Japan-U.S. New Mexico Smart Grid Collaborative Demonstration Project

Yoshinobu Ueda,
Yu Sasaki

Keywords Smart grid, Photovoltaic generation, FRT (Fault Ride Through)

Abstract

The smart grid has been gaining attention as a technology that enables a grid-connection of large amounts of renewable energy resources such as Photovoltaic (PV) generation. The New Energy and Industrial Technology Development Organization of Japan is promoting the "Japan-U.S. New Mexico Smart Grid Collaborative Demonstration Project" in cooperation with the Government of the State of New Mexico, U.S.A. As part of this demonstration project for the smart building demonstration in Albuquerque, we have developed and manufactured the photovoltaic Power Conditioning Subsystem (PCS) equipped with the Fault Ride Through (FRT) function and power output restraining function. Such functions improved the robustness during the grid-connection and islanding operation.

1 Preface

In many countries around the world, introduction of renewable energy resources is promoted in response to global environmental issues and energy security. In the case of the grid-connections with a large volume of renewable energy resources such as Photovoltaic (PV) resources, (which is widely changeable with weather conditions) there are many challenges such as a voltage rise in distribution feeders due to reverse power flows from PV power generation, the occurrence of surplus power, and necessity for taking measures to secure the frequency adjustment power. As a technology to solve such challenges, a technical concept by the name of smart grid has been recently noted where power flows are efficiently managed by using IT expertise and based on information acquired from both grid and electricity user sides.

In consideration of future worldwide business development of Japanese grid-connection technologies, the New Energy and Industrial Technology Development Organization (NEDO) is now undergoing the "Japan-U.S. New Mexico Smart Grid Collaborative Demonstration Project" in cooperation with the Government of the State of New Mexico, U.S.A. This smart grid project is in cooperation with the Green Grid Initiative project conducted by the State of New Mexico.

This demonstration research aims at the building of a MicroGrid in a distribution line scale where the effect from power yield changes of renewable energy resources can be minimized through the cooperative control using electricity user side equipment such as lead-acid batteries and thermal storage tanks. The demonstration project promoted in North America is based on the following missions:

(1) Verification is carried out on the techniques difficult to use in Japan because of regulatory restrictions, and on the performance of various equipment under circumstances different from those in Japan. The acquired data and expertise are fed back to future research and development of smart grids in Japan.

(2) Through the introduction and demonstration of Japanese energy-related equipment and facilities into real power grid systems there, the results of the demonstration project will serve as a springboard to help the Japanese suppliers develop their business in the U.S. and world markets.

(3) Through effectively utilizing various data obtained from this demonstration project, the established expertise is used for smart grid standardization programs which are expected to increase sharply in the future.

As part of this demonstration project, we built a MicroGrid system capable of islanding operation in a commercial building Albuquerque City. This

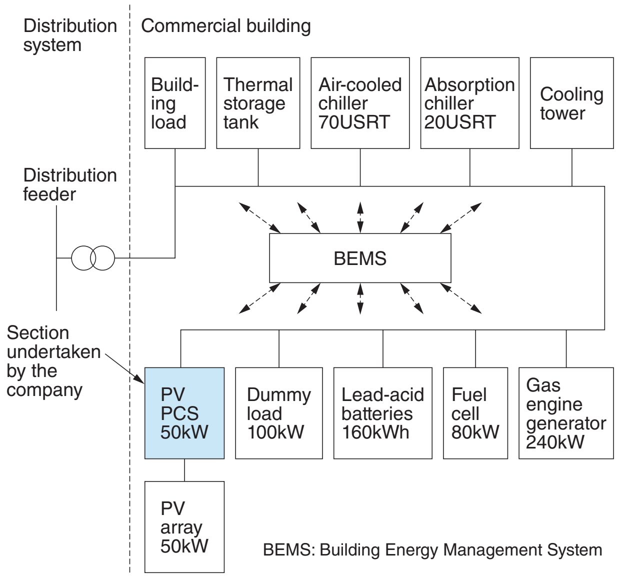

Fig. 1 Configuration of the Demonstration System

This diagram shows the MicroGrid configuration built for this demonstration project. We manufactured the PV PCS.

MicroGrid is grid-connected with an existing U.S. grid power distribution system as shown in Fig. 1. For this project, we built the demonstration system during Fiscal 2010 to Fiscal 2011, and the demonstration test was conducted during Fiscal 2012 to Fiscal 2013. Among the demonstration items of this project, we have been in charge of verification of the improved robustness (stability against system turbulence) in regard to the PV Power Conditioning Subsystem (PCS). This paper introduces the development and manufacturing of PV PCS and the results of functional verification.

2 Contents of Demonstration System Development

2.1 Functions of PV PCS

2.1.1 Improvement of Robustness for PV PCS

Generally speaking, the PV PCS has highly sensitive protection features when viewed from the standpoint of equipment protection and system protection. The PV PCS tends to respond sharply to turbulence occurring in the grid system, thus making unwanted disconnections.

When Distributed Energy Resources (DERs) such as PV generation are introduced to a grid power system in a large quantity, and if amounts of DERs are disconnected as a result of unnecessary disconnection, such a situation is anticipated to adversely affect the grid power system. For this reason, the technologies of Fault Ride Through

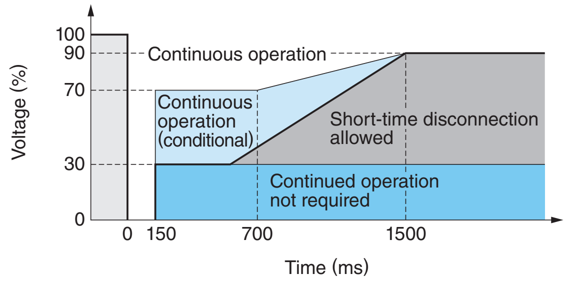

Fig. 2 Scope of Continuous Operation at a Voltage Sag

This diagram shows the scope of continuous operation at a voltage sag defined for this demonstration project.

(FRT) or Low Voltage Ride Through (LVRT) continue operation even in the case of grid power system turbulence are getting recent attention and the standardization programs are gaining traction.

Fig. 2 shows the scope of continuous operation defined for this demonstration project. The defined scope has been stipulated in the grid-connection guidelines[(1)] issued by Bundesverband der Energie- und Wasserwirtschaft (BDEW). The scope of continuous operation denotes the capability of continuous operation to be accomplished by PV PCS. Even though operation is maintained within this scope, the PV PCS will stop working if the set point of grid interconnection protection is exceeded.

In order to increase the added value of the MicroGrid, coordinated operation of multiple DERs including renewable energy sources is carried out. During islanding operation of MicroGrid, however, system voltage and frequency (phase) are likely to change and a phenomenon like voltage balance is also likely to occur. Consequently, unnecessary disconnection tends to take place as compared with the grid-connection operation.

For example, when a disconnection takes place when the PV power yield is high, there can be substantial influence upon the stability of islanding operation. In addition, an active unintentional islanding detection can be a cause of disturbing the power quality during islanding operation. In our demonstration research under this project, whenever the condition of the MicroGrid islanding operation is sensed through the Building Energy Management System (BEMS), an auto-changeover function has been devised so that operation is changed over to the more robust operation and control system by relieving set point for grid-connection protection and by suspending the effect of unintentional islanding detection feature.

2.1.2 Output Restraining Function

Where a large volume of PV power resource is introduced to the grid, the possibility of adverse influence over the stable grid operation is predicted because of the effect of the surplus power under light-load conditions. Even in such a case, in order to achieve effective utilization of energy resources, the PV generation is expected to continue operation for maximum power yield. We then store surplus power in energy storage systems such as lead-acid batteries or thermal storage tanks, and it is desired to feed the power when demand for energy is increased. On the contrary, the storage capacity of energy storage systems is limited and it becomes impossible to operate the system if the upper or lower limits of storage capacity are exceeded. In addition, the energy storage systems are subject to a constant amount of losses at each time process of in and out of energy. Therefore, according to the situation of operation, there may be a case where energy shift by storage does not always contribute to the high efficiency or reduction of CO_2 emission. For a solution in such a case, by adding the function to accept an output reduction command from the BEMS, it allows to realize the stable management of the MicroGrid for a long time. In addition, it also allows for flexible energy management by increasing options of management on the demand side. In particular, for an islanding operation of the MicroGrid, by using PV PCS with the output restraining function, it is expected to contribute to stable grid power system operation.

The output restraining function of PV PCS becomes effective when the operation point is intentionally moved from the Maximum Power Point (MPP) of the PV module output characteristics. **Fig. 3** shows the relationship between the MPP and the working point during output restraint.

The required output restraining level is defined on BEMS side in consideration of loads in the MicroGrid, power output from generation facilities, and total capacity of energy storage systems (power storage equipment, thermal storage tanks).

2.2 Manufacturing Specifications for PV PCS

Table 1 shows the major specifications for the PV PCS manufactured for this project. In order to ensure that the DC voltage range of PV PCS coincides with that of PV battery modules, this DC voltage range is lowered to the level of 50kW class, based on the 100kW machine of the SP100 Series that is for the export model PV PCS.

The PV PCS is accommodated in outdoor casings and installed beneath the PV array.

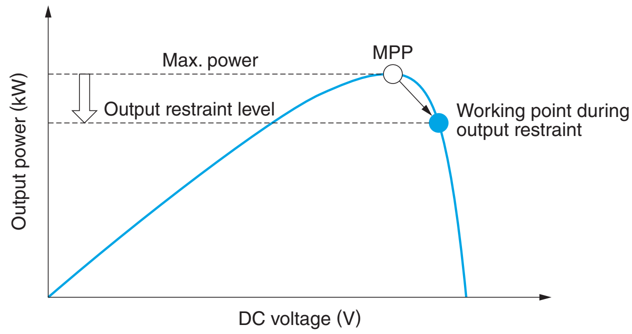

Fig. 3 Output Restrained Operation

The relationship is shown between the MPP and the working point during output restraint indicated on the output-voltage characteristic curve of PV generation.

Table 1 PV PCS Specifications

Major specifications are shown for the developed PV PCS.

Item	Specifications
Rated voltage	480V
Rated frequency	60Hz
Rated capacity	50kW
DC input voltage (MPPT)	250–500V (275–425V)
Power conversion efficiency	94.0% (Max. efficiency)
Installation environment	Outdoors ※A PV PCS specified for indoor use is accommodated in an outdoor casing.

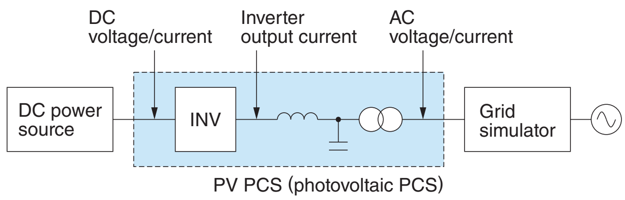

Fig. 4 Testing Circuit for the FRT Function

Configuration of the testing circuit is shown, used to evaluate the FRT function. The grid simulator on AC side can be programmed to cause any type of voltage drop.

3 Result of FRT Function Evaluation

In order to evaluate the newly developed FRT functions, we made internal verification tests using a mini-model of 10kW PV PCS and a grid simulator. **Fig. 4** shows the testing circuit. The grid simulator can be programmed to cause any type of voltage drop.

tinued and a current supply is maintained while residual voltage is 0V. In regard to the range of duration shown in **Fig. 2**, we evaluated the duration time and residual voltage under the conditions other than those of **Fig. 5** and confirmed that the goal range of duration time is attained.

4 Postscript

As part of the MicroGrid demonstration facilities constructed in a commercial building in Albuquerque, New Mexico, U.S.A., we have developed and manufactured the PV PCS that have FRT and output restraining functions. As a result of our internal verification testing, we could confirm that the goal functions and specifications of the project are duly attained.

For our future activities, we will continue to evaluate the effectiveness of the developed functions through verification testing at the project site so that we can contribute to activities for smart grid standardization predicted to progress rapidly.

Lastly, this paper has introduced the result of our activities as a contract research project for NEDO.

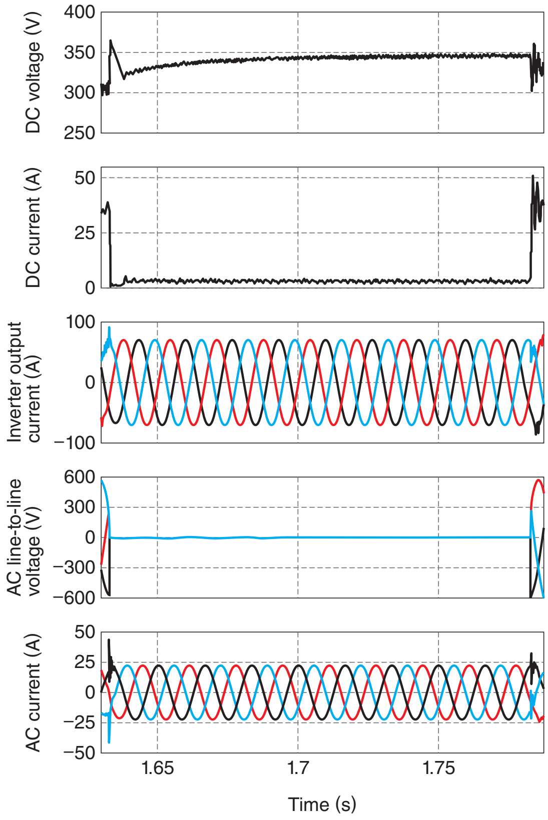

Fig. 5 Result of Continuous Operation Test with a Residual Voltage at 0V

PV PCS operation is continued with a residual voltage of 0V and duration of 160ms.

Fig. 5 shows the result of FRT functional testing with a residual voltage of 0V and duration of 160ms. It can confirm that inverter operation is con-

《Reference》

(1) BDEW: Technical Guideline "Generating Plants Connected to the Medium-Voltage Network," 2010.6