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An analysis of very large-scale tracking PV (VLS-PV) systems in the world deserts

AN ANALYSIS OF VERY LARGE-SCALE TRACKING PV (VLS-PV) SYSTEMS IN THE WORLD DESERTS

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Background and Objective

Nowadays, world energy demand has been rapidly expanding due to the world economic growth and population increase, especially in developing countries. If world energy demands continue to increase, the primary energy will dry up in this century. In addition, too much energy consumption causes a variety of serious environmental problem such as global warming, acid rain and so on. On the other hand, renewable energies are expected to resolve both the energy problem and the environmental problem. Photovoltaic power generation system is one of promising renewables. Because it need no fuel, no maintenance and no emission when it's generating. Although the solar energy is of low density by nature, it has a large potential by assuming that world deserts can be utilized. Therefore the authors have been investigating very large-scale photovoltaic power generation (VLS-PV) systems in deserts. Even the Gobi desert that locates on high latitude has higher irradiation (4.7kWh/m^2/d) than Tokyo (3.5kWh/m2/d). Furthermore, the Sahara desert has more irradiation as 7.4kWh/m^2/d. Theoretically, PV systems installed in the Gobi desert with 50% space factor, has potential to generate energy as much as the recent world energy supply (361EJ in 1997).

The purpose of this study is to design the VLS-PV systems on major world deserts, and to investigate feasibility of the system which is not only fixed flat plate system but also tracking system from economic and environmental view points. As indices taken up for the evaluation, cost, energy requirement, CO_2 emission of large-scale installing, toughness on hard desert condition, elucidated effect on climate and local, etc. are enumerated, and the possibility of solution to world energy and environmental problems is discussed.

Methodology of evaluation

A methodology of "Life-Cycle Assessment (LCA)" is the best way to evaluate the potential of VLS-PV systems in detail, because, a purpose of this methodology is to evaluate its input and output from cradle to grave. In this study, generation cost, energy payback time (EPT) and CO_2 emission rate of the VLS-PV system were calculated with this method.

Design procedure of VLS-PV systems

The authors assumed and designed the VLS-PV systems which are fixed flat plate and sun-tracking system in the major deserts in detail. These variety of case studies show characteristics of systems, and they show the best performance system configuration.

The very large scale fixed flat plate PV system was evaluated in previous papers. They show that the VLS-PV system is very promising for economic and environmental view points. In this paper, the very large scale sun-tracking PV systems are assumed, evaluated and compare these systems. First approach is to analyze real systems such as EUCLIDES in Spain and parabolic dish concentrating system at Sede Boqer in Israel. Second approach is design the sun-tracking systems by using same approaches as fixed flat plate case and same capacity, 100 MW. Next, many geographic data, material prices and LCA data are calculated in order to estimate generation cost, EPT and CO_2 emissions. Table 1 shows required system components for 100 MW fixed flat plate system. It is assumed 30 years life time and 3 % interest ratio. These studies are evaluated in terms of electric transmission systems which are assumed 100km, 2 channel and 110kV. At the last, these systems are evaluated.

Results

100MW VLS-PV systems installed in the six deserts in the world was designed and its potential was evaluated from an economic viewpoint. In case of fixed flat plate study, assuming 1.0 USD/W of PV module price and 3% of annual interest rate, generation cost of the VLS-PV system was estimated 5.2 ¢/kWh in the Sahara desert.

Fig.5 shows a summary of generation cost of VLS-PV systems in the deserts and it suggests that the VLS-PV system is economically feasible for all sites if the module price reduces to 2.0 USD/W or 1.0 USD/W. In addition, very large scale sun-tracking system is much promising in the near future because of its low PV module cost. The feasibility of VLS-PV systems which are fixed flat plate and sun-tracking systems installed in the Gobi desert in China is evaluated in depth from a life-cycle viewpoint by using three indices: life-cycle cost; energy payback time (EPT) and life-cycle CO_2 emissions. This study suggests that the total energy requirement throughout the life-cycle of the PV system considering production and transportation of system components, system construction, operation and maintenance can be recovered in a short period much less than its lifetime. The much lower CO_2 emission rate of VLS-PV than that of existing coal-fired power plants means that it is a very effective energy technology for preventing global warming. The same conclusion must be given for the other desert areas.

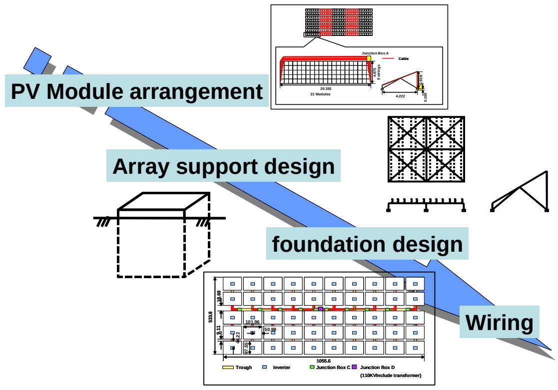

Fig.1: VLS-PV design schemes

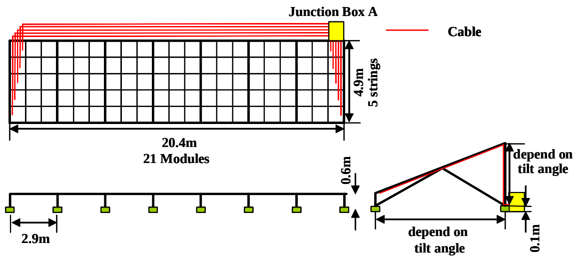

Fig.2: Basic structure of array support

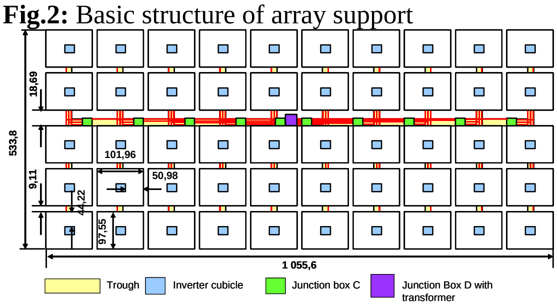

Fig.3 Design for 25MW sub-system consisted of fifty 500kW units

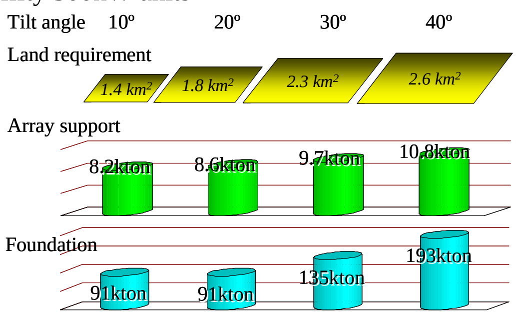

Fig.4: system requirement (Gobi desert case)

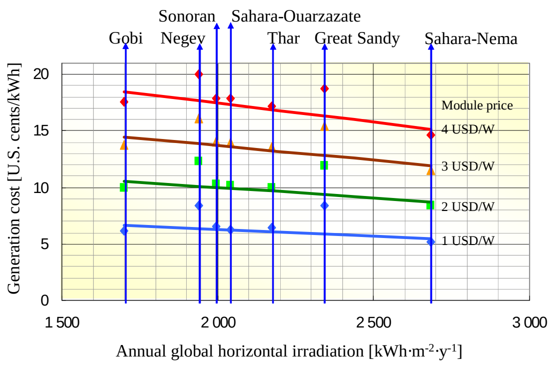

Fig.5: Best estimates of generation cost for each the deserts as a function of annual global horizontal irradiation

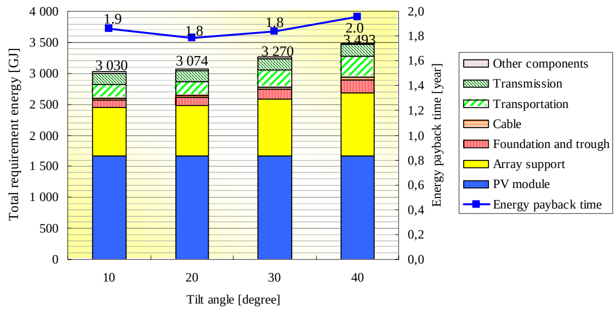

Fig.6: Total primary energy (TPE) requirement and EPT of a 100MW PV system

Table 1 Required system components for 100MW fixed flat palate PV system

	Sahara	Negev	Thar	Sonora	Great Sandy	Gobi
Land requirement [km^2]						
Tilt=10°	1.26	1.28	1.27	1.27	1.26	1.37
Tilt=20°	1.31	1.59	1.48	1.52	1.37	1.80
Tilt=30°	1.48	1.88	1.72	1.77	1.57	2.17
Tilt=40°	1.61	2.11	1.90	1.98	1.72	2.49
PV module [piece]	848 485					
Supporting structure [10^3 ton-steel]						
Tilt=10°	8.29					
Tilt=20°	8.61					
Tilt=30°	9.66					
Tilt=40°	10.76					
Foundation [10^3 ton-cement]						
Tilt=10°	90.9					
Tilt=20°	90.9					
Tilt=30°	135.7					
Tilt=40°	193.2					
Cable [10^{3}km]						
Tilt=10°	1.44					
Tilt=20°	1.59					
Tilt=30°	1.62					
Tilt=40°	1.70					
Power transmission corresponding to 100MW PV system						
Transmission line [km]	134					
Ground cable [km]	11.1					
Tower [ton]	742					
Foundation [10^{3}ton]	17.1					
Common apparatuses						
Inverter [piece]	202					
6.6kV capacitor [piece]	202					
6.6kV GIS [piece]	4					
110kV/6.6kV transformer [piece]	5					
110kV GIS [piece]	4					
2.4MVA capacitor [piece]	1					
Common power board [piece]	1					