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A Study On the Cooling Effect of the Floating Horizontal Solar Cell

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Abstract

In this study, we measured the power and temperature of the floating horizontal solar cell in a coastal lagoon and compared with those of ground solar cell and water platform solar cell. Because the bottom surface of the floating horizontal solar cell was contacting the water, cooling effect was expected stronger than other cells. As a result of the measurement, the power of floating horizontal cell was 11.7% higher than that of the ground cell and 15% higher than that of the water platform cell. During the measurement, it was observed that water waves were continuously flowed on the top surface of floating horizontal cell by the wind, and it could be assumed that the cooling effect occurred not only on the bottom surface of the cell but also on the top surface. In order to analyze the cooling effect and power increasing of the horizontal cell in the wave situation, we measured power and temperature of the cell while generating artificial waves in a laboratory equipped with Zenon lamp as a solar simulator. At the height of the water surface, the power of the cell with waves was 3.7% higher than without waves and temperature was 4.6℃ *lower. At 1 cm and 2 cm below the water surface, power of the cell with waves was decreased by 14% and 11% than without waves while temperature was same . At 3 cm below the water surface, there was no effect of waves.*

Keywords: *Solar Cell, Floating Solar Cell. Horizontal Solar Cell, Cooling Effect, Waves on Cell*

1. Introduction

Solar cells lose their power generation efficiency as the temperature rises, and their efficiency decreases by 5% for each 10˚C rise [1,2]. For this reason, several cooling systems such as geothermal exchager or convectional ducts are being studied to address the disadvantage of power decrease in summer [3,4].

On the other hand, the water platform solar systems, which mount 30° inclined solar modules on a floating platform, generates electric power in many reservoirs or lakes. The water platform solar systems obtain higher power efficiency compared to the ground solar systems due to the cooling effect of water [5].

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Studies on underwater solar modules were also conducted : many researchers reported that the maximum power of the underwater module was higher than that of the ground module, and that the power efficiency decreased by 5% for every 1 cm increase in depth, and the efficiency decreased further when the angle was increased to 30°, 45°, and 60° compared to the angle of 0° [6~8]. In Africa and India where the temperature is higher, some studies about the underwater solar cell suggested to install solar cells directly below the surface of the water [9, 10].

In this study, in order to design floating horizontal solar systems, we compared temperature and power of the floating horizontal solar cell to those of the ground cell and the water platform cell in a coastal lagoon. In addition, to find out how wave affect the cooling effect of the horizontal cell, we compared temperature and power of cell at 4 water depths with artificial waves in lab.

2. Experiments of 3 Type Solar cells on Coastal Lagoon

The ground solar cell was installed at an angle of 30° to the south on the ground, the water platform cell was installed at an angle of 30° on a platform floating on the lagoon, and the floating horizontal cell was installed horizontally on the water surface supported by buoyant objects as shown in Figure 1. All the solar cells were monocrystalline type and had a maximum output of 6 V and 0.45 A. Measurements were taken at 30-minute intervals from 09:00 to 18:00 during sunny days (3days) on May. The coastal lagoon "Bong-Po Ho" is located at N38.25164° and E128.55931°. The photovoltaic power P was calculated as the product of the open-circuit voltage Voc and the short-circuit current Isc. The average ambient temperature was measured at 28.14℃, and the average water temperature was measured at 23.94℃.

Figure 1. Three cells under experiments (left : ground cell, top : water platform cell, bottom : floating horizontal cell)

As shown in Figure 2, the average temperature of the floating horizontal cell was 24.58℃, which was 3.64℃ lower than the average ambient temperature and 0.62℃ higher than the average water temperature. It was 8.3℃ lower than 32.78℃ of average temperature of the ground cell, and 3.58℃ lower than 28.16℃ of the average temperature of water platform cell, showing the greatest cooling effect. The average power of floating horizontal cell was 11.7% higher than average power of the ground cell and 15% higher than average power

of the water floating cell. It is believed that the temperature difference of the solar cell affects Voc open-circuit voltage.

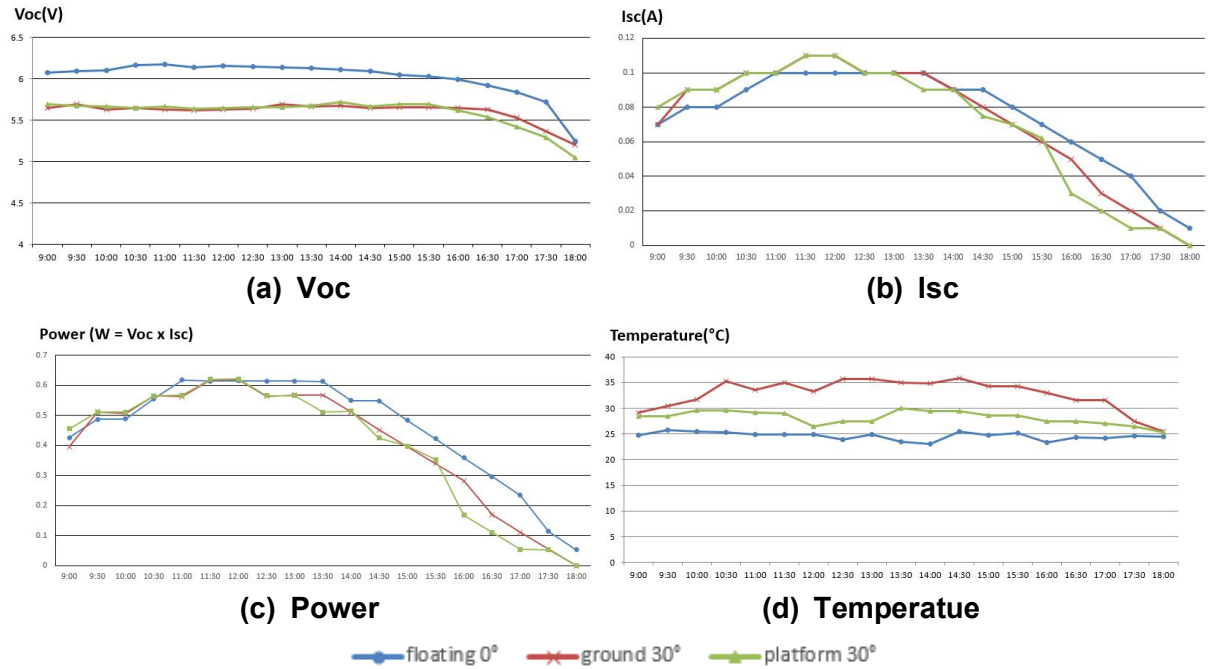

Figure 2. Voc, Isc, Power and Temperature of three panels in the coastal lagoon

In terms of time zone, Voc of the floating horizontal cell was evenly high over the entire time. In the morning (09:00~12:30), Isc of the ground cell and the water platform cell were slightly higher than Isc of the floating horizontal cell, but all of them were almost same from 12:30 to 14:00, and after 14:00, Isc of the floating horizontal cell was found to be slightly high. In the morning when the angle of incidence of sunlight was low, the ground cell and water platform cell installed at an angle of 30° were advantageous, and after that, the cell installed horizontally was found to be more advantageous. During the experiment, it was observed that waves by wind continuously flowed above the top surface of the floating horizontal cell, and it could be assumed that cooling effect occurred not only on the bottom surface of the cell but also on the top surface. Therefore, additional experiments on the cooling effect of waves are needed.

3. Experiments with Artificial Waves in Lab.

A water tank was installed in the laboratory and waves were created artificially by pushing a ladder-piston by hand. Figure 3 (a) shows the waves in the lagoon, observed at height of 1 cm and period of 0.5 s. (b) shows waves artificially created in the laboratory, with a height of 1 cm and a period of 0.5 s, same as the lagoon.

The height of the horizontally installed solar cell was fixed and amount of water was adjusted so that 4 cases : equal to water surface, 1 cm below the water surface, 2 cm below the water surface, and 3 cm below the water surface (marked as 0 cm, 1 cm-, 2 cm-, 3 cm- respectively). Water temperature, cell temperature, open-circuit voltage, and short-circuit current were measured with waves and without wave. As a solar simulator, 1.2kW Xenon lamp was used.

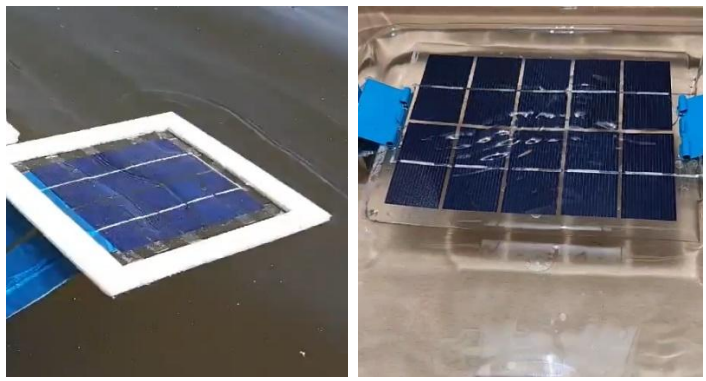

Figure 3. Waves flowed on the top surface of cells (left : cell in lagoon, right : cell in lab)

The power was calculated by multiplying the open-circuit voltage and the short-circuit current. As shown in Figure 4, the power at 0 cm with waves was 3.7% higher than power at 0 cm without wave. The temperature of the cell with waves was lower 4.6℃ than without waves, and that difference of temperature made better power performance. On the contrary, at 1 cm- and 2 cm-, the power of the cell with waves were lower 14% and 11% than without waves respectively. Considering that there was almost no difference in cell temperature, it was assumed that waves made solar radiation more scattered and power of underwater cell decreased. It was found that there was no effect of waves at 3 cm-. The experiments results in lagoon and lab show that if we can float solar cells horizontally on the water, and if we can make waves flow freely over the surface of the cells, we will get stronger cooling and more power.

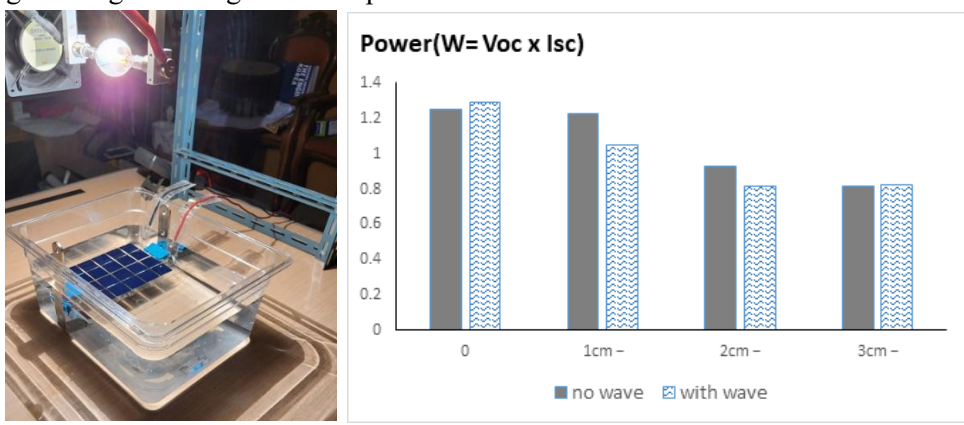

Figure 4. Cell under experiments (left) and average power of the cell of various depth(right)

4. Conclusion

In this study, We measured the power and temperature of the floating horizontal solar cell in a coastal lagoon and compared with those of ground solar cell and water platform solar cell. Because the bottom surface of the floating horizontal solar cell was contacting the water, cooling effect was expected stronger than any other cells. As a result of the measurement, the power of floating horizontal cell was 11.7% higher than the ground cell and 15% higher than the water platform cell. During the measurement, it was observed that water waves were continuously flowed on the top surface of floating horizontal cell by the wind, and it could be assumed that the cooling effect occurred not only on the bottom surface of the cell but also on the top surface. In order to analyze the cooling effect and power increasing of the horizontal cell in the wave situation, we measured

power and temperature while generating artificial waves in a laboratory equipped with Zenon lamp light as a solar simulator. At the height of the water surface, the power of the cell with waves was 3.7% higher and temperature was 4.6℃ lower than without waves. At 1 cm and 2 cm below the water surface, power of the cell with waves was decreased by 14% and 11% than without waves while temperature was same. At 3 cm below the water surface, there was no effect of waves. The experiments results in lagoon and lab showed that if we can float solar cells horizontally on the water, and make waves flow freely over the surface of the cells, we will get stronger cooling and more power.

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