DEVELOPMENT OF LIQUID COOLING TECHNOLOGY FOR SOLAR MODULES

PROJECT OBJECTIVES

This project aims to study and develop various cooling systems that can be deployed to reduce the temperature of solar panels to improve their output efficiency. The ability to reduce the operating temperature of solar panels will enable Singapore to utilise less space in solar panel installation and increase solar generated electricity.

PROJECT SUMMARY

Recently, the use of solar energy has become more prevalent in Singapore. However, because the performance of photovoltaic modules deteriorate as the temperature increases, the efficiency of solar panels in generating electricity is adversely affected in hot regions like Singapore.

The project began with a preliminary study of how the performance of various structures in solar cells are affected by temperature. This was then followed by an in-depth study on the temperature-reduction performance of three types of cooling designs:

(i) Passive cooling - Aluminium and copper fins are used as heat sinks and they are installed behind the solar panels

(ii) Active cooling - Water is pumped, circulated and sprayed onto the solar panel surfaces to reduce their temperature

(iii) Hybrid cooling - A combination of aluminium heat sinks and copper tubes with circulating water is used to cool the solar panels

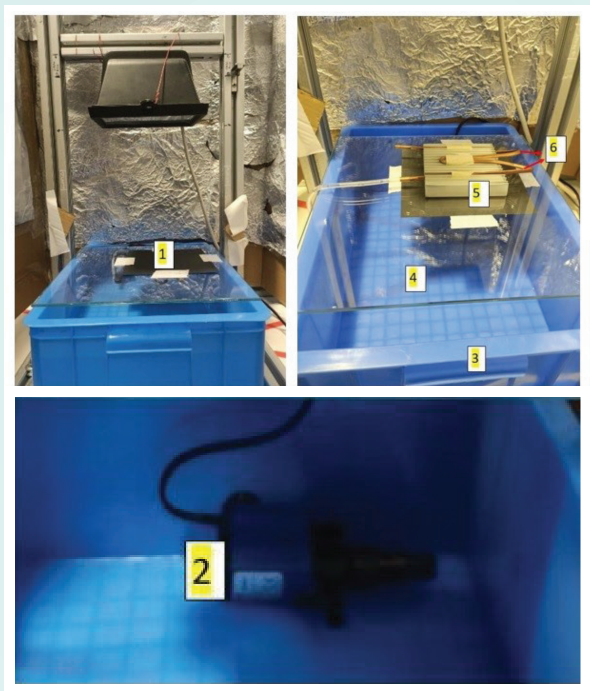
In the study, the project team found that the structure of a solar cell plays an important role in determining the sensitivity of the cell's performance under different temperatures. Specifically, a Passivated Emitter and Rear Contact (PERC) solar cell structure is more sensitive to temperature variations as compared to a monoPoly solar cell structure. For a monoPoly solar cell, the voltage drops by 4.54% as temperature increases from 25°C to 59°C under the sun. There is not much change to the short circuit current (I_{sc}) in the cell as the temperature varies under the same light intensity. At 25°C, the PERC solar cell generates about 1.15% more voltage than the monoPoly cell, with similar behaviour in the I_{sc}. However, once the temperature increases beyond 35°C, for instance at 55°C, the PERC solar cell performs about 3.49% worse than the monoPoly cell.

For the passive cooling design, the study showed that the extent to which temperature reduced depends on the size and number of fins as well as the material used for the heat sinks. However, this design's usefulness is limited if air circulation is weak (e.g. if the solar panels are installed near the ground). For the active cooling design, which involves spraying water over the surface of the solar panels, a temperature reduction of up to 15°C was achieved. That said, the relative effectiveness of the active cooling design in lowering solar cell temperatures is offset by requiring additional power to pump the water. For the hybrid cooling design, where water circulation and aluminium heat sinks are installed at the rear of the solar panels, a temperature reduction of up to 10°C was achieved.

PROJECT OUTCOMES

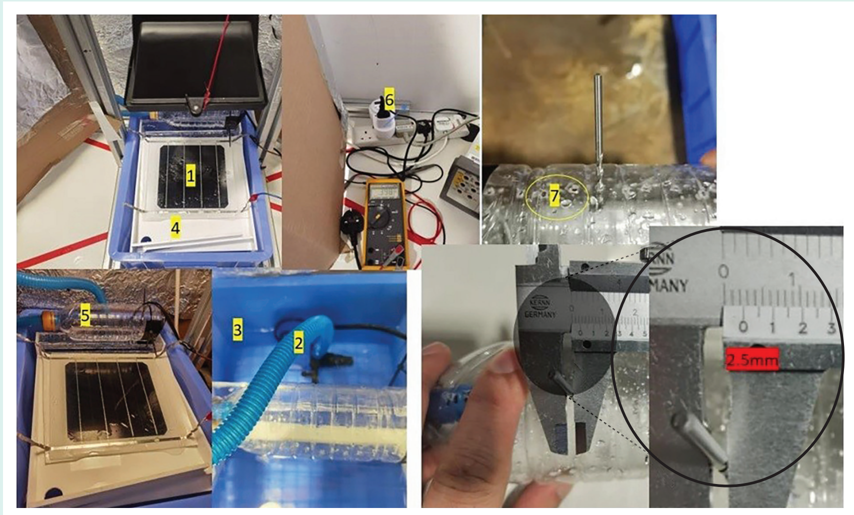
This project determines the optimal cooling design to be deployed depending on the environment that the solar panels are installed in. For dry land or windy locations, hybrid cooling is recommended. For dusty locations or deserts, active cooling would work better as the water serves to cool both the solar panels as well as wash off the dirt/sand that accumulates on the surface of the panels (which will adversely affect their output efficiency).

SETUP OF HYBRID COOLING DESIGN



1. Black Paper 2. Pump 3. Tank 4. Glass 5. Aluminium Heat Sink 6. Copper Tube

SETUP OF ACTIVE COOLING DESIGN USING WATER SPRAY



1. Solar Cell 2. Pump 3. Tank 4. Stand 5. Bottle 6. Timer 7. Holes

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