Solar Energy Materials & Solar Cells 95 (2011) 377–381

Contents lists available at ScienceDirect

Solar Energy Materials & Solar Cells

journal homepage: www.elsevier.com/locate/solmat

Research, development and evaluation of measured data for the second stage in Hokuto Solar project ☆

Hiroo Konishi *, Takeshi Iwato, Mitsuru Kudou, Keiichiro Asano

Solar Project Headquarters, NTT Facilities Inc., Granparktower, 3-4-1 Shibaura, Minato-ku, Tokyo 108-0023, Japan

ARTICLE INFO

Article history:
Received 16 October 2009
Received in revised form
17 February 2010
Accepted 27 March 2010
Available online 27 April 2010

Keywords:
Large-scale power conditioner
Mega-solar system
Individual operating system
LCA
PV module

ABSTRACT

The first stage 600 kW system of Hokuto Mega-solar Project has been installed in Yamanashi Prefecture, Japan in 2008. The outline and the developing target of the project are introduced first and some results that have been provided so far are discussed in this paper.

1. Introduction

Solar generation systems are one of the promising measures for reducing global warming and drying up of the energy. An installed capacity target of solar generation systems in our country will be set 4.82 GW in 2010, 14 GW in 2020 and 53 GW in 2030, while the total installed capacity is still 1.92GW in 2007. About 80% of the systems are mainly for residential use and they are of very small sizes. Some large-scale solar generation systems will be expected to construct and intensive development of related technologies is an urgent problem.

The New Energy and Industrial Technology Development Organization (NEDO) advertised for consignment research business called "Verification of Grid Stabilization with Large-scale Photovoltaic (PV) Power Generation Systems" in 2006. The verification tests are carried out in two sites. One is Hokuto Mega-solar Project (HMP) in Yamanashi prefecture and the other is Wakkanai Mega-solar Project in Hokkaido. About 2 MW of solar system has been constructed in HMP. The outline and the developing target of the HMP are introduced and some results that have been provided so far are discussed in this paper.

2. Outline of HMP

The one-line diagram of HMP is shown in Fig. 1. 600 kW of PV modules were installed in the 1st stage (FY2007). They were 24 kinds of PV modules from inside and outside of Japan and two PV systems and they were evaluated for applicability in future mega-solar systems [1]. Their arrays and systems were connected to a 6.6 kV power grid through conventional 10 kW power conditioners (PCSs) and 3 kW PCSs, respectively. A monitoring/measuring (M/M) system of these PV modules and PV systems were constructed [2]. Their data will be able to be seen on the Web.

In the 2nd stage (FY2008-FY2009), 4 kinds of PV modules were selected from the evaluation of the PV modules in the first stage. About 1200 kW of the PV modules have been constructed. In order to connect large PV generation powers to an existing AC grid with high efficiency and reliability, a 400 kW power conditioner (PCS) with some control functions have been developed. They are connected to a 66 kV extra high voltage power grid. The PCS is discussed in detail in the next chapter.

At the final stage (FY2010), about 40 kW PV modules will be installed additionally and total generating capacity will be about 2 MW. Their electrical and mechanical characteristics are measured and evaluated.

3. Development of PCS

The 400 kW PCS will be manufactured and installed in the 2nd stage. Their control and operation system have been studied.

☆ This work was supported by the New Energy and Industrial Technology Development Organization (NEDO).

* Corresponding author. Tel.: +81 354445066; fax: +81 354445630.
E-mail addresses: konish36@ntt-f.co.jp (H. Konishi), iwatot22@ntt-f.co.jp (T. Iwato), kudoum25@ntt-f.co.jp (M. Kudou), asanok24@ntt-f.co.jp (K. Asano).

0927-0248/$ - see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.solmat.2010.03.030

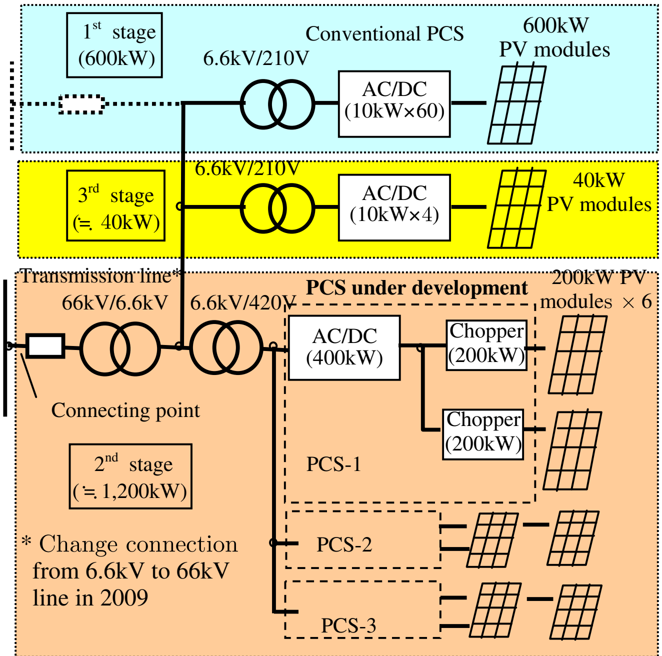

Fig. 1. System configuration.

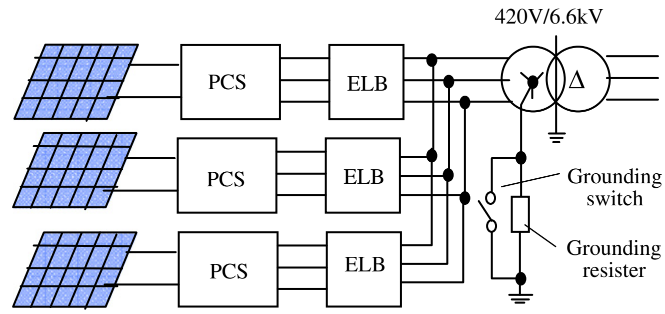

Fig. 2. Detection of DC system fault. ELB: Electric line breaker.

Table 1
Developing target and specification of PCS.

Item	Specification
Capacity	420 kVA/400 kW
Rated AC voltage	420 Vac ± 10%
Rated DC voltage	400 Vdc
Input DC voltage	230–600 Vdc
Switching freq.	4 kHz
Conversion efficiency	95% (including 200 kW × 2 choppers)
Control functions	/MPPT by choppers /Suppression to within 2% of rated AC voltage /Suppression of low-order harmonics to within 80% of the guide-line /Continuous operation over 60% AC voltage within 200 ms periods

Table 2
Comparison of *Po* calculation.

	Individual operating system		Integrated operating system
	Conventional PCS	PCS under development	
Po (%)	91.7	95.6	96.1

The developing targets of the PCS are listed in Table 1. The capacity of the developing PCS was selected 400 kW in consideration of the operation as a mega-solar system, cost, size and expansibility to the future.

The PCS has two 200 kW choppers inside as shown in Fig. 1. A maximum power point tracking (MPPT) function of each chopper finds a maximum PV generation power point between four 50 kW PV arrays by scanning the DC current.

The PCS does not have transformer in order to improve conversion efficiency as shown in Fig. 2. A voltage-up transformer is equipped to connect the grid and its neutral point is connected with a resister to the ground. When a grounding fault occurs in the AC system or the DC system, all the circuit voltages change against the ground. This makes it difficult to detect the fault and to separate the fault part. We adopted the following method to solve the problems. When the grounding fault occurs, it is detected by voltage rise at the neutral line of the transformer. Then a grounding switch is closed and the over-current relay of the electric line breaker (ELB) separates healthy part from the fault part.

Two operating systems are compared for the 1200 kW PV system, which consists of three 400 kW PCSs [2,3]. One of the operating systems is an integrated operating system (master–slave operating system), in which PCSs are operated as if they were one large capacity of PCS. Another operating system is an individual operating system, in which each PCS operates individually responding to the PV generation output. The PCS output *Po* is evaluated for two operating systems using both statistical PV distribution data by JWA (Japan Weather Association) near Hokuto site and assuming efficiency of the large-scale PCS under development.

Table 2 shows the calculation results of *Po*, the integrated operating system is 0.5% higher than the individual operating system. As the difference is little, the individual operating system is taken in HMP because of simplicity of the operating system and reliability improvement by it. When the PV generating output at lower output power becomes large and the efficiency at lower output of PCS becomes high, the efficiency of the integrated operating system becomes high and its difference becomes large. The output by PCS under development is about 4% higher than that of a conventional PCS in an individual operating system. Because the conversion efficiency of the PCS under development is considered to be greater than 95% from 30% to a rated load, the conventional PCS becomes about 3% lower.

A voltage fluctuation suppression function of grid due to the PV generation output fluctuations, the continuous operation function during low AC voltages due to an AC grid fault, and harmonics suppression function have been developed to connect them to an existing AC grid with least influences. The grid voltage fluctuations are controlled within 2% of an AC rated voltage by controlling reactive power of the PCS. Low-order harmonics currents are suppressed within 80% of the harmonics guideline in a distribution line, by generating the same PCS output voltage waveforms as that of the grid voltage. The continuous operation is enabled by suppressing over-currents and over-voltages in the PCS through high control response and synchronizing the phases of PCS output voltages with those of the grid voltages.

These functions of the PCS were confirmed by a miniature analogue model of the HMP system before manufacturing and installation. The algorithm used in real system was also installed in the PCSs of the miniature analogue model.

Fig. 3 shows one of the voltage fluctuation suppression test results. In the tests, active power of PCS1 fluctuates from