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중국 티베트지역의 100kWp급 태양광발전시스템 실증연구

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Installation and Performance Evaluation of 100kWp PV System in Tibet

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Abstract This paper present the performance evaluation of PV systems installed at Tibet area of China in order to identity the key factors that determines system operation at a severe climate conditions and promote the cooperation of PV technology between Korea and China. The installed systems consist of 100kW on-grid connected PV systems, BOS(balance of systems), data acquisition and transmission equipments. The Korea side supplied the solar cell, BOS like as inverter, control box and monitoring system. And the Chinese side assembled solar module, constructed site and built control house. It has been shown that the average radiation per monthly from Tibet is 1.5 times larger than that from Mokpo. Also, radiation time from Tibet is 2hour higher than that from Korea.

Key words Photovoltaic(태양광발전), Solar Cell(태양전지), Inverter(인버터), BOS(balance of system, 주변기기)

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1. Introduction

Recently, world energy demand has been rapidly expanding due to the world economic growth and population increase, especially in developing countries. Renewable energy is expected to have large potential as an alternative energy source without constraint on energy supply or greenhouse gas emissions such as CO2. One promising renewable energy is solar energy.

Korea have made an intensive effort in research and development on photovoltaic (PV) technology over the last 15 years. So the core technology has been developed and now preparing to be commercialized. In order to promote the commercialization which bring up the industry, we realizes that a good sized PV market should be pioneered.

China is of the most important countries in terms of energy production and consumption. Moreover China heavily dependent on coal as the main source of energy, the environmental issue is becoming concern as its

economic situation improve. So the development of renewable energy could be the most important thing. Among the renewable energy, the PV could be an ideal source of electricity in China where the population is distributed over the vast area . And PV is respected to play a significant role in China's electricity portfolio. Therefore, it is believed that China has a huge potential PV market. Although China's manufacturing capability and the technology level in on the way of fast growth, the urgent need for the electrification in the remote areas, as like Tibet, could only be met by a cooperative effort with other countries such as Korea.

In addition to this, desert area in China is expected to be one of the most promising candidate sites for implementing VLS-PV systems specified by the IEA PVPS Task 8 Program [1]. The Korea-China Cooperative agreement includes establishment a 100 kWp grid-connected PV demonstration site in Tibet, China by utilizing the technologies and development in Korea.

This paper presents the installation site, the specification of module and BOS that is supported by Korean industry, and installation.

2. Installation Site

Fig. 1 shows the location of Tibet where this system installed. Tibet lies at the center of Asia and a original name is Xizang. It has an average altitude of 13,000 feet above sea level. The latitude of the region is 27-36 degrees north and the longitude is 75-100 degrees east. The annual precipitation in this area amounts to 250 mm below. Prearranged installation area is Yangbijing of Damxung province in Lhasa. The latitude of the region is 30°.05' north and the longitude is 90°.30' east. and It has an average altitude of 4,205 m above sea level. The earth is composed of mud and gravel. The annual mean wind pressure is 6w/m and maximum is 40w/m . Also the annual mean wind velocity is 2.4m/s and the maximum is 23m/s. It has 7 Richter scale earthquake. The maximum rainfall is 458mm and the maximum snowfall is 12cm during May-October. The average temperature is 1.7℃ and the maximum is 26.5℃ and the minimum is -32.5℃. The sunshine duration is above 7 hours per day. It is possible area for satellite communication.

Fig. 2 shows the general view of installation site. The nature of the soil is mud and it is needed a ground readjustment. Also maintenance work becomes easy after installing and grid-connection is advantageous because the power plant is located nearby. The criterion of the selection a lot are as follows.

-Ground condition
(Direction, soil, geographical feature etc.)
- Publicity effective

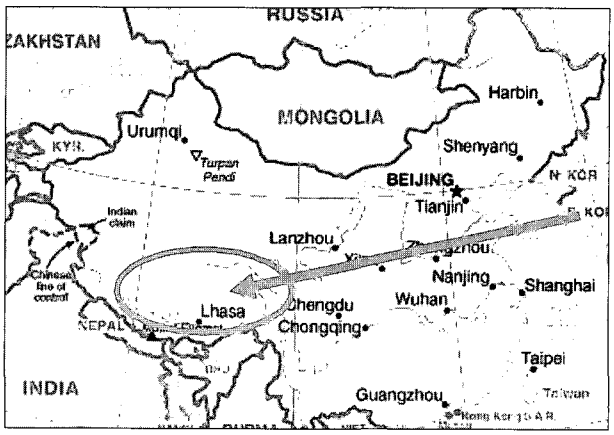


Fig. 1. Map of China 100 kWp PV system is installed at Yangbijing, DamXung Province, Lhasa, China, 70km away from Lhasa City

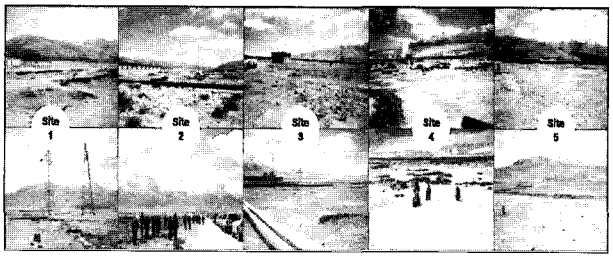


Fig. 2. General view of Yangbijing a site proposed

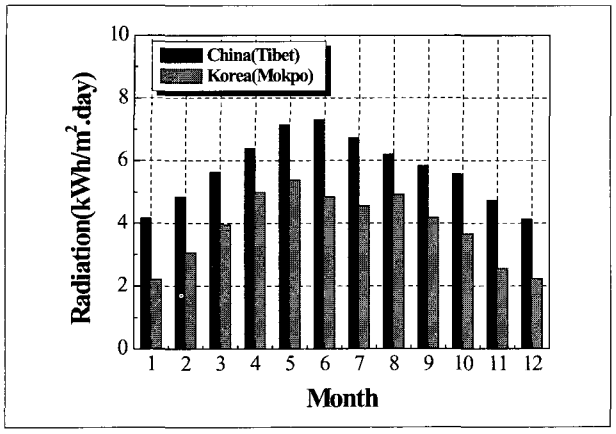


Fig. 3. Average radiation vs. monthly in Tibet area

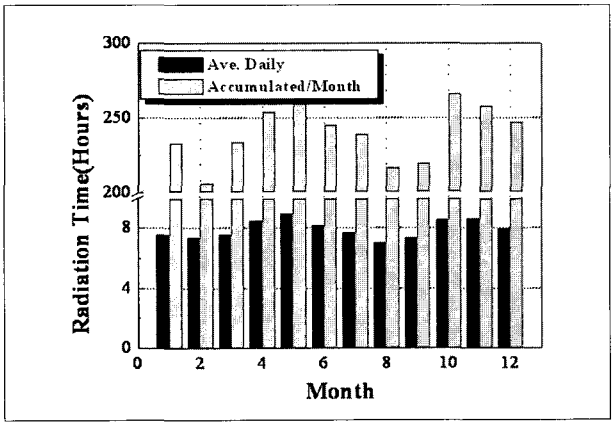


Fig. 4. Average radiation time vs. monthly in Tibet area

-Accessibility of Maintenance
-Accessibility of construction

Fig. 3 shows the radiation data on the average radiation of Tibet area, obtained from Beijing Corona Science and Technology Company. It has the long sunshine duration which is 1.5times longer than the domestic sunshine duration and the average temperature is low. Fig. 4 shows the daily and monthly trend of radiation time. Also the average radiation time is above 7hours per monthly.

3. System component, design and features

As it is mentioned in agreement, Korea prepared Solar cell and BOS like as inverter, control system, junction box, and DC cabinet and China is in charge of module assembling, construction, AC distribution cabinet, and transformer to the grid.

The Photovoltaic generator has a total power capacity of 100 kWp. The PV array consists of 608 modules, each one with a maximum power of 160Wp grade, and array are divided in 4 groups of 11 modules in series and 14 in parallel. As described above, the array block of 100kWp PV system are installed in Tibet shows Fig. 5.

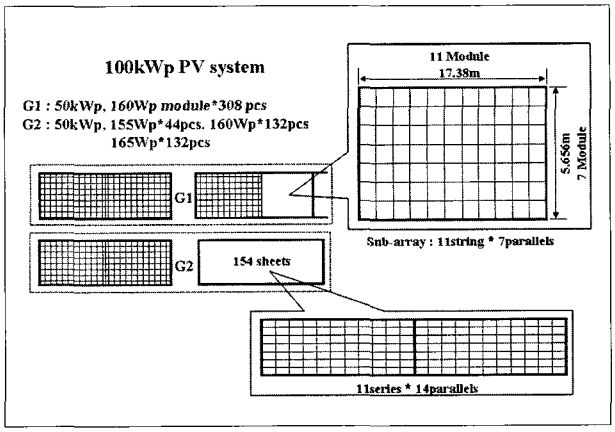


Fig. 5. Schematic diagram of PV array mounted in Tibet

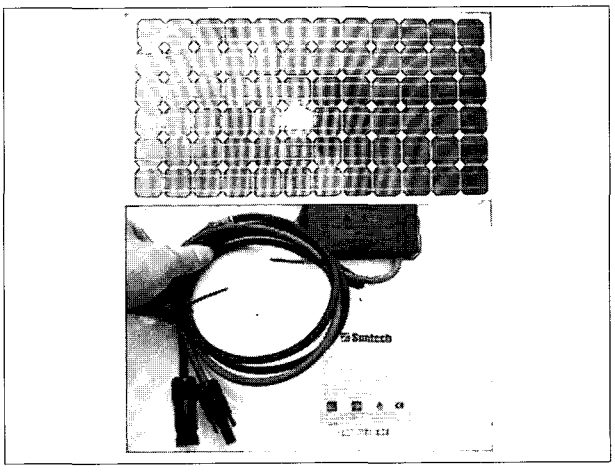


Fig. 6. Photograph of the PV module assemblied by SunTech company in China

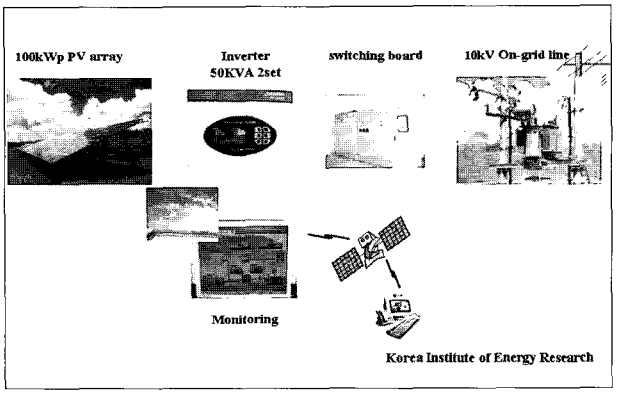


Fig. 7 Schematic diagram of PV power generation system for grid-connected

The solar cells are manufactured and supplied by KPE(KyungDong Photovoltaic Energy) in Korea. And Table 1 (a) shows the specification of PV module by using it and (b) shows the specification of inverter which is manufactured by Korean company(HexPower System). The modules are assemblied by SunTech Company in China. Fig. 6 shows the photograph of the PV module assemblied by SunTech company in China. Fig. 7 Schematic diagram of PV power generation system for grid-connected.

The details about specification of component, type of junction box, and the status of electrical connection are as follow;

- Connection between modules and CB junction box construction using terminal block
  Hughes, breaker not included diodes
- Junction box arrangement : small junction-box(outdoor), large junction-box(indoor)
- Installation of inverter : installation at indoor after constructing control building
- Conditions on-site electricity : 3 phase 4 wire 380V/10kV
- Lighting and surge protection facilities : lighting rod, reflection of grounding design

Table 1. (a) Specification of the sc-Si solar cell fabricated by KPE company in Korea

Grade	A	B	C
Eff.(%)	15.3-15.0	14.9-14.5	14.4-14.0
Jsc	4.90±2%	4.85±2%	4.85±2%
Voc	0.600±0.01	0.600±0.01	0.590±0.01
Vmax	0.495	0.492	0.490
Imax	4.44	4.35	4.25
Pmax	2.25-2.20	2.19-2.14	2.13-2.10

(b) Specification of the PV module fabricated by SunTech company in China

Items	Specification		
Pmax(Wp)	155	160	165
Imp(A)	4.51	4.65	4.74
Vmp(V)	34.4	34.4	34.8
Isc(A)	4.9	5	5.04
Voc(V)	43.2	43.2	43.6
Quantity	44	440	132
Weight(kg)	16		
Dimension	1580 x 808 x 50mm		
Measuring condition : AM 1.5, 1000W/m^2, Tc = 25℃			

(c) Specification of the inverter fabricated by Hex Power system in Korea

	Items	Specification
DC Voltage	Vmax	600V
	Voltage Range	300-600V
	Vmin	300V
AC Output	Phase &Wire	3phase 4 wire
	Voltage	AC 380 ± 10%
	Topology	PWM(IGBT)
	Capacity	50kVA
	Frequency	50Hz +0.5Hz,-0.7Hz
	Power Factor	More than 95%
	Efficiency	Max. above 96%
Cubicle	Cooling type	Forced-air cooling
	Size(mm)	W800*D800*H1688
	Weight	850kg

4. Monitoring of PV System

The monitoring systems for meteorological and system data are also included in this hybrid systems.

The daily generated power and weather data are transmitted to Korea by satellite communication. Through in-vivo monitoring, it is possible to check system operation in Korea.

The performance of grid-connected PV systems depends on weather conditions, the operation of each individual component and the connection of the system to the grid[2].

The PV efficiency varies seasonally due to the monthly variation of the incident solar irradiance angle, cell temperature[3].

Measured output power 50kWp PV system from September 2005 as well as daily solar radiation is shown in Fig. 8. Fig. 9 shows the collect and analyse data over a period of eight months to obtain the PV system performance under real operating conditions. The system performance was analysed on hourly, daily and monthly bases from September 2005 to April 2006.

Generally, system utilization efficiency is expressed by the following formula.

PV system utilization efficiency = Generated energy of the day[kWh/day]/(PV capacity*working day)

The system utilization efficiency is influenced largely by irradiation condition. The PV array which contributed to generation best showed a very high value above 20%.

Fig. 10 shows the electrical properties for 100kWp PV

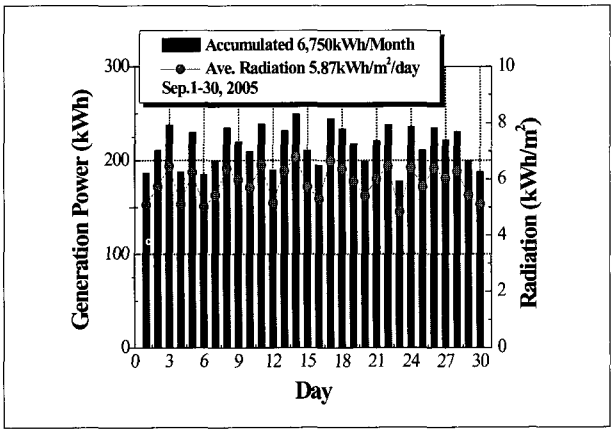
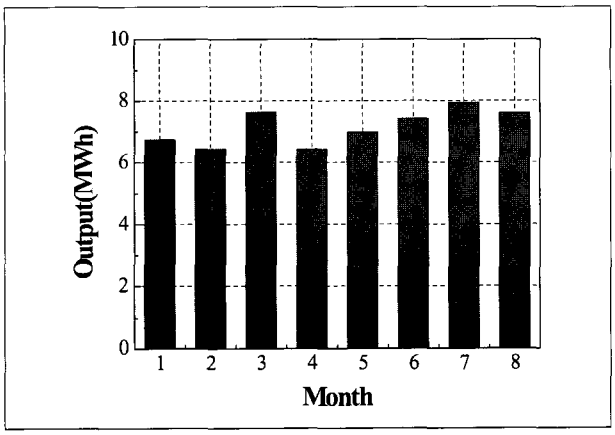
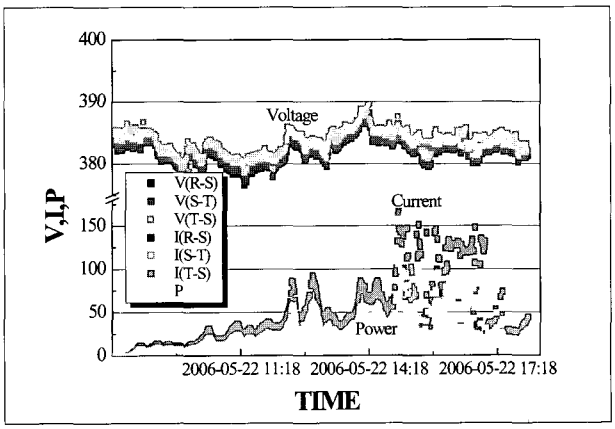


Fig. 8. Generating power and solar radiation for 50kWp PV system as a function of daily



Month	2005				2006			
	Sep.	Oct.	Nov.	Dec.	Jan.	Feb	Mar.	Apr.
Output (MWh)	6.75	6.44	7.63	6.43	6.98	7.42	7.94	7.61

Fig. 9. Monthly accumulated output power from Sept. 2005 to April 2006 about 50kWp PV system.



Date	Voltage(V)			Current(A)			P(W)
	R-S	S-T	T-S	R	S	T	
2006-05-22 14:58	384.7	385	386.2	131.3	132.2	132.9	69.4
2006-05-22 14:59	386.1	386.5	387.6	164.9	165.6	166.4	105.5
2006-05-22 15:00	384.8	385.2	386.3	145.4	146.6	147.1	104.7
2006-05-22 15:01	383.7	384	385.2	97.9	98.8	99.2	85.3

Fig. 10. Electrical properties of 100kWp PV system completed in 22.May 2006.

system as a function of real time. Fig. 11 shows the 100 kWp PV system in Tibet.

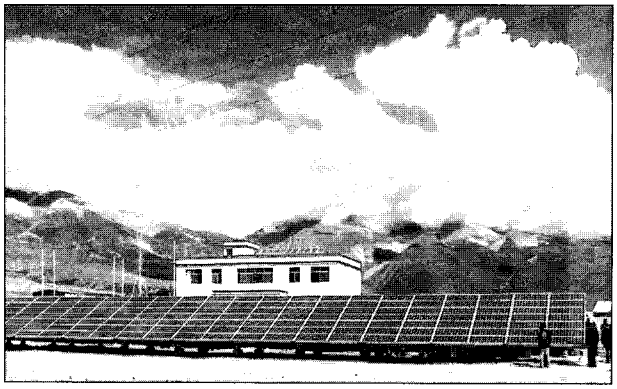


Fig. 11 Photograph of 100 kWp PV system in Tibet

5. Conclusions

In this paper, we designed and installed 100kW PV system as the parf of Korea-China cooperative project: 100 kWp PV system installation for performance evaluation in Tibet area. The installed systems consist of 100 kWp on-grid connected PV systems, BOS(balance of systems), data acquisition and transmission equipments. The Korean side supplied the solar cell BOS like as inverter, control box and monitoring system. And the China side assembled solar module by using Koreans solar cells, constructed site and built control house. We should investigate the performance and stability of the system as the condition of weather. In based on the result of this project, we expect that Korean made products such as PV cells, inverter and/ or control system will be exported to China so that they will be applied to the 500~1000kWp system which will be installed in Tibet from 2006. And royalty and exports of Korean made products will be expected when 3~5MWp PV system will be installed at Tibet. Finally, this project of installation and demonstration will give us a better chance to go into the Chinese market which is in shortage of PV cells.

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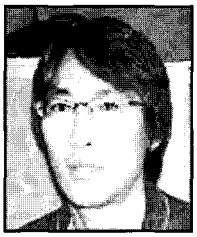

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