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Thermal effects of microinverter placement on the performance of silicon photovoltaics

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Abstract

Typical installation of a microinverter in a plane parallel position on the back side of a monocrystalline silicon photovoltaic (PV) panel can lead to differential heating of the PV cells immediately above the microinverter by as much as 4 °C. Rotation of the microinverter to a perpendicular position allows the microinverter itself to run cooler by about 4 °C and completely removes the distinctive heat signature on the panels. Because the thermal effects of the microinverters are significant for only two of the 72 cells on the panel, changes in DC power output from the panels are not detectable. However, lower microinverter temperatures increase microinverter efficiency by about 0.65%, such that overall AC power production is increased by about 0.09%. In addition to these small improvements to be gained by the repositioning of microinverters, there are also potential long-term concerns that nonuniform heating may lead to accelerated degradation in the affected area of the panel.

Keywords: PV panel efficiency; Microinverter efficiency; Temperature effects

1. Introduction

Crystalline silicon photovoltaics (c-Si PV) are the predominant form of solar panels, and they have become increasingly more affordable and more widespread. In the first quarter of 2014 investment in solar technology worldwide was approximately 27.5 billion US dollars, an increase of 23% over the first quarter of 2013 (Economist, 2014). Although the cost of solar modules has decreased significantly, recently dropping under \$1/W (PVInsights, 2015), soft costs remain high, in particular installation labor. Currently, labor for an individual rooftop installation is approximately \$0.50/W (Ardani et al., 2013), and total installed cost of a system can run as high as \$3–7/W (Shahan, 2014). As we move toward lowering soft costs, microinverters are poised to become more popular; preassembly of microinverters onto PV panels could significantly lower installation costs for small business and homeowner installations.

It is well known that maintaining c-Si PV panels at lower temperatures maximizes energy production and also minimizes degradative processes (Hacke et al., 2010; Skoplaki and Palyvos, 2009). Decreases in performance of c-Si PV panels due to increasing temperature is well

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documented and is understood to be associated with changes in electron transport dynamics (Skoplaki and Palyvos, 2009). The degradation processes due to increased temperatures are correlated with different material thermal expansion coefficients (Hacke et al., 2010) as well as thermal degradation and discoloration of polymeric components in the ethylene vinyl acetate encapsulation layer (García et al., 2003). It should also be noted that when certain cells in a panel have an electrical resistance higher than other cells, either by shading or by increased temperature, these lower-performing cells can disproportionately lower the performance of the entire panel (Kaplani, 2012). Significant losses due to this effect have been largely overcome through the use of bypass diodes between each series of cells (Zheng et al., 2012), but if the cells are not resistive enough to trigger the diode, then there may still be a negative impact on the entire panel's electrical output.

We recently published studies that correlated PV power output with cooling effects of recirculating water over the surface of PV panels (Smith et al., 2014). Around the same time that these experiments were performed, thermal images of the panels showed distinctive heat signatures from the microinverters installed on the undersides of the panels. The placement of microinverters close to the underside of the panels is suggested as the standard installation, presumably to protect the microinverter from environmental conditions (Enphase, 2013a). This study evaluates the usual placement of microinverters with regards to the silicon PV panel, suggesting a new placement in order to lower self-heating of the microinverter as well as incidental heating of the panel.

2. Experimental

Portland State University's Photovoltaic Test Facility (N 45.51°, W 122.68°) consists of 28 SolarWorld USA 175 W monocrystalline Si solar panels (SolarWorld, 2006), mounted over various green roof test surfaces (SolarPDX, 2015). This study used a subset of these panels, specifically two sets (groups 2 and 3) of four panels each (A, B, C, and D). Fig. 1 details the arrangement and identification of these panels. The panels were mounted at 30° from horizontal and directed approximately 20° ± 2° west of true south.

All reported data are calculated from 13 sunny and cloudless days between July 12 and August 5, 2014, specifically five selected days before the microinverters were repositioned and eight selected days after the microinverters were repositioned. Data points were taken every five minutes between the times of 12:00–3:00 pm. Ambient temperatures during these times on all the days of the study were relatively uniform, all within the range of 23–33 °C. These dates and times were chosen for uniformity of irradiation as well as maximum insolation and maximum ambient temperature, all of which would be expected to maximize the temperature and efficiency variations observed upon repositioning the microinverters. Each panel was monitored by an Enphase Model 210 microinverter (Enphase, 2013b). AC power data were reported directly from the microinverters. DC power data were calculated by multiplying the output DC current and voltage data reported by the microinverters. The microinverters also reported internal temperature.

At the initiation of the study, all microinverters were mounted in a uniform position on the aluminum racking parallel to the panels and approximately 0.8–0.9 cm from the backside of the panel. The manufacturer recommends 0.5 inch (1.3 cm) spacing between the panel and the microinverter (Enphase, 2013a); we acknowledge that our microinverters had been placed by the contractor at positions somewhat closer than recommended and this is likely to have generated larger thermal effects than would have been observed with the recommended placement. Between July 18 and July 21, the microinverters on panels 2B, 2D, 3A, and 3C were rotated 90° to a position perpendicular to the panel (see Figs. 2 and 3). No data from any of these days were included in this study. It should be noted that selection of alternating panels for microinverter repositioning was an arbitrary choice and not at all selective or reflective of any prior history or performance of the panels. Microinverter dimensions are 20 × 13 × 3 cm, so the effective area presented to the panel decreased from 260 cm^2 to 39 cm^2; the new mounting arrangement also placed the aluminum racking bar between the microinverter and the panel (Fig. 2).

Data used to determine DC and AC power output contained some inconsistencies, primarily absent data points; any time point that contained any data inconsistency was deleted across all panels, i.e., all data were deleted for that

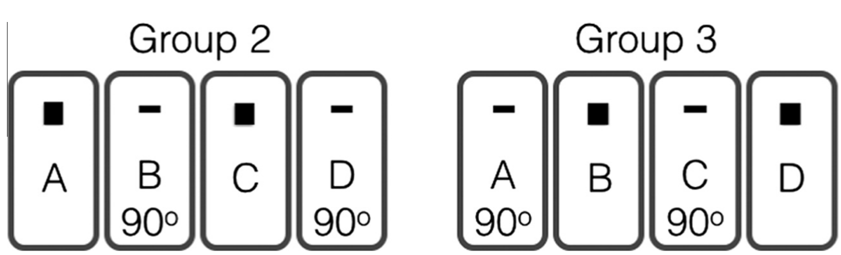

Fig. 1. Layout of the two PV arrays that were selected for testing. Within each array, two panels retained the original microinverter installations (2A, 2C, 3B, 3D), and two panels had their microinverters rotated 90° from the original installation at a particular time (2B, 2D, 3A, 3C).