Performance Analysis of Grid-Connected PCS for PV System by Field Demonstration Test

J.H. So, Y.S. Jung, G.J. Yu, M.W. Jung, G.H. Kang, and J.Y. Choi*

Korea Institute of Energy Research, * Department of Electrical Engineering, Kwangwoon University

Abstract- 3kW photovoltaic (PV) systems and data acquisition system are constructed for performance analysis of PV system at field demonstration test center (FDTC) of Korea. As climatic and irradiation conditions are varied, the performance characteristics of PV system are collected and analyzed in data acquisition system. From these results, the performances of gird-connected power conditioning system (PCS) for PV system have been evaluated and analyzed. Furthermore, performance indices of grid-connected PCS e.g. output power, efficiency, loss factor, and the other index at the site are reviewed.

1. Introduction

The concerns of PV systems have been increased around the world since PV system is becoming widespread as a clean and gentle energy source for earth. As a result, the stability and long-term reliability have become more important issues in this area. [1][2]

This paper presents the performances of gird-connected power conditioning system (PCS) which are resulted from field demonstration test. 3kW grid-connected PV systems were installed at field demonstration test center (FDTC) of Korea in October 2002. Data acquisition system is constructed for measuring and analyzing performances of PV system to observe the overall effect of environmental conditions on their operation characteristics. PV systems installed in FDTC have been operating since mid-October 2002, and continuously monitored since then. [4]-[6]

The objective of this paper is not only to evaluate and analyze the performances of domestic PV systems through long-term operation at FDTC but also to develop evaluation, analysis and application technologies for stability and reliability of grid-connected PCS for PV system.

2. System discription

PV systems installed in FDTC consist of roof mounted systems and ground mounted systems. Nominal capacity of each PV array is 3kW and each PV arrays is made of poly-crystalline silicon and mono-crystalline silicon PV modules, which are provided by different manufactures. Both of PV array are set in a fixed tilt of 18 degree, azimuth of 0 degree. The arrangement of PV array was decided in accordance with the design specification of PCS provided by different manufactures. The parameters of PV module and PCS used at FDTC were summarized in Table 1, 2. A schematic of the system is shown in Fig. 1.

The installed PV systems are fully monitored not only to evaluate and analyze the performances of PV systems on environmental conditions but also to develop PV system application technologies with meteorological sensors and electrical sensors. The data of PV systems is measured five seconds sampling period so that performance characteristics can be evaluated and analyzed. The measurement periods of PV systems are monitored from mid-October 2002 to until today. Measurement data is recorded averaged minutely and averaged hourly and stored to disk on a computer. In this monitoring system, the following items are measured to evaluate and analyze the performances of PV systems.

Electrical measurement items
- DC and AC voltages
- DC and AC currents
- AC power
- Load power
- Power to/from Utility grid
- Utility grid and PCS frequency

Meteorological measurement items
- Irradiance on horizontal plane
- Irradiance on plane of PV array
- PV module surface temperature (T-type)
- Ambient temperature (PT-100)

Table 1 PV module specifications
(Under standard testing conditions)

PV Module	A	B	C	D
Cell type (crystalline silicon)	Poly	Mono	Mono	Poly
Nominal power [W]	77	50	68	75
Short-circuit current [A]	4.88	3.35	4.7	4.75
Open-circuit voltage [V]	21.5	21.7	21.2	21.8
Maximum power point (MPP) current [A]	4.46	3.05	4.20	4.35
Maximum power point (MPP) voltage [V]	17.2	17.4	16.2	17.3
Total amount	42	60	44	40
PV array area [m^2]	27.2	25.4	27.8	25.9

Table 2 PCS specifications (Under rated conditions)

PCS		A	B
Type		Grid-connected	Grid-connected
		MPPT	MPPT
DC input	Input voltage	340 V_{DC}	200 V_{DC}
	Operating voltage range	280 ~ 480 V_{DC}	145 ~ 350 V_{DC}
AC output	Rated output	3.0 kW	4.0 kW
	Efficiency	91 % or more	93.5 % or more
	Power factor	0.98 or more	0.95 or more
	Total Harmonic Distortion	3 % or less	5 % or less
	Maximum Single Harmonic	2 % or less	3 % or less
Protective function	Utility grid	OV, UV, OF, UF	OV, UV, OF, UF

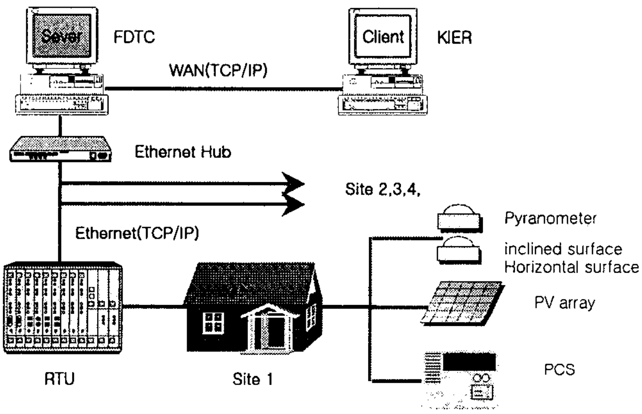

Fig. 1 System overview

3. Analysis of pcs performance

Fig. 2 shows the monthly output energy of each PCS. During the operation period of PV systems, on a whole basis, the PCS of each site generated output energy between 1.5MWh and 1.9MWh. The monthly efficiency of PCS and its operation performance in each site for measurement period is shown in Fig. 3, 4. Both of PCS are equipped with a maximum power point (MPP) tracking system.

When the irradiance is about 80 W/m^2, the inverter starts supplying energy to the grid and stops supplying energy when the irradiance goes down to about 50 W/m^2. Before the inverter starts supplying energy to the grid, it has to carry out procedures of self-activity. The efficiency of the PCS for irradiance values higher than about 200 W/m^2 is approximately constant but for the lower irradiance, the efficiency is strongly dependent on irradiation.

The total averaged efficiency of PCS is individually 90 % (Site1), 85.2 % (Site2), 81.4 % (Site3), 88 % (Site4). From these results of PCS, PCS installed in site3 is less efficient than that of other site. The cause of lower efficiency is generated by the wrong optimum design of PCS component devices etc.

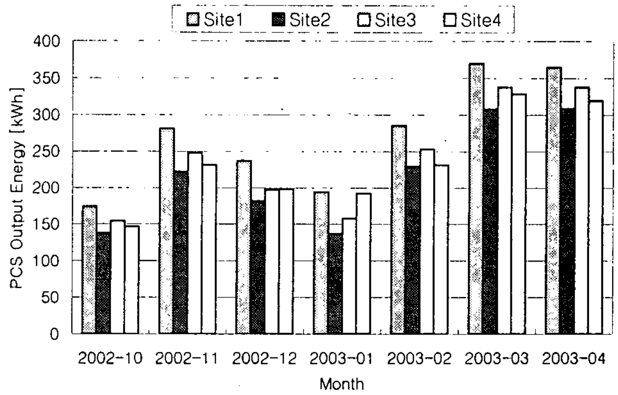

Fig. 2 Monthly output energy

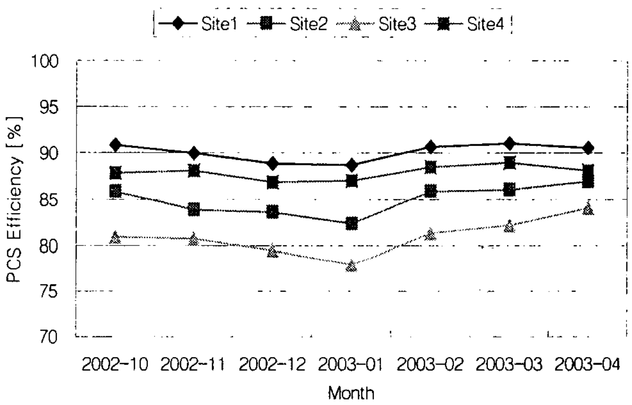

Fig. 3 Monthly PCS efficiency

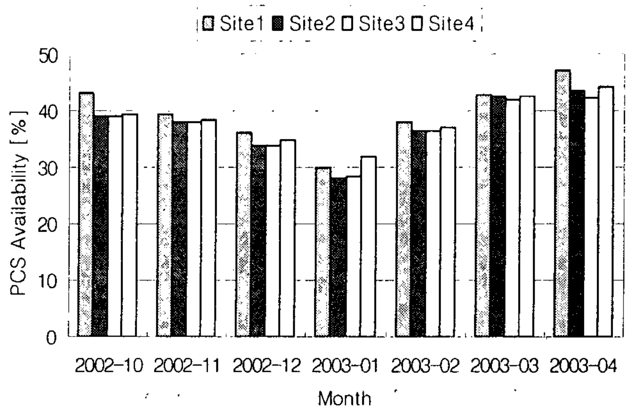

Fig. 4 Monthly PCS availability

Fig. 5, 6 show the analysis results of PCS performance in site1. The efficiency and efficiency error of PCS shown in figures are to evaluate and analyze actual PCS performances in comparison with design specifications of PCS provided by manufactures. As shown in figures, considering loss factors and measured value error, the actual PCS performance has almost the same performance as design specifications.

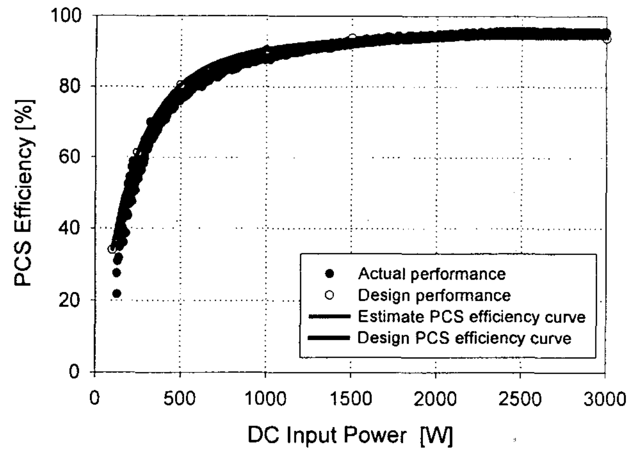

Fig. 5 PCS efficiency (Site1)

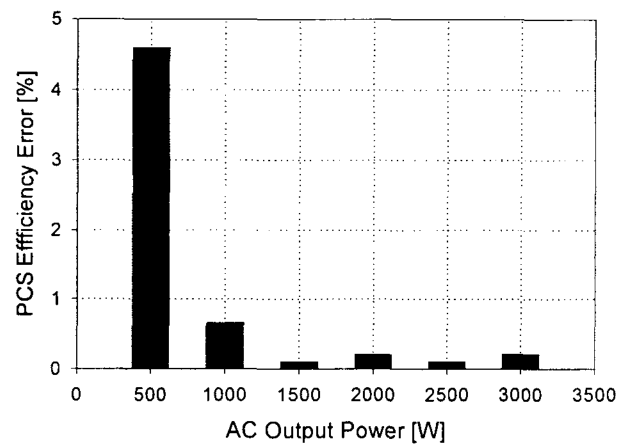

Fig. 6 PCS efficiency error (Site1)

The same method as mentioned above is applied to evaluate and analyze performances of PCS installed at the other site. The main results of PCS performances by field demonstration test are summarized in Table 3 during measurement period mid-October 2002 - April 2003.

Supposing that the performances of PCS have almost the same performances as design specifications provided by manufactures, as shown in Fig. 7, the PCS performance of each site can be estimated using simulation tool. In the figure, The actual versus estimate performances of PCS installed in site1, 4 are almost the same during November 2002-April 2003. In case of PCS installed in site3, the performance of PCS will be able to improve about 15% in comparison with actual performance. In case of site2, the cause of some big difference in actual versus estimate performance of PCS is generated by not PCS losses but PV array losses.

Table 3 Results of PCS performances

PCS	Site1	Site2
DC input energy [kWh]	2114.8	1790.6
AC output energy [kWh]	1907.9	1526.0
PCS availability [%]	39.3	37.2
PCS efficiency [%]	90.2	85.4
PCS efficiency error [%]	1.0	2.4
PCS	Site3	Site4
DC input energy [kWh]	2072.3	1875.4
AC output energy [kWh]	1686.2	1650.9
PCS availability [%]	37.0	38.2
PCS efficiency [%]	81.4	88.0
PCS efficiency error [%]	7.6	2.1

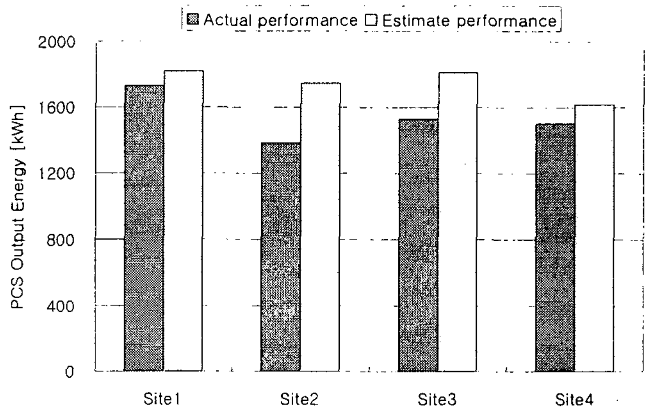

Fig. 7 Comparison of actual versus estimate PCS performance

4. Conclusions

PV systems and data acquisition system were installed at field demonstration test center (FDTC) of korea for evaluating and analyzing performances of PV systems according to the overall effect of environmental conditions on their operation characteristics.

PV systems installed in FDTC have been operating since mid-October 2002, and continuously monitored since then. The overall performances of PCS for PV system were analyzed and evaluated during the measurement period. In the results of performance analysis by field demonstration test, the actual PCS performance of each site is almost the same as design specifications of PCS except for PCS installed in site2. In case of PCS installed in site2, the cause of lower efficiency is generated by the wrong optimum design of PCS component devices etc.

On the basis of these results, new evaluation and analysis technologies will be developed for optimum design of grid-connected PCS for PV system.

Acknowledgement

This work was supported by energy technology R&D project from Ministry of Commerce, Industry and Energy Republic of Korea

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