Featured Articles

Japan's Largest Photovoltaic Power Plant

—Turnkey Construction Contract and Commissioning of Oita Solar Power—

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OVERVIEW: Hitachi won a turnkey (EPC) contract to supply a PV power generation system to Oita Solar Power Corporation, with the plant commencing operation in March 2014. With a PV capacity of 82-MW, it is the largest PV power plant in Japan (as of May 2014). The equipment selected for the plant, which was constructed in a very short time (16 months), includes highly efficient PCSs and amorphous transformers, thus ensuring the system will have a high level of efficiency. Hitachi also has a 20-year maintenance and operation contract to ensure the plant continues to operate reliably.

INTRODUCTION

HITACHI undertakes large ("megasolar") photovoltaic (PV) power plant projects under turnkey engineering, procurement and construction (EPC) contracts that include design and procurement. Hitachi is also involved in the supply of a wide variety of equipment and systems, extending from operation monitoring and instrumentation systems to highly efficient, heavy-duty power conditioning systems (PCSs), amorphous transformers that feature low power consumption during standby operation, and other key items of equipment used in megasolar power generation systems.

This article describes the Oita Solar Power Plant that Hitachi supplied to Oita Solar Power Corporation under a turnkey EPC contract, which commenced operation in March 2014.

PROJECT OVERVIEW

Located in Oita City, Oita Prefecture, the Oita Solar Power Plant is situated on industrial land that had lain idle for many years.

The plant was constructed and will be managed by an operating company, Oita Solar Power Corporation, which is a subsidiary of Marubeni Corporation. The plant is Japan's largest, with a PV capacity of 82 MW, an estimated annual electric power production of 87,000 MWh (enough to power about 30,000 households), and a site area of 105 hectares (1,050,000 m^2). The system is very large, comprising 340,000 PV modules, which, if lined up, would stretch for approximately 500 km, roughly the distance from Tokyo to Osaka. It is estimated that the plant will deliver annual carbon dioxide (CO_2) emission savings of approximately 36,000 t. All of the power generated by the plant will be sold to the power company. Table 1 lists the project specifications.

Hitachi was awarded a turnkey EPC contract for the PV power generation system that encompassed design, procurement, fabrication, installation, and commissioning. Work started in December 2012 and the plant commenced operation in March 2014. Fig. 1 shows a photograph of the completed plant.

FEATURES OF OITA SOLAR POWER

Direct current (DC) generated by the PV modules is converted to alternating current (AC) and stepped up to 6.6 kV at 61 subsidiary substations. It is then stepped up again to 66 kV by three high-voltage (extra-high tension) transformers and supplied to the transmission

TABLE 1. Project Specifications
The table lists a summary of the project.

Project Summary	
Operator	Oita Solar Power Corporation
Plant name	Oita Solar Power
Location	Oita City, Oita Prefecture
Site area	105 ha
PV module capacity	82 MW
Grid interconnection capacity	61 MW
Grid interconnection voltage	66 kV

PV: photovoltaic

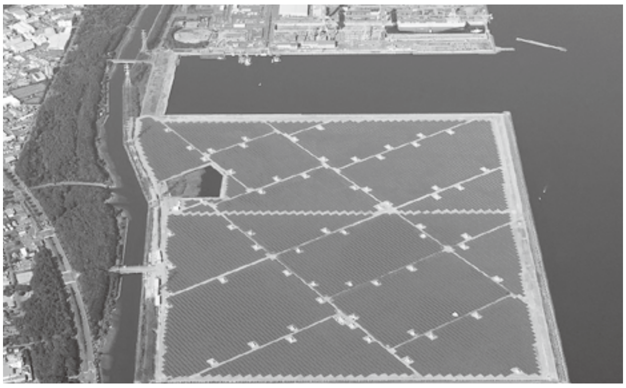

Fig. 1—Oita Solar Power Plant.
The power plant is visible in the middle of the photograph, surrounded by the ocean and a river. The approximately 1 km² site is almost entirely covered with PV modules.

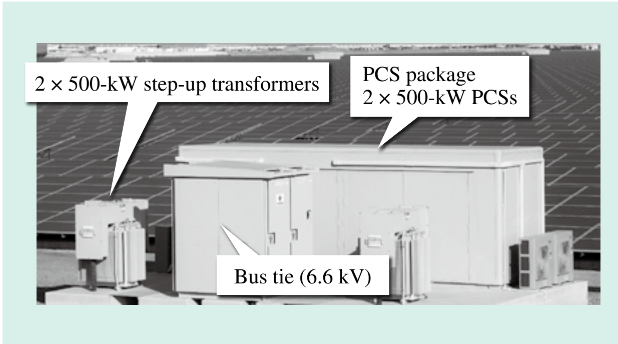

Fig. 2—Subsidiary Substation.
Each subsidiary substation consists of a PCS package with two PCSs, two step-up transformers, and a bus tie. The PV modules are visible behind the subsidiary substations.

pylons of the power company to which the power is sold. Table 2 lists the specifications of the main generation system equipment.

Each subsidiary substation is fitted with two 500-kW PCSs and two step-up transformers (1 MW per substation) (see Fig. 2). The extra-high-tension transformers are installed in three banks, each containing a 21-MW extra-high-tension transformer. The electric power stepped up by these three high-tension substations is consolidated at the extra-high-tension transformer closest to the grid connection point, from which it is connected to the power company's existing transmission pylons (see Fig. 3).

Table 2. Main Equipment Specifications
The table lists the specifications of the PV modules, PCSs, step-up transformers, and high-voltage (extra-high tension) transformers.

	Parameters	Specifications		
		240 W model	245 W model	Total
PV modules	Maximum output/panel	240 W/panel	245 W/panel	—
	No. of panels	307,454	33,586	341,040
	Total capacity	73.8 MW	8.2 MW	82 MW
PCSs	**Parameters**	**Specifications**		
	Capacity/unit	525 kVA/500 kW		
	Rated input voltage	DC 400 V		
	Operating voltage range	DC 230 V – DC 600 V		
	No. of units	122		
	Total capacity	61 MW		
Step-up transformers	**Parameters**	**Specifications**		
	Voltage	440 V (primary)/6.6 kV (secondary)		
	Capacity/unit	500 kVA		
	No.	122		
	Total capacity	61 MW		
Extra-high-tension transformers	**Parameters**	**Specifications**		
	Voltage	6.6 kV (primary)/66 kV (secondary)		
	Capacity/unit	21 MVA		
	No.	3		
	Total capacity	63 MVA		

PCS: power conditioning system DC: direct current

Fig. 3—Extra-high-tension Substation (Grid Connection Substation).
The extra-high-tension transformer is located at the center of the extra-high-tension substation. The lines to the transmission pylon run via the gantry.

System Optimization

While the maximum output of the system's PV modules is 82 MW, the PCS capacity is 61 MW. This design was selected as optimal for Japanese weather conditions.

PV modules generate their rated output when the solar radiation is 1 kW/m². Unfortunately, over the period of a year, the total time during which solar radiation is at 80% or more of this value is less than 10% of the time during which solar radiation is less than 80% (see Fig. 4). This makes it important to operate at higher efficiency during periods of low solar radiation. Installing an excess number of PV modules results in a generation system with higher efficiency than one where the number of PV modules

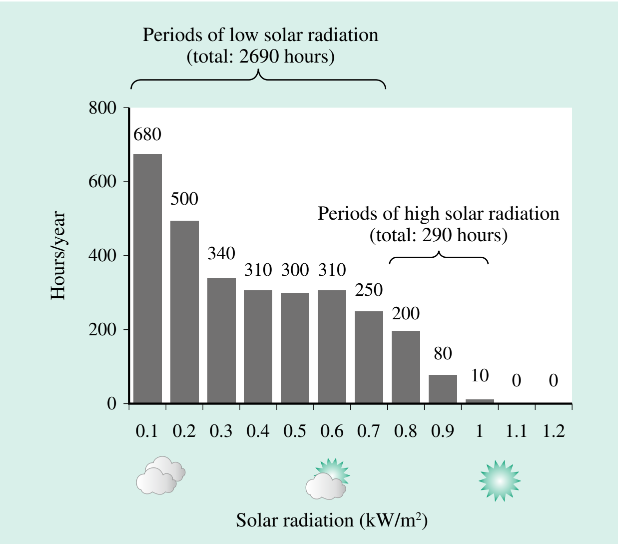

Fig. 4—Annual Solar Radiation Distribution.
The graph shows how periods of low solar radiation are more common.

is set to match the PCS capacity. The higher efficiency means more power is generated overall. For this power generation system 82 MW of PV modules, the optimal system design is a PCS capacity of 61 MW.

Highly Efficient Power Generation System

To improve the generation efficiency of the power plant, Hitachi selected highly efficient equipment and designed the system to have low losses.

More specifically, Hitachi selected highly efficient PCSs (capacity: 500 kW, maximum DC input voltage: 660 V, maximum efficiency: 98.0%) and designed

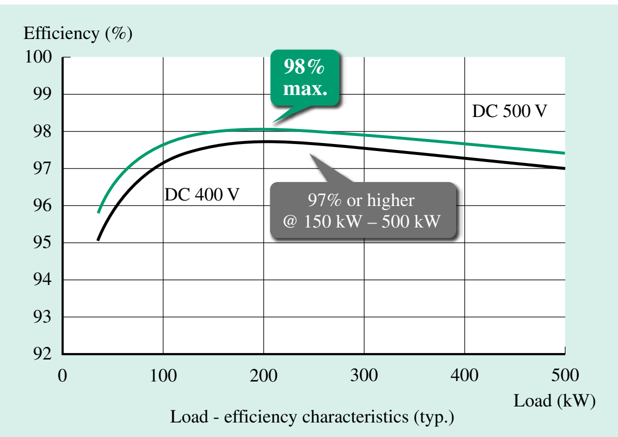

Fig. 5—PCS Efficiency Curve.
The PCS features a high maximum efficiency of 98% and the ability to operate efficiently over a wide range of loads. The specifications listed here are typical measured values and are not guaranteed.

Typical transformer characteristics (three-phase, 500 kVA)

Parameter	No-load loss (W)	Load loss (W)	Efficiency (%) (@25% load)
Electrical steel transformer	600	4,300	99.31
Amorphous transformer	160	6,900	99.53

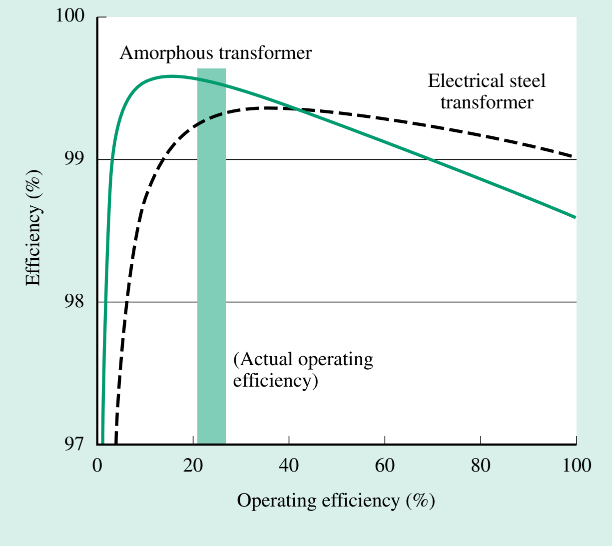

Fig. 6—Characteristics and Efficiency Curve of Step-up Transformer (Amorphous Transformer).
The transformer features low no-load losses and operates efficiently at the low loads common in actual use.

the system to have a high generation efficiency over a wide range of solar radiation levels, including both sunny and cloudy days (see Fig. 5). It combined these features with amorphous step-up transformers (maximum efficiency: 99.6%), which have low standby power consumption (no-load losses) and high efficiency under light loads (see Fig. 6).

To shorten high voltage cable lengths, and thus minimize cable power losses, Hitachi also designed the system to have three extra-high-tension substations (see Fig. 7).

Monitoring System

Hitachi also installed a remote monitoring system and string monitors for power plant monitoring.

For the remote monitoring system, Hitachi built a system capable of monitoring power plant operation and reporting faults from the customer's headquarters or from Hitachi's monitoring center. 24-hour monitoring of the plant from the Hitachi monitoring center means that service staff can be dispatched quickly if needed to respond to a problem.

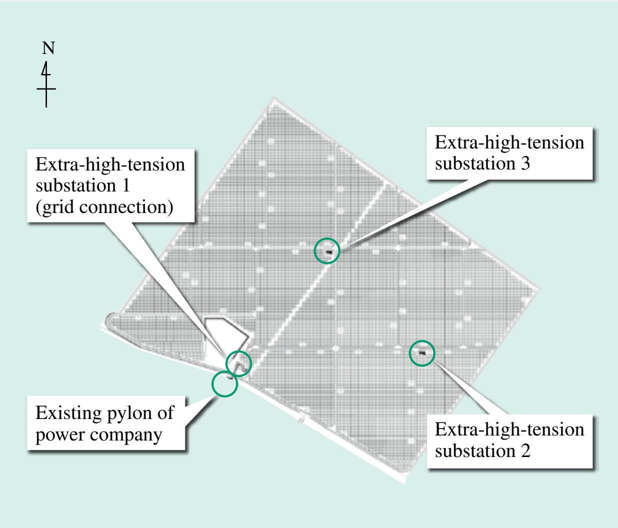

Fig. 7—Locations of Extra-high-tension Substations at Power Plant.
The locations of the site's three extra-high-tension substations were chosen to minimize high-voltage cable lengths.

Fig. 8—Use of Slipforming to Lay Foundations.
The photograph shows the concrete array foundation being laid by the Huron concrete slipform paver, which pours and forms the foundation as it moves along. The Huron machine is on the right and the concrete mixer on the left supplies it with concrete.

As mentioned above, in addition to the remote monitoring system, Hitachi also installed string monitors. These monitor the current from a string of PV modules connected in series to identify performance degradation or other faults in the PV modules in the string. Monitoring the strings individually rather than centrally at the PCS provides greater sensitivity and makes it easier to identify faulty components (see p.38 of this issue).

Short Construction Time

Plant construction was completed in just 16 months, which is a very short time for a plant of this size.

To achieve this rapid construction schedule, Hitachi selected installation techniques that would make laying the 190 km of panel frame foundations more efficient, including the use of slipforming (which does not require a mold), as well as conventional mold-based techniques. Slipforming uses a concrete slipform paver supplied by Huron Manufacturing Corporation that pours and forms the foundations as it moves along. Use of this technique played a major role in shortening the construction time. Fig. 8 shows a photograph of the slipform paver being used to lay foundations.

Tasks such as equipment delivery management and work progress management were supported by the use of Hitachi's own delivery time management system, which ensured that the delivery of major items of equipment, such as the PCSs and step-up transformers, was timed to suit the site work schedule.

Hitachi sought to complete the job ahead of schedule, with more than 450 people working at the site each day during the peak period when the civil engineering and electrical installation work was at its busiest.

Through these measures, the work was completed more quickly than originally planned, allowing the commencement of operation to be brought forward by more than a month.

Future Activity at Oita Solar Power

Following on from its EPC contract for the Oita Solar Power PV power generation system, Hitachi has also been awarded a 20-year contract for maintenance and operation.

Hitachi's responsibilities will include monitoring the operation of the generation system, providing operational support for managing power production, periodically inspecting and replacing parts, and responding promptly to faults or other problems.

CONCLUSIONS

This article has described the Oita Solar Power PV power generation system.

In addition to PCSs and step-up transformers, which are the core products for its PV power generation systems, Hitachi is also striving to make further efficiency and quality improvements through measures such as fault diagnosis for PV modules. Hitachi also intends to utilize the experience and knowledge it has built up through this EPC contract to continue supplying highly efficient PV power generation systems.

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