EVALUATION AND OPTIMIZATION OF WIDE ACCEPTANCE ANGLE CONCENTRATOR PHOTOVOLTAIC MODULE

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One of the main concerns of concentrator photovoltaic (CPV) with concentration ratio above 100 suns was always the acceptance angle of the system and the non-uniform irradiance profiles on the solar cell. Small acceptance angle has an impact on the precision of the solar tracker which can lead to increase in the total cost of the system, while the non-uniform irradiance can result in electrical losses caused by the non-uniform irradiance profiles impact on the cell performance and operation, compared with the uniform irradiance on the solar cell.

In this study, we introduce a CPV system that uses a wide acceptance angle optical lens made from S-TIM2 glass and dielectric kaleidoscope (homogenizer) secondary optical element. Ray-trace simulation in ZEMAX for the system was conducted as shown in Figure 1. The real CPV module is illustrated in Figure 2. Simulation results for the optical model showed an optical efficiency of 86.9\% and acceptance angle of about 4.5°. This wide acceptance angle allowed us to use 30-min intermittent tracking system that had a maximum tracking error angle of 3.65° at noon. The use of 30-min intermittent tracking system allowed substantial decrease in the system cost because of the low needed precision and the potential of power saving when the tracker is not moving. Heat transfer simulation was also conducted to evaluate the working temperature of the cell under concentration conditions. The solar cell temperature reached a maximum of 28.2°C. The temperature distribution on the solar cell surface is shown in Figure 3.

Using equivalent circuit model for a triple-junction solar cell in the case of no tracking error condition at noon on February 15, 2017, we obtained the electrical characteristics of the system. The simulated electrical characteristics were compared to the real experimental data outputs as shown in Table 1. The results revealed that there are noticeable differences in short circuit current and module efficiency between the experimental and simulated outputs. These differences are expected to be caused by the excessive use of silicone sealing in the real module, which was not considered in the used optical model.

We are currently evaluating the system using a new optical model which take the excessive silicone sealing into consideration and measure its effect on the irradiance distribution and electrical characteristics using sensitivity analysis.

Different secondary optical elements are currently being optimized and evaluated to accomplish better irradiance distribution on the solar cell. The effect of using this different secondary optical elements on the current matching and thermal performance of the solar cell is also being investigated.

Table 1: Electrical characteristics of the triple-junction solar cell

<table>
<thead>
<tr>
<th></th>
<th>$I_{sc}$ (A)</th>
<th>$V_{oc}$ (V)</th>
<th>$P_{m}$ (W)</th>
<th>$FF$</th>
<th>Module efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation</td>
<td>0.3162</td>
<td>3.0012</td>
<td>0.8489</td>
<td>0.8945</td>
<td>32.99</td>
</tr>
<tr>
<td>Experiment</td>
<td>0.2628</td>
<td>3.0010</td>
<td>0.6979</td>
<td>0.8852</td>
<td>27.11</td>
</tr>
</tbody>
</table>

Figure 1: Optical model for ray-trace simulation. Figure 2: Real CPV module. Figure 3: Temperature distribution on the triple-junction solar cell.