Performance of Enphase Microinverter Systems v. PVWatts Estimates

Authors: David Briggs, Marketing Manager; Mark Baldassari, Director of Codes & Compliance
Contributors: Astrum Solar, Inc., Real Goods Solar, Inc., Solar Universe, Inc.,
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SUMMARY

Results

The results of a recent field study of over 143 sites in operation for 6 months or more indicate that **Enphase installations outperform their PVWatts estimates by 8% on average, with most sites outperforming by more than 11%**. A review of similar published studies indicates that solar installations using standard inverters actually underperform PVWatts estimates by 8% on average. When considered together, these results indicate that Enphase Microinverters can improve the performance of solar installations by 16% on average versus standard inverter technology.

Methodology

PV system design information was collected for 143 Enphase installations. The expected performance of these systems was estimated using NREL's PVWatts calculator. These estimates were then compared to actual energy production data collected by Enphase's Enlighten website.

INTRODUCTION

Today, NREL's PVWatts Calculator is the leading performance forecasting tool for residential and small commercial solar applications. Yet, few studies have examined the actual performance of solar installations relative to their PVWatts estimated values.

In 2009, Gostein, et al. published the most extensive study to date [1] comparing the actual performance of more than 480 solar installations to their PVWatts estimates. In the study, monthly performance data for each site is compared to the monthly PVWatts estimate for that site, allowing the actual performance for each site to be presented as a percentage of the PVWatts estimate. The results of the analysis indicate that PV systems typically underperform PVWatts estimates by 8%. Similar performance results have appeared in other empirical studies [2], as well as theoretical modeling [3].

To better understand the performance of microinverter technology relative to PVWatts estimates, Enphase Energy conducted a similar study to Gostein, et al.

METHODOLOGY

Data Collection

PV system design information, such as module type, tilt and azimuth, was collected for 143 installations of Enphase Microinverters. Installations were geographically spread across California and the Eastern US. The sites were comprised of residential and commercial

installations, with an average size of approximately 5kW. Monthly performance estimates for each site were then obtained by inputting the design information into NREL's PVWatts Calculator. In the PVWatts Calculator, a standard DC-AC derate factor of 0.77 was used, which does not adjust the estimates for the impact of shade.

Actual monthly performance data was collected for each site from the Enphase Enlighten website. Each site had production data for at least 6 full months, with an average of 12 months. Performance data from the Enlighten website is reported by Enphase's Envoy device, which is a qualified +/-5% energy meter. The Envoy device aggregates power measurements from individual microinverters. To increase the precision of power measurement, the meter accuracy for each microinverter was factored into the study's calculations (see "Site Bias" calculation below). The meter accuracy is determined by comparing the microinverter's internal power measurement to its actual power output, as tested during the manufacturing process of the microinverter.

The energy losses due to resistance in system wiring could not be accurately accounted for in this study. Because Enphase Microinverters are collecting energy production information at the module, the reporting by Enphase Microinverters could be 1-3% higher than the energy production registered at the meter, which is what the PVWatts calculator is designed to predict. These losses vary depending on wire length, conductor size and other system design factors.

Data Accuracy & Analysis

Meter accuracy data for each microinverter was used to create a "Unit Bias" factor. The Unit Bias for each microinverter at a site was combined according to the following formula to generate a "Site Bias" figure for the site:

Site Bias (SB) = ($\sum$ Unit Bias at site)/(Number of units at site)

This site bias number gives the expected percent error in the reading of the Envoy device at the site. The monthly energy production values reported to Enlighten by the Envoy device were then adjusted for metering accuracy according to the following formula:

Adjusted Monthly Production $P_{j.adj} = P_j*(1-SB/100)$
P_j – Energy production for month j, taken from Enlighten

These adjusted monthly production values were compared to the monthly PVWatts predicted values for each site to create a "Performance Ratio" for each month. Monthly Performance Ratio was calculated as follows:

Performance Ratio for month j, $PR_j = P_{j.adj} / P_{j.est}$
$P_{j.est}$ – Estimated monthly output for month j, taken from PVWatts

The overall performance ratio for each site (PR) was calculated by taking the average of all PR_j's for that site.

$PR = \sum PR_j / N$
where j = 1 to N
N – Number of months for which data is available

RESULTS

Of the 143 sites analyzed, the average Performance Ratio was 108%, and the median performance ratio was 111%. More than three-quarters of Enphase installations were outperforming their PVWatts estimates, by as much as 134% of expectation. Of the approximately one quarter of sites that were underperforming their PVWatts estimates, most were performing at 90% or better of their estimates.

Summary Statistic	Enphase	Gostein, et al
Average Performance Ratio	108%	92%
Percent outperforming sites	76%	36%

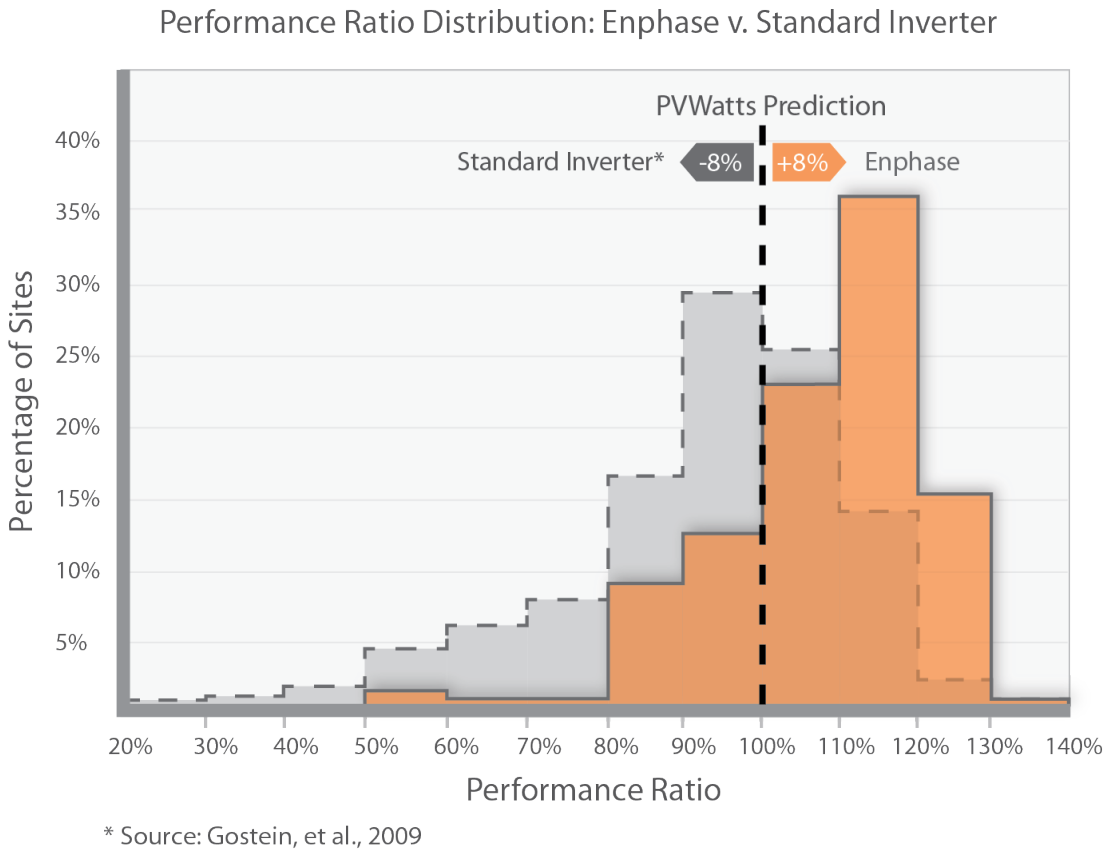

Figure 1 The distributions of performance ratios from Enphase installations and Gostein, et al. are shown in orange and grey, respectively.

These results were observed in spite of significant shade (>5%) affecting approximately half of the 143 Enphase installations. The average performance ratio for sites with ≤5% shade was 115%, with more than 95% of these sites outperforming PVWatts estimates. An analysis of sites with greater than 5% shade would require adjusting the DC-AC derate factor in the PVWatts Calculator, which was not part of the scope of this study.

CONCLUSION

The average performance of PV systems using Enphase Microinverters significantly exceeds PVWatts performance estimates. This advantage appears even more significant when compared to prior studies, such as Gostein, et al., which indicate the potential performance disadvantages of standard inverter technology. It is likely that factors such as module-level MPPT, high efficiency during low-light levels and high system reliability are driving the performance advantages of Enphase installations.

Enphase Energy continues to expand the number of sites and monthly data points used in this analysis, as part of an ongoing research effort. Additional studies will be released in the future to provide greater detail on the impact of various geographic and site-specific variables.

REFERENCES

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3) Dean, S.R., "Quantifying the variability of solar PV production forecasts", American Solar Energy Society, 2010.