Development of New Megasolar PCS Models and Functions Conforming to Feed-in-Tariff System in Japan

Kazuho Hasegawa,
Naoto Kameda

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Abstract

Four years have passed since the enforcement of the Feed-in-Tariff (FIT) System in July 2012. The demands for the construction of solar farms have rapidly increased in Japan. The demands for our Power Conditioning Subsystems (PCSs), SP310 Series, sharply increased due to our adoption of a 750V system where maximum DC input voltage is 750V, which is ahead of our competitions. Along with an increase in solar farms, there have been new rules for grid connections requiring new functions such as a Fault Ride Through (FRT) and customer requests for PCS price reduction due to the gradual lowering of FIT prices. Under such circumstances, we could maintain an order amount level for photovoltaic PCS because of our on-going efforts to develop new PCS models and new functions. This photovoltaic generation market is in a time of big changes. In order to increase orders in the future, we need to improve our products.

1 Preface

It has been four years since the Feed-in-Tariff (FIT) system was enacted on 1 July 2012. Ahead of our competitors, we developed Power Conditioning Subsystems (PCS) of 750V class, the SP310-250T. We adopted the maximum DC input voltage of 750V as the highest voltage in the low-voltage class defined in Japan. Our new PCS models have been favorably accepted by our customers because our models help reduce the parts of the power distribution equipment and power distribution losses in the system building at the solar farm. This compares with our conventional 600V-class PCS model. As such, we increase sales significantly in synch with a sharp expansion of demand for PCS triggered by the enforcement of the FIT System. In regard to PCS product lineups for our 750V systems, only one model of the SP310-250T type was available previously. Then, there were some model changes and newly developed models were added. Currently, four models are available: SP310-250T-DG, SP310-250T-DN, SP310-100T-DG, and SP310-100T-DN. We continue on to develop new more models.

This paper explains why, despite our strong photovoltaic (PV) PCS sales, we made changes to the models and added new models so frequently in such a short time of about four years after the start of FIT. We will explain according to the each development factors. This paper also introduces some future developments.

2 Development of New Models

While orders of PV PCS kept on increasing based on the FIT Law, we developed the products described below according to trend analysis on the ordered transactions.

2.1 Development of New PCS Models Exclusively for Outdoor Use

In many cases, the PCS for megasolar farm is installed outdoors. Since the SP310-250T first model uses an indoor panel, we had to prepare and accommodate it in an outdoor panel for outdoor application. Under the conditions where we can intake outdoor air into the PCS, the outdoor panel will be of the fan-cooled type. Meantime, there are challenging issues like a salt hazard areas where outdoor air cannot be taken inside or in the cold where air temperatures are lower than the specified operating temperature range for the equipment. In such cases, we will select an enclosed package of the air-conditioned cooling type for the outdoor panel. While the number of received orders increased, the installation condition requiring air-cooled outdoor

Fig. 1 Outdoor Installation Type PCS, SP-310-250T-DG

As a result of outdoor installation type product development, there was no need for adopting a double enclosure construction and suspension work due to the weight limit.

panels account for almost 70% of the orders. Thus, the air-cooled outdoor installation type PCS, SP310-250T, was developed (Fig. 1). Further, there was no need for adopting a double enclosure construction: one for the PCS and other for the outdoor panel. The light design made it easier to install. To tell the difference between an outdoor and indoor PCS model, the PCS type description was added with a branch number of an indoor "N" or outdoor "G." [Example: SP310-250T-DN (for indoor type) and SP310-250T-DG (for outdoor type)]

2.2 Development of PCS Models with a Maximum Output of 100kW

Since the SP310-250T specifies the maximum output of 250kW, the PCS capacity for the megasolar farm comes in 250kW or its multiples. The solar panel installation capacity is dependent in many cases on the site area where the panels can be installed. The PCS capacity therefore, often required to be less than 250kW or its multiples. In responding to this subject, we developed a PCS model with a maximum output of 100kW ("100kW unit" hereafter) by the name of the SP310-100T Series. We already had a 100kW model in the past (see SUNGENEC Series: Meiden Jiho No.324, 2009/No.3, pp.64-69.). The main reason why we developed a new 100kW unit in this time is that the 100kW model adopts the DC 750V system. This is a key feature of the 250kW models for the SP310 Series. Since the 750kV system is used in common with all models, the number of series connections of solar panels in a solar farm can be unified. This greatly reduced the design work

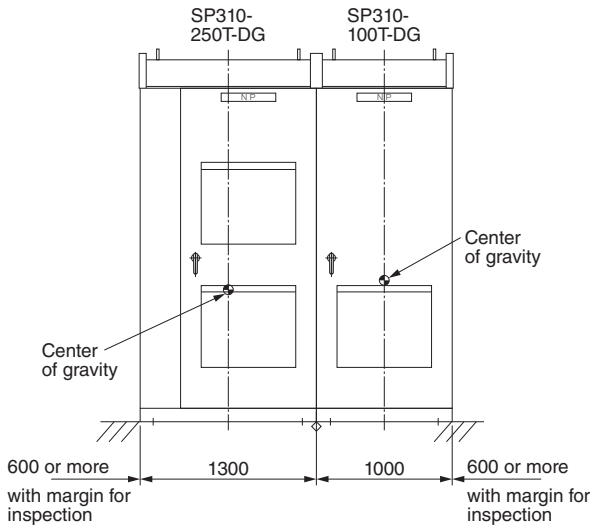
Table 1 Outdoor Installation Type PCS: Specifications of Maximum Output 250kW and 100kW Models

Specifications of SP-310-250T-DG and SP-310-100T-DG are shown. Both types are unified into the 750V system based on the MPPT control voltage range of 400-750V.

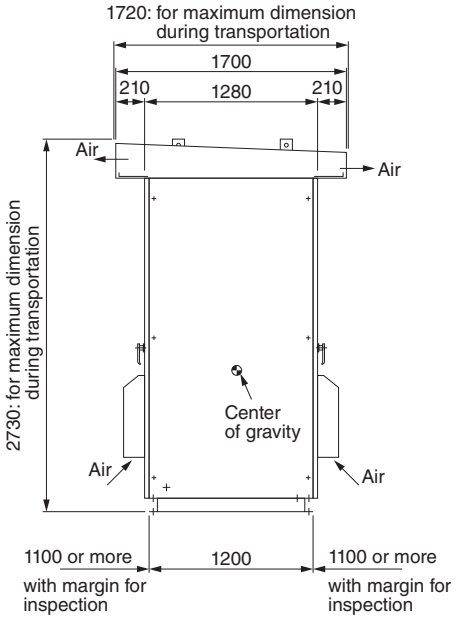
Model (Outdoor installation type)		SP310-250T-DG	SP310-100T-DG	Remarks
DC input	MPPT operation voltage range (V)	400～750		
	Rated voltage (V)	500		
	Input circuit	2 circuits		
	Connection cable size (sq)	325 Max.	200 Max.	
AC output	Electrical system	3-phase 3-wire		
	Insulation system	Power frequency insulation transformer system		
	Rated output power (kW)	250 (250kVA)	100 (100kVA)	
	Rated output voltage (V)	420/440		
	Rated output current (A)	344/329	138/131	
	Output power factor	0.99 or above (control for unity power factor) ※ Leading as seen from PCS		At the rated output
	Connection cable size (sq)	325 Max.	200 Max.	
Conversion efficiency (%)		96.5	96.5	At the rated output
Construction		Steel plate fabricated self-standing outdoor panel (general outdoor specifications) ※ Without salt damage durability specification		IP44
Dimensions (mm)		W1300 × H2730 × D1200	W1000 × H2730 × D1200	
Mass (kg)		2650	1750	
Environment	Ambient temperature (℃) / Relative humidity (%)	−10～40 / 5～100		

burden for the customers. Table 1 shows specifications of the latest outdoor installation type 250kW (SP310-250T-DG) and 100kW (SP310-100T-DG) models. Since the equipment configuration of 250kW and 100kW machines have been developed into a unified product, horizontal development (having the same features) among models becomes easy and we can be ready for quick development against new functions (for example: new functions needed to meet grid connection rules introduced in Section 3 below) required for the PCS in the future.

To provide a good design harmonization between 250kW and 100kW machines for easier installation work, the panel size of the 100kW model



(a) Front elevation: 250kW model (left) and 100kW model (right)



(b) Side view: 100kW model

Unit: mm

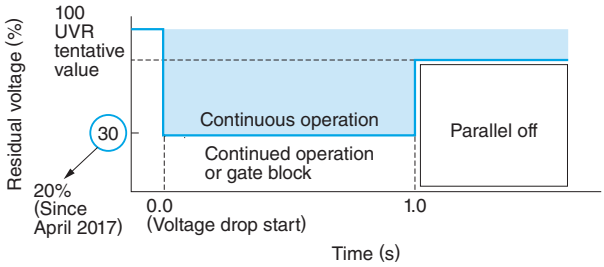
Fig. 2 **Outdoor Installation Type PCS: External Drawing of Panel Installation Side-by-Side**

By unifying outer size (H × D) of maximum output 250kW machine (SP310-250T-DG) and 100kW machine (SP310-100T-DG), the panel installation arrangement side-by-side becomes possible.

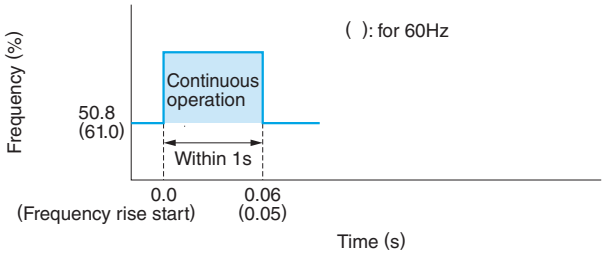
was made to fit the 250kW PCS outdoor panel. We can realize the installation of the 250kW and 100kW model panels side-by-side. Fig. 2 shows an external drawing of side-by-side panel installation.

3 New Functions of PV PCS Needed for Future Grid Connection Rules

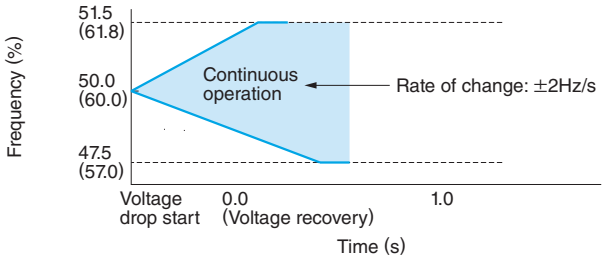
As many solar farms started commercial operations by the enactment of the FIT System, provi-



(a) Voltage drop durability



(b) Frequency regulation durability (step-up)



(c) Frequency regulation durability (ramp-up/down)

Fig. 3 **FRT Voltage and Frequency Deviation Range Stipulated by the Grid-Interconnection Rule JEAC 9701-2012**

Since continued operation of power generation was required even in the case of residual voltage 20% down, design change was needed for the security of energy resources.

sion of new functions described below is needed for future PCS installations in order to easily clear the approval of the grid-connection application from a relevant power company. This is from a viewpoint of the stable management of grid systems. It is anticipated that the PCS will be required to provide new functions in the future. Accordingly, the development of new functions is always indispensable. Significant necessary functions are introduced below.

3.1 Fault Ride Through (FRT) Function

The FRT function is the requirement to maintain PCS operation of power generation even under the specified conditions of voltage drop or frequency deviation. Fig. 3 shows FRT Voltage and Frequency Deviation Range Stipulated by the grid connection Rule JEAC 9701-2012.

Since the system voltage is stipulated to continue operation even though the voltage has lowered down below the rated voltage level by 20%, it is necessary to secure the control voltage source in the event of a voltage drop. For a solution in such a case, we developed a new model (D Series: the last letters of the type description is -DN or -DG) that is applicable without an Uninterruptible Power System (UPS). The scheme is that another new model (F Series: the last letters of the type description is -FN or -FG) or part of solar panel generation (DC source) is used as a direct control source from the DC side while a UPS is installed inside or outside the PCS unit. Presently, models of the D Series are used to provide the FRT functions. Regarding frequency deviation, the islanding operation sensor function of the PCS is used to define the setup value of frequency deviation. To avoid wrong detection of an islanding operation, we reviewed the setup value of the frequency deviation specified for the FRT function.

3.2 Newly Developed Active Islanding Operation Sensor Function

If there is a power outage on the utility grid and it becomes an islanding operation, the solar farm side needs to detect this islanding operation and stop its power generation. Currently, the active method of detecting islanding operation is different among PCS suppliers. In the case of our PCS, the reactive power injection system is adopted. In this system, a small amount of reactive power in a periodic waveform, amounting to several percent of equipment rating, is injected into the grid side so that a frequency deviation in the grid system can be caused to detect the state of islanding operation by the frequency change in the grid system. The PCS in the solar farm is synchronized with the reactive power injection timing, but if there is another solar farm using reactive power injection type PCS in the same grid network, there will be interference between solar farms by the effect of reactive power injection. It then becomes difficult to accomplish the detection of islanding operation. Because of such a challenge, and due to necessity for fast parallel off upon the occurrence of islanding operation, it is indispensable to install a new type of active islanding operation sensor function (step-injection frequency feedback type). We are now working on the development of related products because this will become an imperative function in April 2017.

3.3 Output Suppression Control Function Based on Generation Forecast

Since the quantity of power generation at a solar farm is dependent on the weather, power generation operation during holidays continues like operation during weekdays despite holidays having a relatively less load demand. When the quantity of solar power generation exceeds the demand level, the generation has to reduce. As such, we set up a condition of output suppression to control power generation in the unit of one whole day, per a request of output suppression transmitted on the previous day when demand on the next day is predicted to be low. In addition, if the number of solar farms is increased to affect the demand level in the future, reverse tidal flow is considered to occur in the time zone where power demand is small. In such a case, power suppression control is frequently required. For this reason, the present program of output suppression in a one-day unit by means of manual ON/OFF function is canceled and a new function of remote operation for output suppression control in the time unit shorter than one whole day will be adopted with the use of output command by calendar function. A provision of a better output control functions will be the condition for grid connection application approval in the future.

4 Additional Functions Needed for Future PV PCS

Additional functions considered necessary in the future are introduced below.

4.1 Self-Supporting Mode Operation Function

The self-supporting mode operation function is a function by which electric power generated by solar panels can be utilized even in the middle of a power outage from the grid. When the self-supporting mode operation function is added to the PCS, this PCS can be switched over to the self-supporting mode and power can be used effectively. In this case, the PCS regularly supplying power to the grid system according to the FIT System is switched over to the circuit of local load machines by changing the destination of power supply at the time of a power outage from the grid. Fig. 4 shows an example of PCS system configuration provided with a self-supporting mode operation function (rated voltage 440V). As an emergency power source in the case of a disaster, we are expecting a potential demand

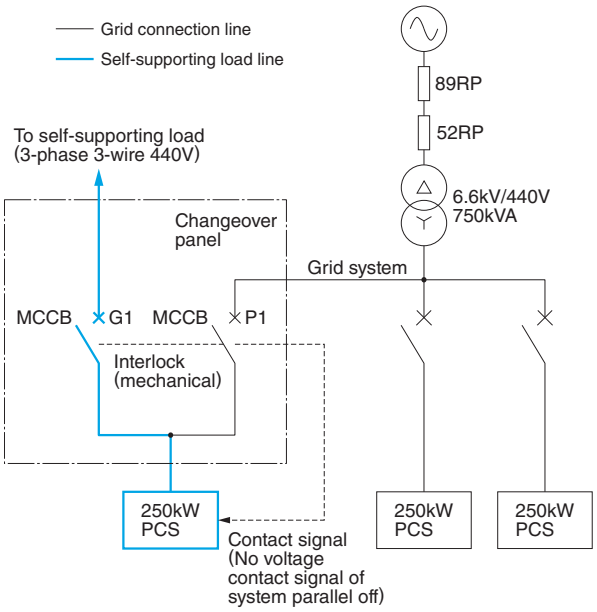


Fig. 4 **Example of PCS System Configuration Provided with Self-Supporting Mode Operation Function (Rated Voltage 440V)**

In the case of a power outage from the grid, self-supporting mode operation is possible with a switchgear through which the PCS connection is switched over from the utility system to the autonomous load side.

for self-supporting mode operation function in the future. The SP310 Series shipped in June 2015 and thereafter is provided with the self-supporting mode operation function. Even models of former types can perform an interlinked operation with emergency generators. When an emergency generator is included in local load facilities, both self-supporting mode operation and interlinked operation with an emergency generator can be performed.

4.2 Development of High-Performance Products through Adoption of New Technical Factors

While we need to improve our products for convenience, FIT-based prices are constantly lowering. Under such circumstances, the development of high-performance PCS is needed in the market.

Inverter elements used in PCS equipment are now composed of Silicon (Si). As a high-performance material that is considered to replace Si, Silicon Carbide (SiC) is getting high attention in the market and active development programs are promoted in Japan for commercialization. If SiC inverters are adopted in the future, it is expected to improve power conversion efficiency and reduce PCS size as a result of inverter compact design. In order to use capabilities of SiC inverters effectively, inverter operation at high temperatures will become necessary. For this reason, the mounting of SiC inverters requires modification of not only electrical circuits but also peripheral components in terms of thermal durability. Therefore, an entire perspective on the issues is needed for the development of such products. The adoption of SiC inverters has already begun for small-capacity PCS (up to 5kW) in the industry. Going forward, when the use of SiC inverters in the PCS becomes common and the capacity becomes bigger, there is a possibility that the adoption of the SiC inverter may go to industrial PCS (up to 250kW).

As for other technological factors, we can indicate local cooling technologies to be used in PCS equipment. Presently, the PCS to be delivered to coastal areas is accommodated in an enclosed package of air-conditioned type. When an enclosed PCS panel construction is adopted and a concentrated cooling system is established to cool the heat-generating parts located inside the enclosure, we consider that package-less versions can also be delivered to salt hazard areas. Development of such products, however, will require substantial modification in structure. FIT-based prices tend to be reduced year after year and requests for PCS price reduction will be getting stronger. Since highly efficient solar farm operation will be required more in the future, development of products must be carried out with long-term perspective.

5 Postscript

This paper introduced the present state of new model and function development regarding the PV PCS, focused mainly on the four years after the enactment of the FIT System. Against the technical background of new models and function developments, we can cite various factors: factors of solar farm installation condition after the start of FIT, factors of grid connection rules where adding new functions in PV PCS is a must, and factors of customer's needs for more functions and higher performance. The business climate for photovoltaic generation is always changing. Going forward, to assure orders for the PV PCS, we need to keep working on product development.