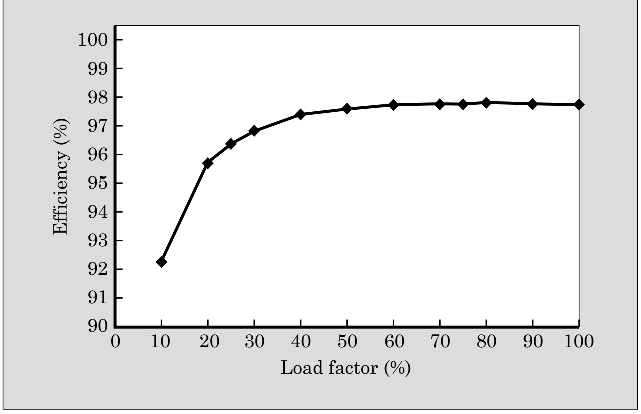

Fig.10 Efficiency characteristics during AC-AC operation

eration for this model are shown in Fig. 10. When the load factor is between 20% and 100%, maximum efficiency is above 97% and minimum efficiency is above 95%. In other words, efficiency is high even when the actual operation load is low, and this, in turn, produces high energy savings.

5. Postscript

In this paper, we introduced the “7000HX-T3U” AT-NPC 3-level large-capacity, high-efficiency UPS for the North American market. The model is compliant with North American standards and various power management systems, and it can be expected to be adopted for a wide range of power supply applications that require safety, high reliability and a low environmental burden.

We will continue pursuing energy savings and globally-compliant features for our power supply products so that we can meet the expectations of our customers.

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