Australian Government
Australian Renewable Energy Agency

ARENA

Lessons Learnt

Lessons Learnt Report: *Hot-Spot Cell Temperature in Half-Cell Photovoltaic Modules*

Project Name: *Photovoltaic Modules for the Australian Environment (PV-MATE)*

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Solar PV
State/Territory:	Canberra ACT, Adelaide ACT

Key learning

We have compared the partial shading induced hot spots in half-cell modules and full-cell modules. Compared with a conventional module shown in Fig. S1(a) with 60 series connected full-size cells, the proposed module in Fig. S1(b) consisting of 120 half-cut cells exhibits reduced peak hot-spot cell temperature by 20 °C. Minor temperature elevation is found on a few cells located in the substring (Substring B) that is parallel connected with the shaded string (Substring A). This phenomenon is correlated with the variance of the short-circuit current of the cells. Decrease of cell temperature ranges are also found in the half-cell module for all simulated shading conditions as depicted in Fig. S2.

Implications for future projects

The hot-spot temperature simulation of the half-cell module provides theoretical support for its improved partial shading endurance. The reverse bias found in the illuminated parallel connected substring implies further word is required to study the correlation between cell variance and the resulted cell temperature elevation. Additionally, the electronic simulation of photovoltaic module with mixed series and parallel connection allows us to simulate module output with complex cell connections.

Knowledge gap

Solar modules using half-cut cells are reported to have reduced cell-to-module losses. However, the reliability of this module design has not be reported. The temperature of photovoltaic (PV) cells increases when they are shaded in the module and put in reverse bias by the illuminated cells, which is also called the hot spot effect. The hot spot effect is ranked as the most significant degradation mode in silicon photovoltaic modules in the last 10 years. A method for hot-spot endurance testing is provided in the International Electrotechnical Commission's (IEC) standard IEC 61215-2 (2016) for simple cell interconnections under the worst-case partial shading setup. Existing simulative studies of the shading impact focus on module performance, whereas a cell-level hot spot simulation is still lacking for the half-cell module.

Background

Objectives or project requirements

We are looking at improving the cell-to-module losses of current PV modules. While the half-cell module has reduced resistance loss and improved light collection, its long-term reliability was not clear. Hence a study on the shade induced hot spots in the half-cell module is critical for the design process.

Process undertaken

The simulation was conducted in two parts including electronic-circuit simulations for the operating current and voltage (*IV*) conditions of cells and a two-dimensional thermal simulation for the cell temperature. We assume similar cell properties, adjusted for halving of the area, neglecting the impact of cell cutting.
First, we generated *IV* curves for both full-size and half-size cells using the one-diode solar cell model and the reverse breakdown model of Bishop. Manufacturing variance in the cell parameters account was also accounted for by sampling the cell parameters from a distribution of cell properties determined from measurements of commercially procured cells. A reduction of the photocurrent in the one-diode model was applied to simulate the effect of partial shading on a typical cell, Cell 15 highlighted in Fig. S1, for both modules. The spatially resolved cell temperatures of reverse biased cells (Cell 15 in the full-cell module, Cell 15, 22, 25,30 and 38 in the half-cell module) were then simulated under an irradiance of 1000 W/m^2, ambient temperature of 25 °C and wind speed of 1 m/s.

Supporting information

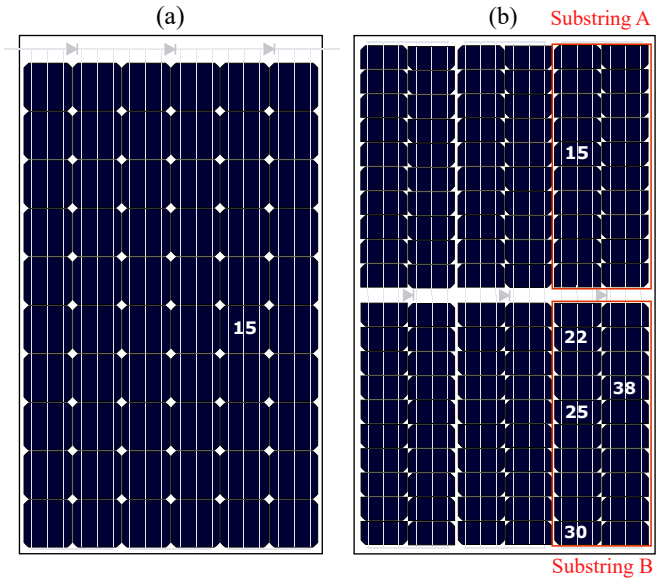

Fig. S1. Module cell layout for: (a) conventional full-size photovoltaic cells connected in series, and (b) series-parallel-series connected half-size cells. The numbered cells labelled in the graph are reverse biased from simulation described in this paper. Specifically, Cell 15 is shaded in both modules, and the numbered Cells in (b) Substring B are reverse biased owing to the series-parallel-series connection.

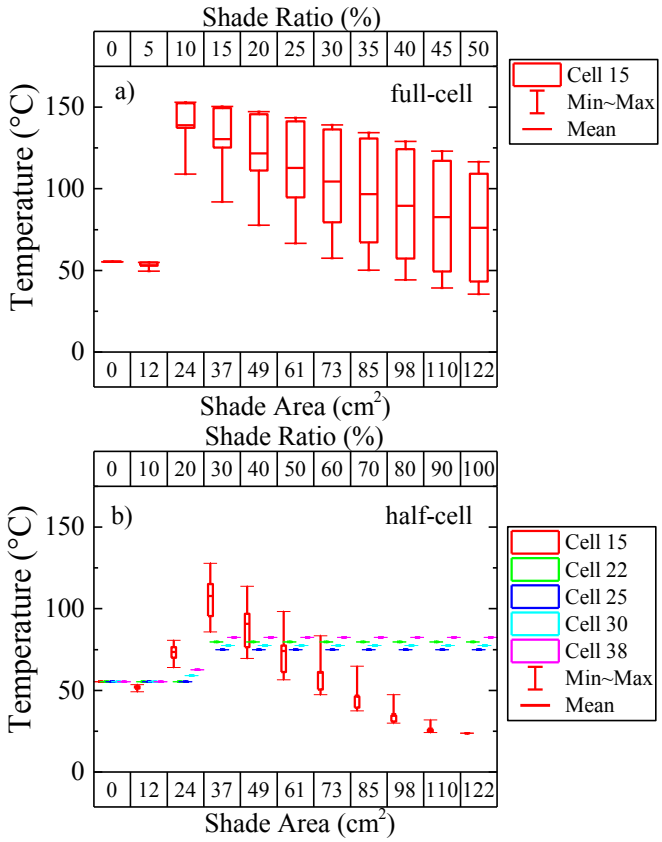

Fig. S2 Simulated cell temperatures for reverse-biased cell(s) in the (a) full-cell module and (b) half-cell SPS module.