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Estimate Expected Power Generation of Solar Panels with Freely Adjustable Tilt and Azimuth Angles

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1. Introduction [1]

The Japanese government has stated that it intends to attain national carbon neutrality by 2050 and achieve zero national greenhouse gas emissions as a response to the global challenge of climate change. The National Economic and Industrial Agency (METI) has taken the initiative in creating a carbon-neutral green growth strategy as a result, and in the energy sector, offshore wind power, solar power, and geothermal power have been given high importance. Spreading solar power generation to Japanese households and creating corresponding aggregation businesses have become fundamental goals of the solar energy development plan among the new energy sources, particularly in the sector of solar power generation. The use of renewable new energy has also become an important strategic development goal for each country, with photovoltaic power generation being a top priority, due to the current international unrest and the detrimental effects of the global economic downturn caused by COVID-19. As a result, the price of oil, crude oil, and liquefied natural gas is rising sharply globally.

Solar panels are typically mounted with a tilt angle of 36° and pointing south. In reality, it can be challenging to put solar panels in one direction because of a variety of factors, including the time of year, weather, and shadows cast by nearby structures. Changes to the solar panel's tilt angle and azimuth direction as well as overloading the power conditioning system (hereafter referred to as PCS) connected to the solar panel are among the solutions offered to address this issue. These changes will increase the solar panel's power generation efficiency and allow for the production of more power.

In this research, we provide the findings of our estimation of potential power generation with the objective of enhancing the full-year power generation in both Tokyo and Sapporo through flexibility in the installation direction and tilt angle of the PV panels.

2. Simulation module [2]

Fig.1. shows the estimation model developed for this research, which estimates the assumed power generation when two PV panels are installed on a PCS with variable installation orientation angle and tilt angle. The specifications of the estimation model were set as shown in Table 1.

In addition, the estimated power generation at 100%,150%, 200%, and 300% of PV panel overload are also calculated.

The assumed power generation is calculated using equation (1), using the annual hourly solar radiation database of the web-based Japanese solar radiation database view system published by NEDO (METPV-20):

$$P = \frac{eAU}{N} \quad (1)$$

P=Solar power generation per hour [kWh]
e=Power generation efficiency of PV panels
A=Area of PV panel [m^2]
U=Irradiation $[\frac{mJ}{m^2}]$
N=Ratio between solar irradiance and power generation

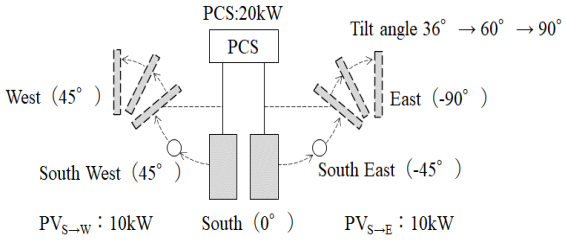

Fig.1. Estimation model of solar panel

Table 1. Calculation model specifications

PCS capacity	20kW
Solar panel	10kW+10kW (total 20kW)
Azimuth	0°(South), (45° (Southeast-Southwest),90°(East-West)
Tilt angle	36°,60°,90°

3. Analysis

Based on annual generation data for Tokyo and Sapporo and the "Solar Power Generation" report published by the Agency for Natural Resources and Energy in December 2021, the analysis and discussion that follows are based on the 200% overload rate, which is the optimal rate for this model after taking into account economic and other factors.

As shown in Fig.2, when the solar panels are mounted with a tilt angle of 36°, the average yearly power generation in Tokyo is at its highest.

According to Fig.3, the ideal azimuth for power generation is 0° when the solar panel's tilt angle is 36° and the overload rate is 200%.

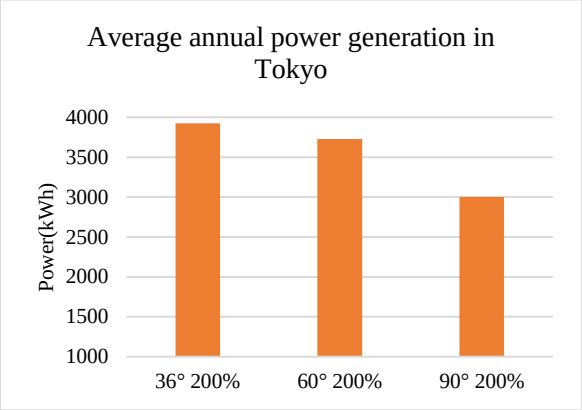

Fig.2. Average annual power generation in Tokyo

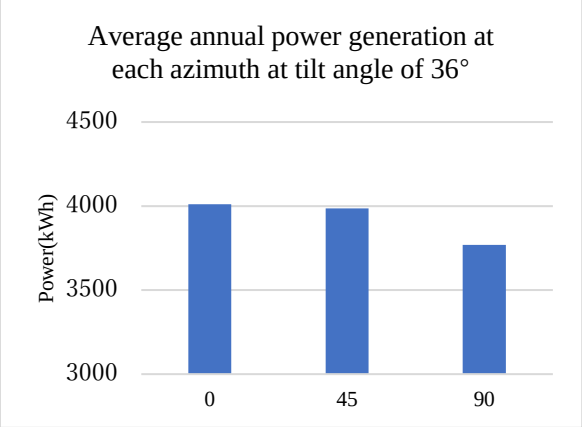

Fig.3. Average annual power generation at each azimuth at tilt angle of 36°

As can be seen from Fig.4, the average annual power generation in Sapporo reaches its maximum when solar panels are installed at a tilt angle of 36°.

The optimal azimuth angle for power generation is 0°, as shown in Fig.5, when the solar panel's tilt angle is 36° and the overload rate is 200%.

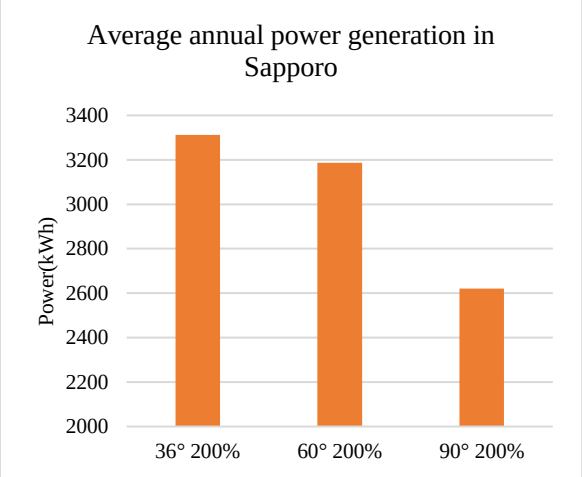

Fig.4. Average annual power generation in Sapporo

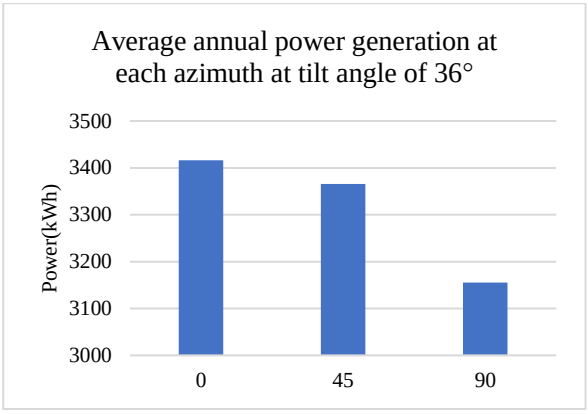

Fig.5. Average annual power generation at each azimuth at tilt angle of 36°

4. Conclusion and future work

For solar panels installed in Tokyo, a tilt angle of 36° and an azimuth angle of 0° are the ideal angles for installation. Given that the effect of other elements prevents the adoption of the ideal mounting solution (tilt angle 36°, azimuth 0°), a mounting solution with a tilt angle of 36° to 60° and an azimuth angle of 0° to 45° can be used instead.

The ideal tilt and azimuth angles for solar panels installed in Sapporo are 36° and 0°, respectively. The tilt angle should be between 36° and 60°, and the azimuth angle should be between 0° and 45° if the ideal installation scheme (tilt angle of 36° and azimuth angle of 0°) cannot be employed for some reason.

According to the estimating model created this time, effective cost savings can be predicted to vary between 200% and less of the overload rate, which is a relative proportion. Future estimates of power generation trends will be validated for comparison across a range of latitudes and longitudes.

Reference

[1] Agency of Natural Resources and Energy: “About Solar Power Generation”, Dec. 2021. https://www.meti.go.jp/shingikai/santeii/pdf/073_01_00.pdf

[2] New Energy and Industrial Technology Development Organization, “NEDO solar irradiation database browsing system”. https://appww2.infoc.nedo.go.jp/appww/index.html

＊Research Achievement

1. YU HAIHAN, TAKUBO RYU, FUJITA GORO: “Estimating thermal transmittance using AI in buildings”, 2022 Electricity and Energy Competition
2. YU HAIHAN, TAKAMI KEISUKE, FUJITA GORO: “Optimal design of PV panel installation in different orientations”, 40th National Conference of the Electrotechnical Equipment Society (EES) in 2022