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New Mexico's First Enphase Microinverter Rooftop Solar Installation – 13 Years of Performance Data

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Abstract. This paper presents a description of the first Enphase microinverter-based photovoltaic (PV) rooftop solar installation in New Mexico installed in 2008. Annual energy production during the first 13 years of operation is presented. During the first six years of operation, the annual energy production met or exceeded predicted energy production using the PV Watts model. During the first 13 years of operation, the annual energy production showed a ~1.5% annual degradation assuming a linear regression. Degradation could include reduced performance of the PV modules and/or microinverters, soiling of the PV modules, and individual microinverter failures prior to replacement. Ten of the 15 original first-generation Enphase microinverters have been replaced due to failures within the first 14 years of operation.

Keywords: Rooftop solar, microinverter, reliability.

1 Introduction

Over the last decade, microinverters have gained in popularity relative to central (or string) inverters because of purported advantages: (1) ability to produce more energy from an array of photovoltaic modules with partial shading, (2) greater reliability, (3) ease of installation, (4) safety (no high-voltage DC lines, and (5) ability to monitor performance of individual modules. Disadvantages include higher capital cost and potentially difficult access for rooftop mounted systems (microinverter is mounted underneath each module). This paper provides performance data for New Mexico's first Enphase microinverter-based solar photovoltaic (PV) rooftop system installed in 2008.

2 System Description

Figure 1 shows an aerial view of the 3 kW PV system installed on a two-story Spanish-tile roof in Albuquerque, NM. The original system consisted of 15 PV modules (200 W Sanyo HIP-200BA3) and 15 Enphase microinverters (200 W M200-32-240) with a 15-year warranty. The 10 modules on the top roof have an elevation tilt of 27°, and the five modules on the lower roof have a 30° tilt. Both arrays are flush mounted with the roof. The azimuthal orientation for all modules is 20° west of true south. Based on this configuration and the annual solar irradiance in Albuquerque, the system was predicted to produce ~5300 kWh using PV Watts [1], without consideration of partial shading or soiling.

Figure 1. 3 kW photovoltaic installation in Albuquerque, NM, using Enphase's first-generation microinverters.

3 System Performance

3.1 Energy Production

Figure 2 shows the actual annual energy production during the first 13 full years of operation from 2009 – 2021. During the first six years of operation, the system met or exceeded the predicted annual energy production of ~5300 kWh, despite no active cleaning of the PV modules (only periodic rain and snow). However, the chart shows a steady decline in annual energy output, which can be caused by degradation of the PV modules and/or microinverters, soiling, and/or periodic microinverter failures. When a microinverter failed, an automated e-mail notification was issued, but it often took several months or more to replace the bad microinverter (including obtaining a return merchandise authorization for the bad microinverter under warranty, scheduling a service technician, and replacing the microinverter). Accounting for all these factors, and assuming a linear regression of the actual annual energy output from 2009 - 2021, the annual "degradation" of the PV system was ~1.5%.

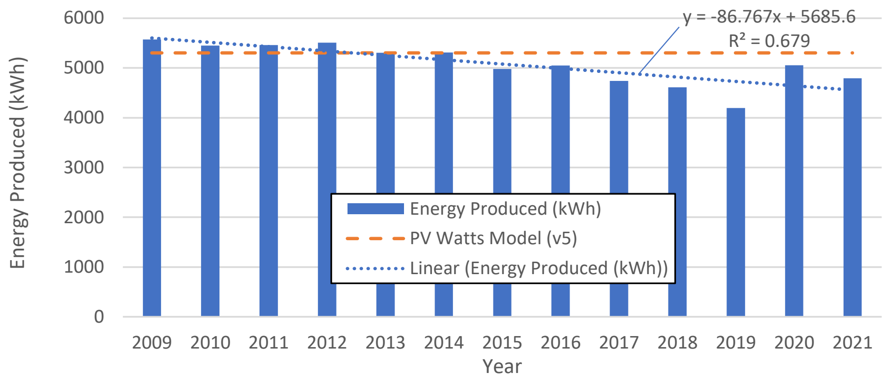

Figure 2. Actual annual energy production from 2009 to 2021 for 3 kW photovoltaic system. Total annual degradation assuming linear regression is ~1.5%. PV Watts model prediction for annual energy production is ~5300 kWh.

3.2 Microinverter Performance and Reliability

In general, the Enphase microinverters performed well when the units were functional. Frequent monitoring of the power production showed that during periods of partial shading from the chimney, power output was reduced only in the individual modules that were shaded. Figure 3 shows an example of the reported module power production during partial shading.

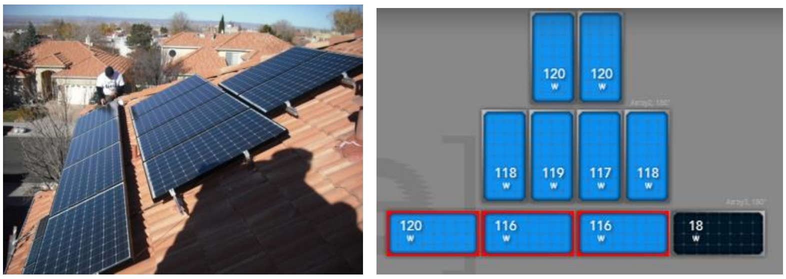

Figure 3. Left: Photo of shading from chimney encroaching on panels. Right: Image of module power production showing impact of shading on one of the modules.

However, within the first 14 years of operation, 10 of the original 15 microinverters had to be replaced, and two of the replacements also failed. So, 12 microinverters in total failed during the first 14 years of operation. Figure 4 summarizes the number of failures by year.

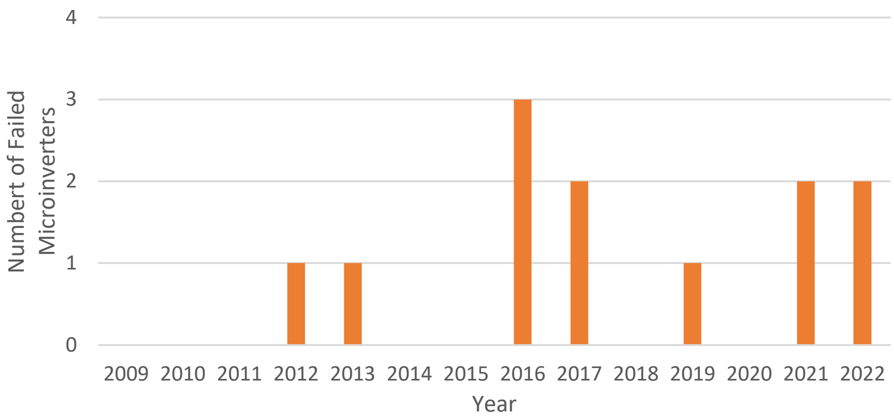

Figure 4. Number of failed microinverters each year since 2009. A total of 12 microinverters on 10 PV modules have failed, and five originals remain.

4 Discussion

Analyses were performed to evaluate potential improvements to the system, including changes to the orientation (which was not readily possible due to the orientation of the roof and house) and sizing of the microinverters. It was predicted that changing the azimuthal orientation from 20° west of true south to 10° east of true south and the elevation tilt from ~30° (27° for the top array and 30° for the bottom array) to 35° would have resulted in a ~3% improvement in annual energy output. In addition, under sizing the microinverters (i.e., using a 175 W microinverter vs. a 200 W microinverter with the 200 W modules) could also increase the annual energy output due to greater efficiency of the smaller (lower-capacity) microinverter when the module output is less than the rated capacity of the microinverter,[1] but the predicted improvement was negligible in the current system (~0.1% improvement).

Replacing the Enphase microinverters was straightforward, from requesting replacements under warranty from Enphase to installing the new microinverters. There are numerous online videos describing how to replace the microinverters safely. Replacing the microinverters on a pitched Spanish tile roof was challenging, but with two people, it was manageable. Be aware that a special tool is required to separate the cabling between the module to the microinverter, and the negative coupler was nearly impossible to disconnect without cutting through the tabs that held the connection together for the 1st-generation microinverters. It should also be noted that the latest IQ7 microinverters do not require an external electrical grounding cable, which was required for the early-generation microinverters.

[1] A tradeoff exists between greater efficiency of the smaller microinverter if the module output is less than or equal to the rated capacity of the microinverter and clipping that occurs if module output is greater than the rated capacity of the microinverter.

5 Conclusions

The 13-year performance of the first commercial deployment of Enphase microinverters on a residential rooftop photovoltaic system was reported in this paper. Of the original 15 first-generation microinverters, 10 have been replaced as of April 2022 due to failures and performance issues, and two of the replacements also failed and had to be replaced. Annual energy production of this 3 kW system was compared to predictions using PV Watts [1], and performance was comparable to predictions for the first six years. Over the last 13 years, degradation of the system output was determined to be ~1.5% per year, which included potential degradation in performance of the modules and/or microinverters, soiling of the modules, and/or microinverter outages prior to replacement. Optimizing the orientation, pitch, and microinverter sizing for this system relative to its deployed configuration was predicted to increase the annual energy production by several percent.

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