# Development of a Power Conditioner for Photovoltaic Power Generation "SANUPS P61B"

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## 1. Introduction

After the Great East Japan Earthquake and the subsequent nuclear power plant accident, concerns for electricity shortages and society's demand for energies which consider the global environment have led to an ongoing increase in the number of power generation facilities using reusable energies, with a focus on photovoltaic power generation systems. In particular, the rising concern regarding the reduction of $CO_2$ in order to prevent global warming is raising expectations towards even more efficient power conditioners for photovoltaic power generation. The feed-in tariff system for renewable energy implemented in 2012 is another factor behind the acceleration of market growth. Moreover, small-scale photovoltaic power generation systems which efficiently utilize limited spaces are attracting attention recently such as the roofs of housing complexes, stores and small offices as well as vacant land, etc.

This paper provides an overview of "SANUPS P61B", a power conditioner for photovoltaic power generation developed in response to these requirements.

## 2. Background of the Development

In the case of the mentioned small-scale photovoltaic power generation system, installation and set-up are performed by system integrators and mass retailers, therefore introduction and operation must be easy. Many such systems are installed in housing or relatively close to residential areas, therefore there is a demand for different specifications to the conventional power conditioners for industrial applications. The main specifications in demand are as follows.

(1) The system is low voltage grid connection not requiring a cubicle installation and discussion regarding connection with electronic power companies in the planning phase.
(2) A general electrical work item (less than 50 kW) not requiring the assignment of a primary technician nor notification of safety regulations.
(3) Single-phase output not requiring insulation.
(4) Long life
(5) Low noise
(6) High environment resistance

In response to this situation, Sanyo Denki has developed a power conditioner for photovoltaic power generation "SANUPS P61B" series consisting of models with basic unit capacities of 1.5 kW and 5 kW single-phase output, which cover the under-10 kW capacity area previously not included in our product line-up.

## 3. Product Overview

### 3.1 Power conditioner main unit

Fig. 1 shows the 1.5 kW model and 5 kW model of the "SANUPS P61B" series. A maximum of three power conditioners can be centrally managed on an LCD panel supporting both wired and wireless connection (mentioned later), therefore can be used to configure systems from 1.5 kW to 15 kW. Also, if wired connection is used by operating a remote switch to start and stop, up to 10 power conditioners can be connected, therefore enabling configuration of a system with a capacity as high as 50 kW if the 5 kW model is used. Fig. 2 shows the main system configurations of the "SANUPS P61B" series.


Fig. 1: “SANUPS P61B” series

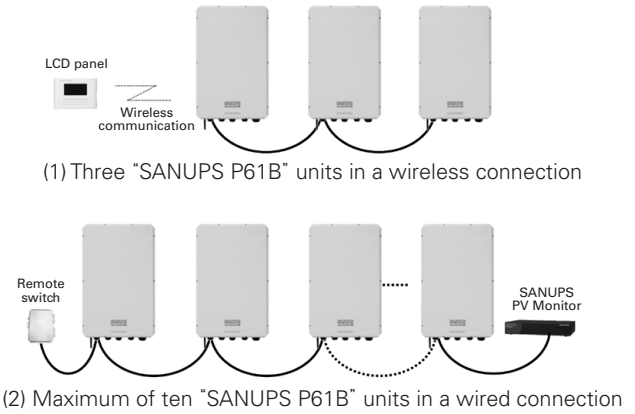


Fig. 2: Main system configurations of the “SANUPS P61B” series

### 3.2 LCD panel

Fig. 3 shows the LCD panel.

The LCD panel is used to operate the “SANUPS P61B” and confirm internal information. Communication with the main unit can be either via wired connection or wireless connection. In the case of wired connection, the LCD panel is powered by the “SANUPS P61B” unit and can be used independently in the event of a power outage. Wireless connection enables systems to be installed in any location by using the IEEE802.15.4 standard (Note 1) which uses a 2.4 GHz frequency range.

Moreover, the LCD panel features a 128 x 64 dot matrix LCD display and increases visibility by displaying up to 5 lines of 10 full-width alphanumeric characters (20 half-width characters), providing information related to the power conditioners in an easy-to-understand way. The panel is operated using the 4 buttons below the screen. Descriptions of button operations are displayed on the screen, achieving both an easy-to-understand user interface and sophisticated design.


Fig. 3: LCD panel

## 4. Features

### 4.1 High efficiency

The main circuit for the “SANUPS P61B” uses a non-insulating method that does not use an insulation transformer. Moreover, optimum part selection and circuit design have led to reduction of heat loss and higher efficiency.

In general, switching frequency must be lowered in order to reduce switching loss which can cause high frequency noise to occur however our optimum design achieves both high efficiency and low noise, which is explained next.

As a result, the “SANUPS P61B” 5 kW model has achieved top class conversion efficiency in the industry (Note 2) at 95% (Note 3).

### 4.2 Ultra low noise

In order to achieve ultra low noise, the “SANUPS P61B” series was developed with no fan and less inverter high frequency noise (mosquito noise). A thermal analysis tool was introduced from the initial development phase in order to achieve a fan-free design. As a result, the development timeframe was shorted and a product with less noise than the conventional product through optimum design of performance and cost.

### 4.3 Superior environment resistance

The “SANUPS P61B” series adopts an enclosed design and separates the operation function from the main unit, therefore achieving a configuration with superior dust-resistance and waterproof properties. This means the power conditioners are protected from infiltration by rainwater, dust, small insects, animals, etc., making allowing them to be used outdoors for extended periods of time with high reliability.

The “SANUPS P61B” series has been allocated a protection level of IP65 (Note 4) for dust-resistance and waterproofness at the protection performance test implemented by the Research Institute of Marine Engineering.

### 4.4 Isolated operation function

The "SANUPS P61B" series can switch to isolated operation mode by a manual operation on the LCD panel. Two specifications for output method during isolated operation have been prepared. These are a single-phase, 2-wire 101 V type and a single-phase, 3-wire 202 V type. In the case of the 202 V model, the rated output during isolated operation is identical to the rated output during grid-connected operation mode, therefore even if a power outage occurs, as long as the photovoltaic power generation systems are generating power, the generated electricity will be used to the fullest on emergency equipment.

### 4.5 Junction box function

A junction box function enabling a maximum of 4 circuit inputs is a standard feature of the "SANUPS P61B" 5 kW model. It also supports DC concentrated input and a system configured of various photovoltaic battery modules.

## 5. Circuit Architecture

This device consists of a booster converter circuit, inverter circuit, control circuit, utility protective circuit, communication circuit, etc. Fig. 4 shows the circuit block diagram for the "SANUPS P61B" 5 kW model.

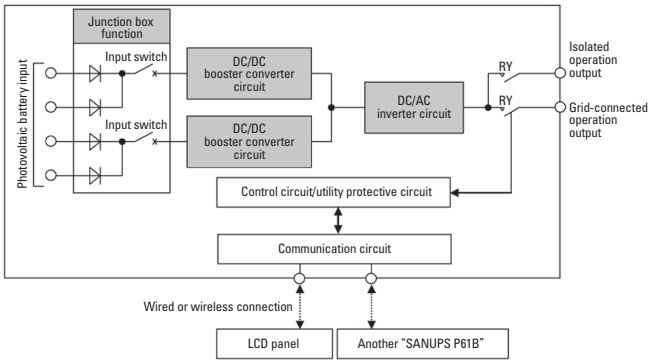


Fig. 4: Circuit block diagram (5 kW model)

### 5.1 MPPT circuit

The "SANUPS P61B" 5 kW model is equipped with two MPPT circuits. Even if the voltage of the two strings connected to the input circuit differs (a string consists of multiple photovoltaic battery modules connected in series), power generation efficiency can be improved by efficiently extracting the electricity generated by each string.

### 5.2 Communication circuit architecture

Communication between the power conditioner and LCD panel is either wired or wireless.

The wired connection interface uses RS-485. RS-485 adopts a balanced channel with a twisted pair cable and achieves relatively stable communication over long distances. Communication protocol conforms to standard Modbus protocol and increases customer's system configuration flexibility. Moreover, compatibility with the information data arrangement of conventional SANUPS P series models is maintained, therefore connection with Sanyo Denki's "SANUPS PV Monitor" is possible.

Moreover, a wireless communication function adopting the IEEE802.15.4 standard is a standard feature, therefore when wireless connection is used, communication cable installation work can be omitted.

## 6. Operational Advantages

### 6.1 Can be installed anywhere

Due to the low noise of the "SANUPS P61B" series, it does not need to be located far from residential areas and can be operated with peace-of-mind in places where people pass regularly and near buildings. It is also able to withstand environments such as vacant agricultural land, etc. where people do not normally go, therefore providing long-term usage with peace-of-mind. The ability to install the "SANUPS P61B" series anywhere is a big advantage to system integrators and mass retailers who receive a wide-range of installation requests from customers.

### 6.2 Easy introduction

The "SANUPS P61B" series adopts single-phase, 3-wire output, therefore there is no need to prepare an insulation transformer. The "SANUPS P61B" series is also currently applying for JET certification (Note 5) as an outdoor power conditioner for photovoltaic power generation. This will reduce the time and cost customers must invest in discussing connection with electricity power companies.

### 6.3 Utilization as a string inverter

If a photovoltaic battery string is connected in parallel and the battery capacity is increased, common power conditioners require the voltage of each string to be leveled out otherwise it will not be possible to extract the generated electricity to the fullest. As a countermeasure for this, a power conditioner could be installed for each string and using power conditioners in this way is known as "string inverter".

The "SANUPS P61B" series offers the optimal power

conditioners for string inverters and by using system configurations with multiple units and a two MPPT circuits, the generated electricity of each string can be extracted, increasing the power generation efficiency of the overall system. This utilization method is beneficial as photovoltaic power generation systems in limited spaces such as the roofs of housing complexes, stores and small businesses. Fig. 5 shows an example of use as a string inverter. The operational status and power generation of each power conditioner are different depending on the string however this can be centrally monitored on the LCD panel or the “SANUPS PV Monitor”.

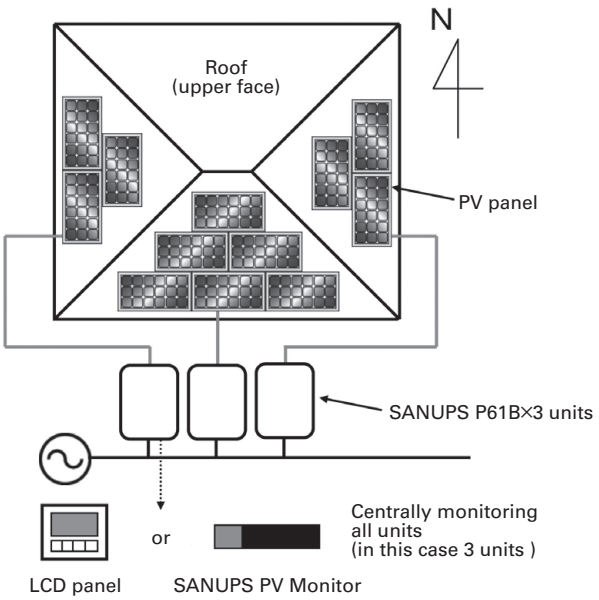


Fig. 5: Example of use as a string inverter

## 7. Options

### 7.1 Sunshade

The sunshade is an option available for the “SANUPS P61B” which serves the purpose of blocking direct sunlight. By mounting a sunshade on the “SANUPS P61B”, temperature elevation due to direct sunlight exposure can be alleviated.

The sunshade can be mounted on the “SANUPS P61B” using the provided brackets without losing the IP65 protection level. Fig. 6 shows the sunshade mounted on the 5 kW model.


Fig. 6: Sunshade

### 7.2 SANUPS PV Monitor

Connecting our “SANUPS PV Monitor” to the “SANUPS P61B”, enables remote monitoring as well as collection and analysis of data relating to the power conditioner’s status and measurements. Fig. 7 shows an image of the connections when using the “SANUPS PV Monitor” for remote monitoring.

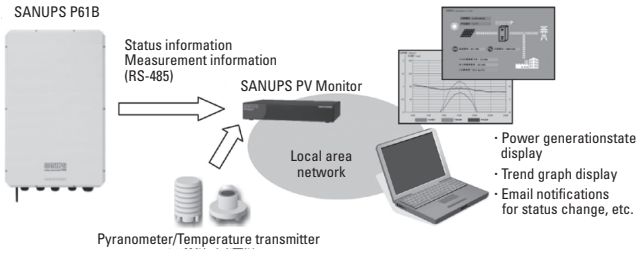


Fig. 7: Image of connection to “SANUPS PV Monitor”

## 8. Specifications

Table 1 shows the standard specifications of this device.

Table 1: Standard specifications for “SANUPS P61B”

| Item \ Model | | | P61B152SJ | P61B502SJ | Remarks |
|---|---|---|---|---|---|
| Rated output capacity | | During grid-connected operation | 1.5 kW | 5.0 kW | |
| | | During isolated operation | 1.5 kW (with a rated voltage of 202 V AC) 0.75 kW (with a rated voltage of 101 V AC) | 5 kW (with a rated voltage of 202 V AC) 2.5 kW (with a rated voltage of 101 V AC) | |
| Insulation method | | | No insulation transformer | | Transformer-less system |
| DC input | Rated voltage | | 220 V DC | 280 V DC | |
| | Input voltage range | | 0 to 450 V DC | | |
| | Input operating voltage range | | 60 to 400 V DC | 60 to 450 V DC | Startup voltage: 80 V DC Rated output range 1.5 kW: 150 V to 350 V DC 5 kW: 150 V to 400 V DC (With suppression of output by temperature) |
| | No. of input circuits | | 1 circuit | 4 circuits (with batch input) | |
| | No. of MPPT circuits / mode | | 1 circuit | 2 circuits / batch mode, 2 system independent modes | |
| | Max. current capacity | Overall / MPPT circuits | 11 A / 11 A | 35 A / 18 A | |
| | | Overall / input circuits | 11 A / 11 A | 35 A / 9 A | |
| AC output | No. of phases / wires | | Single phase, three wires | | |
| | Rated voltage | During grid-connected operation | 202 V AC | | |
| | | During isolated operation | 101 V AC | | 202 V AC specifications also available (set upon dispatch) |
| | Rated frequency | | 50 Hz / 60 Hz | | |
| | AC output current distortion rate | | 5% or less of the total current, 3% or less of each next harmonic wave | | Rated output current ratio |
| | Output power factor | | 0.95 or higher | | At rated output in grid-connected operation |
| Efficiency | | | 94.5% | 95% (excluding the junction box function) | Efficiency measurement method based on JIS C 8961 |
| Communication method | | | Wired: RS-485, wireless: IEEE802.15.4 | | |
| Cooling system | | | Natural air-cooling | | |
| Utility protection function | | | Over-voltage (OVR), under-voltage (UVR), over-frequency (OFR), under-frequency (UFR) | | |
| Islanding operation detection | | Passive method | Voltage phase jump detection method | | |
| | | Active method | Frequency feedback method with step injection | | |
| Multiple units linkage function | | | With | | |
| LCD panel | | | Display: Monochromatic graphic LCD with backlight (128 x 64 pixel) | | Option |
| Acoustic noise | | | 28 dB or less | | A-weighting: Front 1 m |
| Operating ambient temperature | | | -20 to +60˚C | | (With suppression of output by temperature) |
| Dust-resistance and waterproofness level | | | IP65 | | Main unit |

## 9. Conclusion

Moving forward, the further popularization of photovoltaic power generation will see an emergence of demands for diversification of photovoltaic power generation systems and further enhancement of the power conditioner lineup. Moreover, it is believed that power conditioners will be required to have higher reliability, higher efficiency, higher functionality and lower cost.

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

We would like to extend our deepest appreciation to the cooperation and advice of the working group members and other involved persons who helped make this development and commercialization possible.

(Note 1) IEEE802.15.4 is a set standard established by IEEE, an organization headquartered in the U.S.
(Note 2) As of August 2013. For power conditioners for photovoltaic power generation with the same capacity for use within Japan. Results from Sanyo Denki inspection.
(Note 3) Rated load ratio based on “JIS C 8961 Measuring procedure of power conditioner efficiency for photovoltaic systems” .
(Note 4) Classification defined in “JIS C 0920 Degrees of protection provided by enclosures (IP Code)” .
IP65: No ingress of dust, no impact of water jets from any direction.
(Note 5) JET: Japan Electrical Safety & Environment Technology Laboratories

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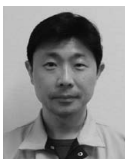

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