A Preliminary Study on Potential for Very Large-Scale Photovoltaic Power Generation (VLS-PV) System on the Gobi Desert from Economic and Environmental Viewpoints

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ABSTRACT

The authors focused on introduction of very large-scale photovoltaic power generation (VLS-PV) system on desert and designed 100MW PV system assuming that the system would be installed on the Gobi desert, which is one of major deserts in the world. Then energy payback time (EPT), life-cycle CO_2 emission rate and generation cost of the system were estimated by means of the methodology of life-cycle analysis (LCA). As a result of the estimation, 1.7-year of EPT and 12-g-C/kWh of CO_2 emission rate were obtained. These are very promising for the global energy and environmental issues. The generation cost was calculated at 13 Yen/kWh in case that PV module price was 100 Yen/W and system lifetime was 30 years.

1. Introduction

World energy demands have been rapidly expanding due to the world economic growth and population increase, especially in developing countries. Though more energy will be required to meet the increasing energy demands, there will be serious problems: world energy supply problem and the global environmental issue. The need for nuclear power will enlarge as one of major options, but difficulties in its siting are more and more notable at the same time. Renewable energy is considered to have large potential as an alternative energy resource without constraint on energy supply and greenhouse gas emissions. One of promising renewable energies is solar energy. Although the solar energy is low density by nature, it has a large potential if world deserts can be available. Therefore we focused on introducing very large-scale photovoltaic power generation (VLS-PV) system on desert, and evaluated its potential from economic and environmental viewpoints as a preliminary study.

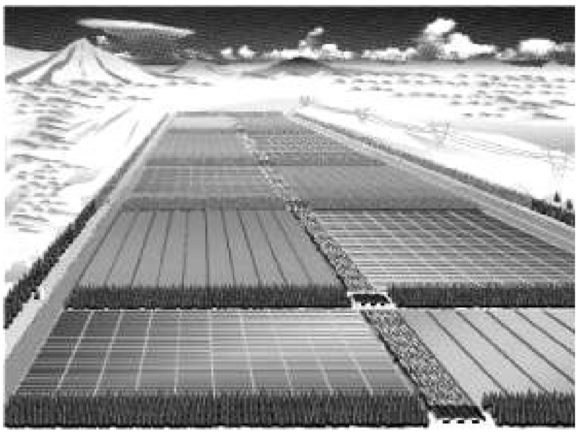


Figure 1 Image of VLS-PV system on desert

2. Methodology of Evaluation

A methodology of "Life-Cycle Analysis (LCA)" was employed in this study to evaluate the potential of VLS-PV system. The LCA is becoming a major tool to evaluate environmental impact of product throughout its life-cycle. We estimated requirement of energy and material for life-cycle of VLS-PV, that is, production and transportation of system components, system construction, and operation. Then we calculated three indices, Energy Payback Time (EPT), life-cycle CO_2 emission rate and generation cost. EPT, a special index for energy technology, means years to recover life-cycle primary energy consumption by its own energy production.

3. Major Assumptions

In this study it was assumed that 100MW VLS-PV system would be installed on the Gobi desert, one of large deserts in Asia. We designed the VLS-PV system based on the following assumptions:

(1) Irradiation and ambient temperature data were based on those for Huh-hot (40° 49' N, 89° 12' E), inner-Mongolia, China, shown in Table 1;
(2) Polycrystalline silicon PV module with 12.8% efficiency was employed;
(3) Fixed flat plates, which faced south, were employed for array structure;
(4) Capacity of a minimum unit was 500kW;
(5) System performance ratio was 78% considering

Table 1 Annual average data for Huh-hot

Ambient temperature	5.8 C°
In-plane irradiation	
Tilt angle=10°	1,854 kWh/m²/yr.
Tilt angle=20°	1,964 kWh/m²/yr.
Tilt angle=30°	2,026 kWh/m²/yr.
Tilt angle=40°	2,037 kWh/m²/yr.

operation temperature and so on, and lifetime was 30 years;

(6) Both module price and array tilt angle were valuable parameters;

(7) Array support and foundation were produced in China, and other system components such as modules, cables and inverters were manufactured in Japan. All the components were transported to installation site on the Gobi desert. Land preparation was also considered.

4. Evaluation Results

Based on the assumptions described above, the VLS-PV system on the Gobi desert was designed in detail. Figure 2 is an example for array design in case that 30 tilt angle was assumed. The 100MW system occupies approximately 2 km^2 land space and requires large amount of system components shown in Table 2.

Estimation results for generation cost shown in Figure 3 suggest that employing 30°-tilt angle gives the minimum generation cost. independent of PV module price. In case that PV module price is assumed to be 100 Yen/W, generation cost was calculated at about 13 Yen/kWh, around one third of which was from PV module cost.

EPT and life-cycle CO_2 emission rate are given in Figure 4. EPT was less than 2 years, that is, the VLS-PV system can produce net power after 2-year operation. CO_2 emission rate was 12g-C/kWh, which was much less than average CO_2 emission rate of utility in China (=260g-C/kWh).

5. Conclusion

The authors designed a 100MW VLS-PV system assuming that the system would be installed on the Gobi desert and evaluated potential from economic and environmental viewpoints. Both EPT and life-cycle CO_2 emission rate calculated in this study suggest that large-scale introduction of PV technology is very promising for energy resource saving and the global environmental issue. On the other hand, generation cost was estimated at about 13 Yen/kWh in case of 100 Yen/W of PV module price. In order to reduce the generation cost, we have to examine simpler system design.

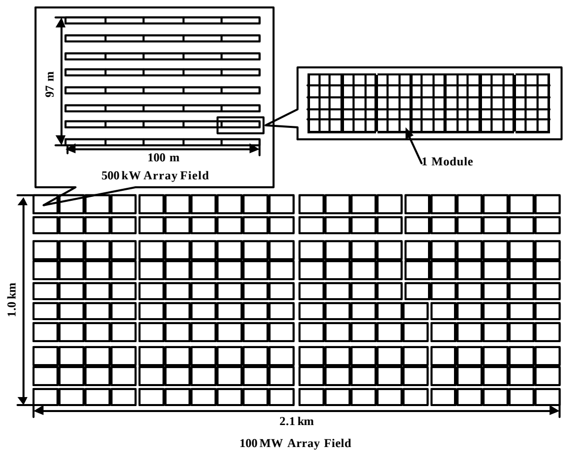
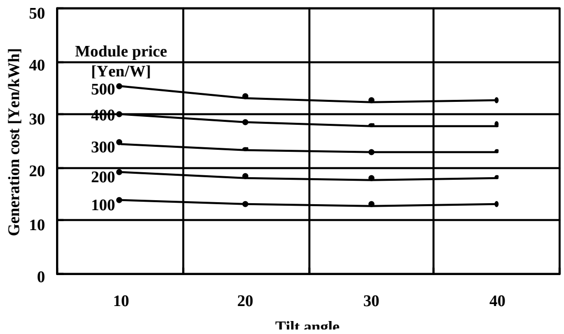


Figure 2 Array Field Design (30)



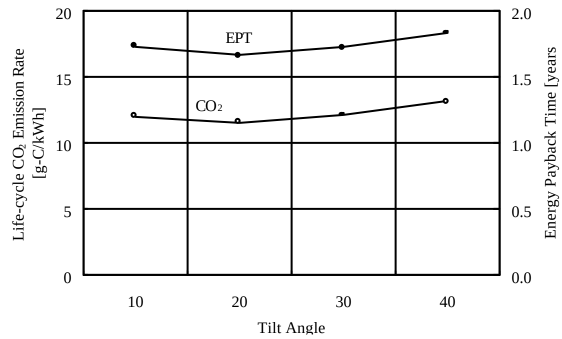


Table 2 Requirement for major components (tilt angle=30°)

Item	Unit	Amount
PV module	piece	840,000
Array support	ton	9,700
Foundation	ton	136,000
Cable		
600V CV	km	1,500
6.6kV CVT	km	29
6.6kV CV	km	34
110kV CV	km	13
Inverter with transformer	set	200
Circuit breaker	set	200
Common apparatus	set	18

Now we are planning to design and evaluate the VLS-PV system installed on other world deserts such as Sahara, Thar, Great Sandy, and Sonora by applying the same approach used in this study. Furthermore, applications appropriate for the system on the desert should be discussed. One of possible options may be an application for irrigation.

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