Development of Uninterruptible Power Supply “SANUPS A11J” Three-phase, Four-wire Model

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1. Introduction

Economic globalization is prevalent across the globe, however the economic development of Southeast Asia in particular is attracting much attention. This region was formerly a world production base, but population growth and industrial development has given way to an increase in middle-class, resulting in the region maturing into a major market.

Many Japanese companies have established themselves in this region and industrial infrastructure, in particular power infrastructure as the foundation of corporate activities, is a key topic. As such there are high expectations of the demand for uninterruptible power supply (hereinafter “UPS”) will be grown.

Up until now, Sanyo Denki has sold the single-phase, two-wire 5 kVA to 20 kVA small capacity UPS “SANUPS A11J” series to overseas buyers, however foreseeing an expansion in demand for the mid-capacity range in the Southeast Asian region, we have added a three-phase, four-wire 15 kVA to 45 kVA model to this series.

This document introduces the newly developed “SANUPS A11J” series, three-phase, four-wire 15 kVA to 45 kVA model.

2. Background of the Development

In general, AC power of 15 kVA or more adopts the three-phase method of power supply. In Japan, most three-phase AC systems use the three-phase, three-wire system to supply power along three power wires. This is an economical method and has a large power supply capacity per wire.

However, most indoor three-phase AC systems used in overseas adopt the three-phase, four-wire method. Power-receiving equipment of buildings, etc., receive high voltage three-phase, three-wire power, then connect a secondary winding of a transformer in a Y connection and draw a neutral wire from a neutral point to become a three-phase, four-wire method.

The three-phase, four-wire line voltage becomes magnified by $\sqrt{3}$, and has the advantage of being able to use both the interline (three-phase) and interphase (single-phase) voltages. In Southeast Asia, voltages such as 380 V / 220 V (three-phase/single-phase) are used for power distribution of both three-phase power and single-phase lights.

Due to the differences in three-phase AC systems, the three-phase, three-wire UPS for the Japanese domestic market must support not only different voltages, but also different power feeding systems, hence cannot be used overseas with the current specifications.

As such, Sanyo Denki has reapplied our single-phase technology from the current “SANUPS A11J” series, and developed a new product in a short timeframe in order to apply a three-phase, four-wire UPS product on the market at an early stage. The three-phase, four-wire model of the “SANUPS A11J” series supports the differences in power feeding methods by making a Y connection for 3 single-phase UPS units using a common neutral wire, as described above.

3. Product Overview

The three-phase, four-wire model of the “SANUPS A11J” series was developed for server and network equipment application. This model comprises of an inverter unit, current collector and battery unit and is designed for installation on an EIA standard 19 inch rack (hereinafter referred to as rack).

The current ”SANUPS A11J” series uses the single-phase 5 kVA inverter as the base unit, and stacks four units in parallel to enable construction of a single-phase UPS with a maximum of 20 kVA.

For the newly developed three-phase, four-wire model, a single-phase, 5 kVA to 15 kVA inverter is arranged on each of the three-phases (R, S, T) to enable construction of a three-phase, four-wire UPS with a maximum of 45 kVA. Fig. 1 shows a schematic for the inverter.

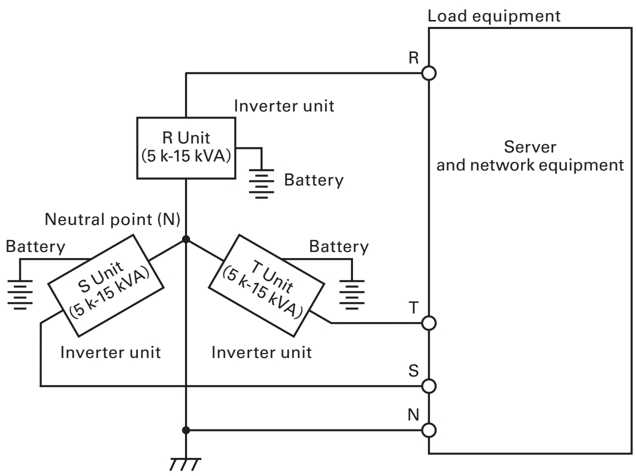

Fig. 1: Schematic for the inverter

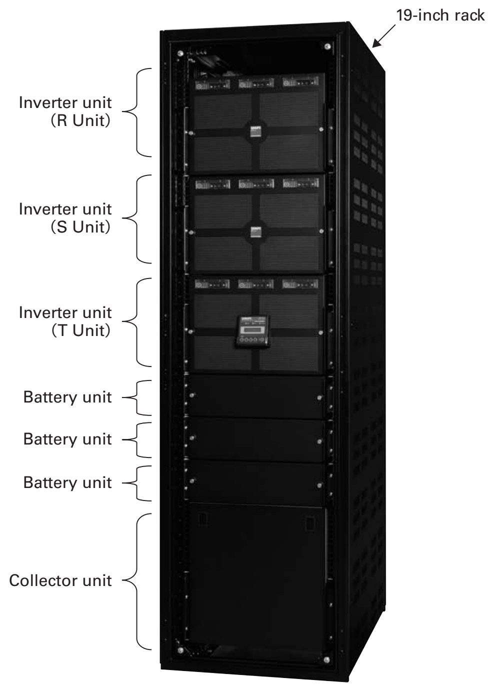

Fig. 2: Front view when installed on a rack
(15 kVA to 45 kVA)

The circuit configuration adopts the double-conversion method that puts the power supply quality first, and it achieves high efficiency while using the CVCF (Constant Voltage Constant Frequency) method that is not affected by input voltage or input frequency.

By selecting I/O voltage from phase voltages of 220 V, 230 V and 240 V, it is possible to set line voltage at 380 V, 398 V or 415 V, thus supporting the power source environments of Asia and Europe.

Also, the operation panel uses an LCD display, providing the device with an easy-to-use user interface.

Fig. 2 shows a front view when the new model is installed on a rack and Fig. 3 shows its back view. Fig. 4 shows an external view of the inverter unit with an operation panel, and Fig. 5 shows an external view of the inverter unit without an operation panel.

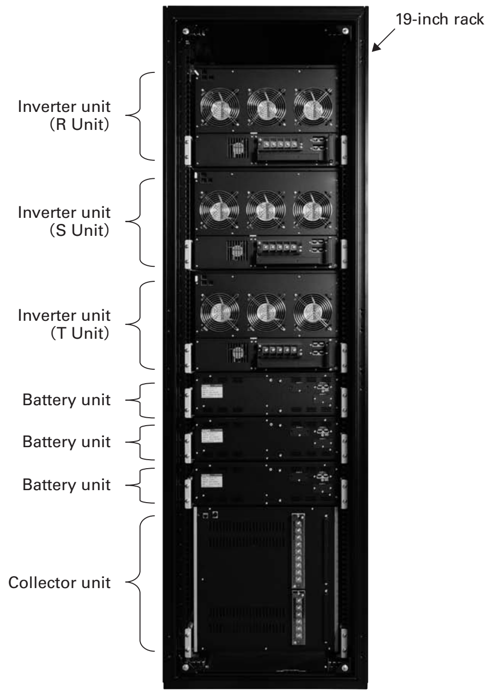

Fig. 3: Back view when installed on rack
(15 kVA to 45 kVA)

Fig. 4: Inverter unit with an operation panel (single-phase 5 kVA to 15 kVA)

Fig. 5: Inverter unit without an operation panel (single-phase 5 kVA to 15 kVA)

4. Features

4.1 High efficiency

By adopting a three-level inverter in the DC/AC conversion circuit, it is possible to achieve an efficiency of 93% or higher with a single-phase 5 kVA inverter. This efficiency enables the device to reduce running costs and contribute to energy saving.

4.2 Output power factor 0.9

In recent years, many types of control power supplies built into servers have gained functions to compensate for the power factor of the input current. This tends to raise the load power factor.

In order to handle this situation, the new model has achieved an output power factor of 0.9. This makes it possible to feed power with leeway in the load device with an increasingly higher input power factor.

4.3 High reliability by parallel redundant operation

In the case of the current “SANUPS A11J” series, 5 kVA base units can be stacked in parallel up until four units. Because of this, for example if there was leeway in the output capacity in regards to load capacity for at least 1 unit (5 kVA), even in the unlikely event of an error occurring on the unit, the remaining error-free units would continue inverter power feeding, thus providing high reliability.

This function was also adhered in the new model and if the inverter units connected to each phases have enough leeway to cover the inverters installed on each phase (5 kVA) against the load capacity, it would be possible to continue inverter power feeding with the remaining error-free units even in the case of an error or maintenance on one unit.

Moreover, the inverter of this unit has eliminated the common wire in order to acquire synchronization of the voltage phases during parallel operation and secures a high reliability which is not dependent on the reliability of the common portion.

4.4 Battery management function

In order to reliably provide backup power from a battery during a power outage, the self-diagnosis function is included to automatically test the battery. Furthermore, a variety of battery management functions, including battery life warning, estimated battery operation time, battery charging rate, and estimated backup time, are included in order to improve reliability.

4.5 Weight reduction

In this development, a three-phase, mid-capacity UPS was separated into an inverter unit, current collector and battery unit, forming a structure able to be installed on generalized racks.

Moreover, the inverter unit is equipped an inverter module, while the battery unit is equipped with a battery module, therefore they can both be divided into blocks and have successfully achieved weight reduction as individual devices.

Reducing weight on the new model has lowered costs associated with transporting the unit to the installation location compared with general mid-capacity UPS. Also, when the unit is delivered, a mixed delivery service can be used, consolidated cargo instead of charter service.

4.6 Improved maintainability

By modularizing the inverter and battery portions to modules, the maintainability of the device including replacement and so forth has significantly improved. Fig. 6 shows an external view of the inverter module, Fig. 7 shows an example of inverter module installation and Fig. 8 shows an example of battery module installation.

Each module is a plug-in system and during parallel redundant operation, even in the unlikely event of an error occurring, inverter power feeding will continue as per normal, allowing speedy replacement and high availability. Moreover, there is a built-in maintenance by-pass circuit, making it possible to perform maintenance and replace modules while continuing power feeding from utility power.

The mass of both the inverter module and battery module are kept under 18 kg, reducing the risk of maintenance engineers injuring themselves during their tasks.

Fig. 6: Inverter module (single-phase 5 kVA)

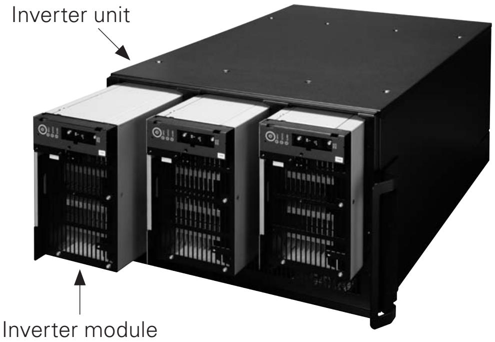

Fig. 7: Example of inverter module installation

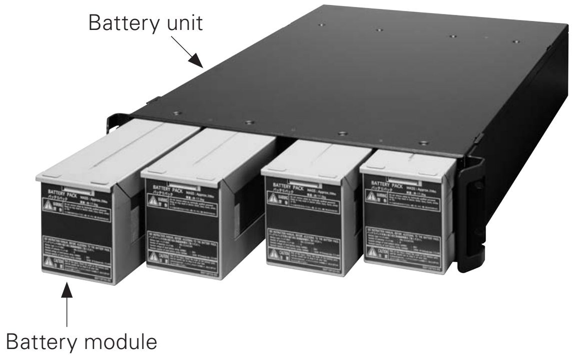

Fig. 8: Example of battery module installation

4.7 Operation panel

The operation panel has also been modularized and can be removed. Fig. 9 shows an external view of the operation panel. This panel can be connected to any inverter unit. The display is a 16 digit x 2 line LCD, displaying information on equipment status, measurements etc. clearly.

Fig. 9: Operation panel

4.8 Network compatibility

The UPS management software, "SANUPS SOFTWARE" and the "LAN interface card" have been prepared as optional products enabling control of UPS in a network environment. By using these options, a flexible and powerful network environment can be constructed.

4.9 Wide range input

There is a wide input voltage allowable range of -20% to +15% if the load factor exceeds 70%, and -40% to +15% if the load factor is 70% or less.

Moreover, in regards to the input frequency also, if the frequency is fixed (I/O asynchronous mode) power feeding at an output frequency of 50/60 Hz is possible within an input frequency range of 40 Hz to 120 Hz.

With corresponding to wide range of input, the frequency of switching to battery power feeding decreases and it is possible to arrest the battery deterioration.

5. Circuit Architecture

Fig. 10 shows a circuit block diagram of this device.

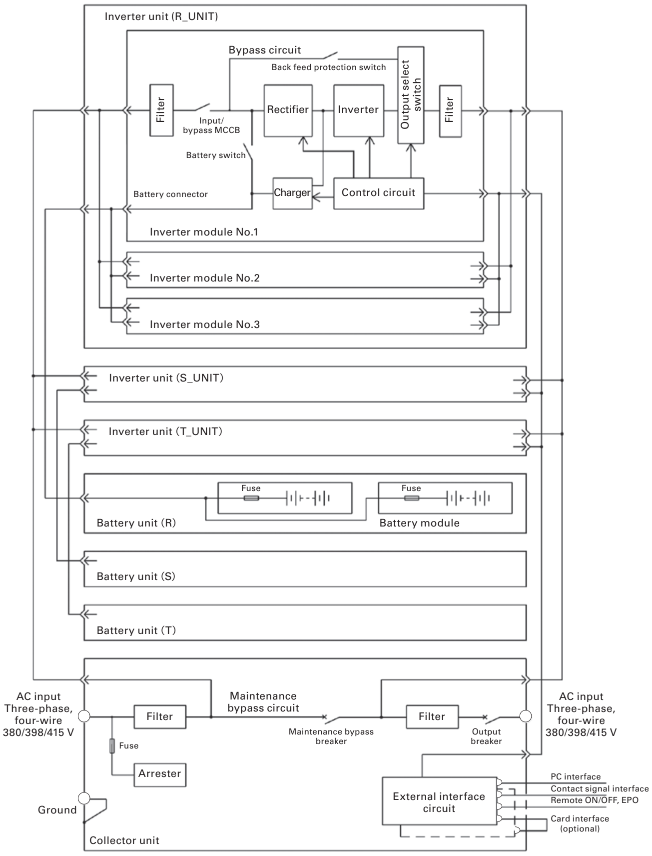

Fig. 10: Circuit block diagram (45 kVA)

5.1 Main circuit configuration

The inverter module of the new model is comprised of a rectifier, inverter, and charger, and it includes the following improvements.

(1) By using high input power factor chopper in the rectifier, the UPS input power factor can be improved and it can support a wide range.
    In the case of the chopper method, it is possible to jointly use as a booster circuit of the battery voltage, thereby the number of components can be reduced.

(2) Conversion efficiency of the inverter has been improved by adopting a three-level method. The three-level method has the following features.
    a) The switching frequency is halved compared to the half-bridge method.
    b) A low-voltage switching device can be used.
    c) The ripple current through the AC filter is halved compared to the half-bridge method.

(3) It is now possible to control and change the charging current of the charger with the CPU. This means that there is sufficient charging ability even if specifications call for prolonged periods of backup and it is possible to flexibly respond to charging currents which differ depending on battery configuration (capacity), therefore eliminating the need to install more chargers or change specifications.

5.2 Control circuit configuration

By using surface mounting for the control circuit board, the mounting area was reduced for the new model. Furthermore, communication between the units and operation panel adopts CAN bus (Controller Area Network: A highly reliable communication method developed as a LAN for use in automobiles) therefore realizing high-speed and high reliability communication.

5.3 Electrical characteristics

Table 1 shows the general specifications of this device.

6. Benefits for Our Customers

In the past, when customers performing system integration (SI) ordered UPS, it was restricted due to the UPS output capacity of each individual order. Due to this, if changes in output capacity (increases/decreases) occurred immediately before shipment there were problems such as wasted time and expense related to specification changes and impact on lead time, which all resulted in increased costs.

With this unit, by adjusting the number of inverter modules installed on the inverter unit, it is possible to construct 15 k / 30 k and 45 kVA UPS systems. This means there is no need for orders to be constrained by UPS output capacity, making low-risk procurement possible.

Table 1: General specifications of the "SANUPS A11J" Three-phase, Four-wire model

Item			Units	Rating or characteristic			Remarks
MODEL			-	A11J153	A11J303	A11J453	
Rated output capacity (N units setting)			kVA/kW	15/13.5	30/27	45/40.5	Apparent power/effective power
Rated output capacity (N+1 unit setting)			kVA/kW	-	15/13.5	30/27	Apparent power/effective power
Method	**Charging method**		-	Utility synchronous continuous inverter power supply			
Method	**Cooling method**		-	Forced air cooling			
Method	**Inverter method**		-	High frequency PWM			
AC input	**Number of phases**		-	Three-phase, four-wire			
AC input	**Rated voltage**		V	380/398/415 (phase voltage: 220/230/240)			Allowable voltage range: -40% to +15% (Note 1)
AC input	**Rated frequency**		Hz	50/60			Choice of automatic judgment or fixed (Note 2)
AC input	**Maximum Capacity**	**N units setting**	kVA	16.5 or less	33 or less	49.5 or less	Max. capacity when charging the battery
AC input	**Maximum Capacity**	**N+1 unit setting**	kVA	-	18.6 or less	35.1 or less	Max. capacity when charging the battery
AC output	**Number of phases**		-	Three-phase, four-wire			
AC output	**Rated voltage**		V	380/398/415 (phase voltage: 220/230/240)			Same as input voltage
AC output	**Voltage setting precision**		%	Within ±2			
AC output	**Rated frequency**		Hz	50/60			Same as input frequency
AC output	**Frequency precision**		%	Within ±1/±3/±5			When asynchronous: ±0.5% or less
AC output	**Waveform distortion rate**		%	3/8 or less			Linear load/wave rectifier load during rated operations
AC output	**Transient voltage fluctuation**	**Sudden variation of load**	%	Within ±5			0 ⇔ 100% sudden variation
AC output	**Transient voltage fluctuation**	**Power outage/return**	%	Within ±5			During rated operations
AC output	**Transient voltage fluctuation**	**Sudden variation of input voltage**	%	Within ±5			±10% sudden variation
AC output	**Transient voltage fluctuation**	**Response time**	Cycle	5 or less			Except when load is open
AC output	**Load power factor**		-	0.9 (delay)			Fluctuation range: 0.7 (delay) to 1.0
AC output	**Overcurrent protection**		%	110 or higher	110 (220) or higher	110 (165) or higher	Automatic switching to bypass circuit (Note 3, 4)
AC output	**Overload endurance**	**Inverter**	%	110/118	110/118 (220/236)	110/118 (165/177)	1 minute/instantaneous (Note 4)
AC output	**Overload endurance**	**Bypass**	%	200/800	200/800 (400/1600)	200/800 (300/1200)	30 seconds/2 cycles (Note 4)
Battery		**Type**	-	Small-sized valve regulated lead-acid battery			
Battery		**Backup time**	Minutes	10	5	3	Ambient temperature 25°C, initial value, load power factor 0.8
Battery		**Expected life**	Years	5			Ambient temperature 25°C
Operating environment		**Ambient temperature**	°C	0 to 40			
Operating environment		**Relative humidity**	%	20 to 90			
19 inch rack installation space			U	40			EIA standard
Mass			kg	460	496	532	
I/O terminal block position			-	Front bottom (field wiring type)			Suitable wire size: AWG1 (max)
External interface position			-	Bottom of the front side (serial communication, LAN, contact signal and remote ON/OFF, EPO)			LAN interface is optional

Note 1. The allowable voltage range for AC input varies depending on the load factor. -40% to +15% if the load factor is 70% or less.-20% to +15% if the load factor exceeds 70%. Regarding the voltage error detection -40% if load factor is 70% or less, the power return detection will be -20%.

Note 2. When automatic judgment is set, the frequency synchronous range can be set from ±1%, ±3% and ±5% (factory setting: ±3%) and the allowable frequency range at this time (asynchronous operation range) will be ±8%. The device will switch to battery operation once ±8% is exceeded.
If set to fixed frequency, the output frequency will be fixed at 50 Hz or 60 Hz regardless of the input frequency and the allowable frequency range at this time will be 40 Hz to 120 Hz. The device will switch to battery operation once the 40 to 120 Hz range is exceeded.
In the case of either setting (automatic judgment and fixed frequency) recovery from out of allowable range will occur when the frequency has returned to ±8% or less. Moreover, the input frequency must be within the values set in the frequency synchronous follow-up range (±1%, ±3%, ±5%) or the inverter will not start.

Note 3. The synchronous changeover conditions with the bypass circuit are that the frequency setting mode is set to automatic judgment and that the input frequency is within the frequency synchronous range and the input voltage is within the rated value fluctuation range.

Note 4. Values within parentheses are when the N+1 unit setting is enabled.

Note 5. When starting up, the output supplies from the inverter. (Inverter start-up type)

7. Conclusion

Further globalization of the economy moving forward will position the securement of power infrastructure across various regions as an important issue. Therefore, higher reliability, higher efficiency, and lower cost UPS will be in demand.

We will continue to quickly develop products to meet these market demands and provide the products that fulfill our customers' needs.

We sincerely thank the many people involved in the development and realization of this UPS product for their advice and support.

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