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Submerged power generation using mono-crystalline silicon solar panel - possibility of electric power generation under seawater

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Abstract
In recent years, photovoltaic power generation has spread around world as the performance of solar panels has improved. However, small islands such as Japan and Singapore does not have enough land space to install solar panels. On the other hand, they have enough install space at their exclusive economic sea zone. Recent efforts shows deployment of solar panel in water bodies provides increased cooling which in turn increases the PV cell's power generation. In this paper, the authors have investigated the possibility of solar power generation under seawater. Preliminary experiments of the present study were conducted using a single crystal silicon solar panel under incident light in the room. Results shows: 1) The power generation efficiency does not decrease until the water depth reaches 200mm. 2) The power generation efficiency is greatly influenced by the water temperature. The lower the water temperature results in increased power generation efficiency. 3) Electric power generation efficiency is not affected by salinity up to 5wt.%.
Key Words : Solar panel, Sea water, Mono crystalline silicon, Water depth, Temperature, Salinity, Sunlight, incident Light

1. Introduction

In recent years, solar power generation has spread worldwide as the performance of solar panels has improved and the system price has decreased due to mass production. On the other hand, mountainous countries such as Japan do not have enough land space to install solar panels. Furthermore, small island nations have vast exclusive economic seazone but depend on fossil based fuels for their economic growth. Therefore, active use of the seazone is a possible way to deploy novel solar PV renewables to achieve an energy self-sufficiency.

In 2014, the New Energy and Industrial Technology Development Organization Japan, conducted a demonstration project for multi-use of photovoltaic power generation, and a demonstration experiment on water power generation was conducted[1)]. Among these, problems remain such as a decrease in power generation efficiency due to contamination of the panel surface due to bird droppings and haze dust sedimentation and an increase in panel temperature.

In this study, we propose underwater solar power generation system and examine its feasibility when installed under sea water. In the sea, there is no risk of the panel surface becoming dirty with bird droppings or haze dust, and water may suppress the temperature rise of the solar panel. Therefore, a preliminary experiment on underwater solar power generation is performed using a commercially available single crystal silicon solar panel. The effects of water depth, water temperature, and salinity on the output voltage were studied experimentally, and the associated technical problems in the installation of the solar panel below the sea surface were investigated and overcome.

2. Experimental apparatus and method

For preliminary experiments on underwater solar power generation, a commercial solar panel made of single crystal silicon (20W, SN Solar Technology) with the specifications shown in **Table 1** is used. The solar panel is installed at the bottom of a polypropylene water tank with a capacity of 58little (540mm x 370mm x 290mm), and the outer periphery of the tank is covered with a light-shielding cover so that it is not affected by incident light from the side.

A scale is attached inside of the water tank to monitor the water depth. In order to make the measurement environment constant, the output voltage is measured under an indoor fluorescent lamp with a constant room temperature. The output voltage from the solar panel is measured by a tester (AM33D, made by Astral), the illuminance of incident light is measured by an illuminance meter (TLX-204, made by TORUSCO) with a measuring range of 0 to 200,000lx, and the water temperature and room temperature are measured by a thermometers (Multithermometer, Nichido Product).

3. Experimental results

3.1. Preliminary experiment

In order to clarify the difference in power generation capacity between indoor fluorescent lamps and sunlight, preliminary power generation experiments are conducted in the illuminance range of 200 to 800lx. To compare under the same illuminance, the measurement is performed in the evening under sunlight.

As shown in **Fig. 1**, the output voltage of sunlight is higher at the same illuminance. This is due to sunlight having a wider spectrum width of light and the conversion efficiency to electrical energy by Si solar panel is higher. Under the low illuminance conditions such as in this experiment, the output

Table 1 Specification of solar panel

Type of solar panel	Mono-silicon type
Dimensions of generator	530mm x 350mm x 25mm
Mass	2.6kg
Maximum output voltage	20V
Model of solar panel	GW-020H (GW SOLAR)

voltage is almost proportional to the illuminance under any environmental conditions.

Since sunlight and fluorescent lamps have different light spectrum, indoor data cannot be directly used for sunlight data. Therefore, the indoor measurement results in this report are intended to relatively consider the effects of water depth, water temperature, and salinity at a constant temperature, and we do not consider applying the measured values directly to underwater solar power generation.

3.2. Effect of water depth of cut on power generation

Tap water (22.4°C) left for 1 day under constant temperature was gradually added to the water tank in which the solar panel was submerged to increase the submerged water depth of the solar panel. The change in output voltage was measured with increase in water depth. The output voltage in the atmosphere at room temperature 22.4°C (water depth 0mm) condition was found to be 13.12V.

As shown in **Fig. 2**, the output voltage is almost constant in the depth range of 0 to 200mm. In other words, the effects of liquid surface reflection and underwater scattering are small even in water, and there is no significant gain or loss in power generation efficiency even in the air or below the water surface.

Therefore, in the case of a demonstration experiment in which a solar panel is installed in the sea, it is not necessary to consider the effect of sea level. In other words, no significant investment is required when designing a floating body for mounting a solar panel, and it can be understood that a simple floating body as shown in **Fig. 3** can be used.

3.3. Effect of water temperature on power generation

In order to obtain the relationship between water temperature and voltage output under the same illuminance, the power generation experiment under the same illuminance of the fluorescent lamp was repeated 3 times. The difference in the color of the symbol mark in the figure indicates the difference in the experiment date. Ice cube and dry ice were put in the water tank in the low temperature state, and hot water was poured into the water tank to set the water temperature to an arbitrary temperature.

As shown in **Fig. 4**, the output voltage increases in proportion to the decrease in water temperature. Even if the measurement conditions are different, if the water temperature is the same, the output voltage is constant and the reproducibility is high. The output voltage V under the fluorescent lamp in the case of the test solar panel can be approximated by the following equation as a function of the water temperature T.

$$V = 0.008T \qquad (1)$$

3.4. Effect of salinity of seawater on power generation

The salinity of seawater varies depending on the sea area, but the maximum concentration is 5wt.%[2]. Therefore, the influence of the salt concentration on the power generation output at a water depth of 10mm and a water temperature of 23.1°C is studied by mixing tap water with salt collected from seawater. Figure 5 shows the relationship between salinity and power generation efficiency. In the range of 0 to 5wt.%, no influence on the output voltage due to the difference in salinity is observed.

4. Conclusion

In order to examine the feasibility of solar power generation under the sea level, a preliminary experiment was conducted using a solar panel made of single crystal silicon, and the following conclusions were obtained.

1) If the installation depth of the solar panel is up to 200mm, the output voltage is about the same as in the atmosphere.
2) The output voltage under fluorescent light is proportional to the water temperature, and the lower the water temperature, the higher the output voltage.
3) When the salinity is in the range of 0 to 5wt.%, the output voltage is not affected by the salinity.

References

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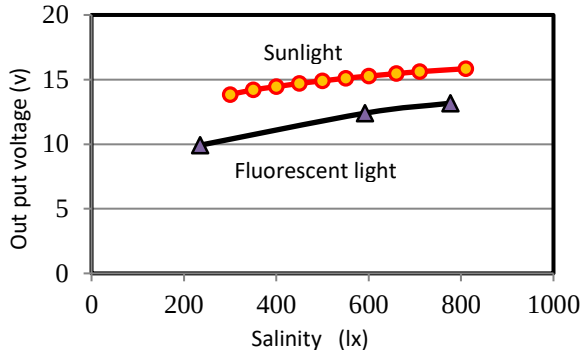

Fig.1 Power generation difference between sunlight and fluorescent light

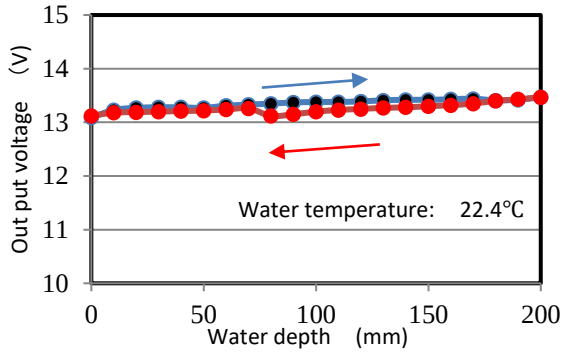

Fig.2 Effect of water depth upon output voltage

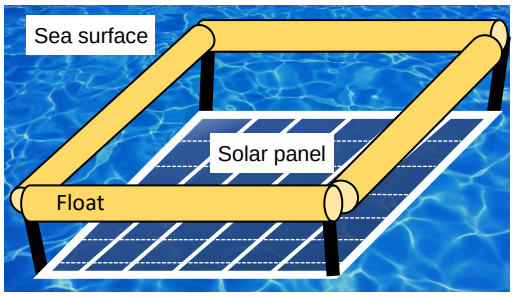

Fig.3 Submerged Solar Panel

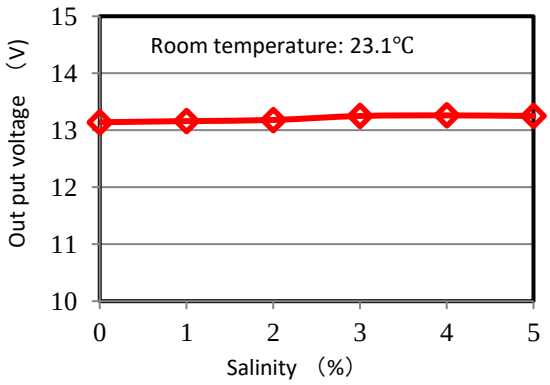

Fig.4 Effect of salinity upon output voltage