TECHNICAL BRIEF

Guide to PVWatts Derate Factors for Enphase Systems When Using PV System Design Tools

PV systems equipped with the Enphase Microinverter Systems frequently exhibit improved performance over traditional string inverter systems, yielding higher energy harvest over the lifetime of the system. In this paper, we identify and quantify the source of the increased energy harvest by evaluating the various types of losses (or derates) present in most PV systems.

Enphase systems deliver superior financial returns to all stakeholders by combining greater annual production with a standard 25-year warranty and lower operating expenses.

PVWatts is a tool commonly used by installers to model the annual production of a PV system. When using PVWatts or design tools like the ModSolar platform that use PVWatts data, it is important to realize that the default settings of PVWatts do not accurately represent differences between microinverters and central or string inverters.

PVWatts applies derate factors to determine the amount of AC power that will flow into the grid from the solar array, accounting for many of the environmental characteristics of the site as well as system design and chosen components. The PVWatts default “Overall DC-to-AC Derate Factors” are based on a system with a string inverter. They include limits to the input values for Mismatch, DC Wiring, and System Availability that are below the values that reflect the profile of an Enphase system. Since design tools like ModSolar are not constrained by these limits, they enable users to model the additional production from Enphase’s impact on those derate factors.

Correctly capturing the increased energy harvest is a critical element in modeling the expected financial performance of the system for system owners. **This paper provides guidelines to installers for how to adjust PV Watts derate factors to model Enphase’s energy harvest gains[i].**

The following table shows the default values for the PVWatts overall DC to AC derate factor[i] and Enphase’s recommended adjustment to the derate factors in PVWatts with changed component derate values in bold. Further explanation of these changes follows the table.

Enphase Adjustments To PVWatts Default Derate Factors

Derate Category	PV Watts Default (String)	PV Watts Adjusted (Enphase Systems)	PV Design Tools (Enphase Systems)
PV Module Nameplate DC Rating	0.950	0.950	0.950
Inverter and Transformer*	**0.920**	**0.965**	**0.965**
Mismatch*	**0.980**	**0.995 (Max Value)**	**1.000**
Diodes and Connections	0.995	0.995	0.995
DC Wiring*	**0.980**	**0.990 (Max Value)**	**0.995**
AC Wiring	**0.990**	**0.980**	**0.980**
Soiling	**0.950**	**0.970**	**0.970**
System Availability*	**0.980**	**0.995 (Max Value)**	**0.998**
Shading (See Table)	**1.000**	**1.000**	**1.000**
Sun-tracking	1.000	1.000	1.000
Age	1.000	1.000	1.000
Total Derate Factor (Project Efficiency)	**0.770**	**0.850**	**0.861**

***Note:** PVWatts default value for Inverter and Transformer loss takes a conservative view of modern inverter efficiency. PVWatts also sets limits on the values for Mismatch, DC Wiring, and System Availability that are below the values that likely apply to Enphase Systems.

Inverter and Transformer Derate Factor

PVWatts Definition: *The derate factor for the inverter and transformer is their combined efficiency in converting DC power to AC power. A list of inverter efficiencies by manufacturer is at http://www.gosolarcalifornia.ca.gov/equipment/inverters.php. These inverter efficiencies include transformer related losses when a transformer is used or required by the manufacturer.*

Enphase Guidance: Enphase's latest-generation microinverters with integrated ground have a CEC efficiency rating of 96.5%. This efficiency rating includes the inverter's internal transformer losses.

Mismatch Derate Factor

PVWatts Definition: *The derate factor for PV module mismatch accounts for manufacturing tolerances that yield PV modules with slightly different current-voltage characteristics. Consequently, when connected together electrically, they do not operate at their respective peak efficiencies. The default value of 0.98 represents a loss of 2% due to mismatch.*

Enphase Guidance: Enphase eliminates the effects of module mismatch by maximizing the production on a per-module basis. These differences may become greater over time as modules age and individual modules within an array degrade at varying rates. With mismatch effects eliminated, the correct value for an Enphase System is 1.00. *However, PVWatts limits the acceptable inputs for mismatch at 0.995, leaving 0.005 of additional value from Enphase Systems unrecognized in PVWatts.*

DC Wiring Derate Factor

PVWatts Definition: *The derate factor for DC wiring accounts for resistive losses in the wiring between modules and the wiring connecting the PV array to the inverter.*

Enphase Guidance: DC wiring for Enphase Systems is limited to each module's direct connection to its corresponding microinverter. There are no long DC homeruns, nor are there DC taps at each stop along the way coming into a DC combiner box. DC wiring losses for an Enphase System should be no lower than 0.995. *However, the maximum value allowed by PVWatts for DC wiring is 0.99, leaving at least 0.005 of additional value unrecognized for an Enphase System in PV Watts.*

Soiling Derate Factor

PVWatts Definition: *The derate factor for soiling accounts for dirt, snow, or other foreign matter on the front surface of the PV module that reduces the amount of solar radiation reaching the solar cells of the PV module. Dirt accumulation on the PV module surface is location and weather dependent, with greater soiling losses (up to 25% for some California locations) for high-traffic, high-pollution areas with infrequent rain. For northern locations in winter, snow will reduce the amount of energy produced, with the severity of the reduction a function of the amount of snow received and how long it remains on the PV modules. Snow remains the longest when sub-freezing temperatures prevail, small PV array tilt angles prevent snow from sliding off, the PV array is closely integrated into the roof, and the roof or other structure in the vicinity facilitates snow drifting onto the PV modules. For a roof-mounted PV system in Minnesota with a tilt angle of 23^o, snow was observed to reduce the energy production during the winter by 70%; a nearby roof-mounted PV system with a tilt angle of 40^o experienced a 40% reduction.*

Enphase Guidance: While an Enphase system does not impact the degree of soiling on a module or string, it does mitigate some of the loss by maximizing the performance of each individual module independently and preventing modules compromised by snow, dirt or debris from dragging down the performance of the rest of the string. Enphase assumes that, on average, soiling in a residential system is largely non-uniform. Such variance in soiling across a string or entire array creates module mismatch much like direct shading. Accordingly, to capture the impact of Enphase on soiling, the recommended adjustment is to take into account the impact of mismatch due to soiling and roughly half the losses. This results lead to a change in the default PVWatts value for soiling from 0.950 to 0.970. A representative table of derate changes for different soiling rates is below.

Soiling Derate Factor for String Inverter	Enphase-adjusted Soiling Derate	Difference
0.95	0.970	+ 0.020
0.92	0.952	+ 0.032
0.90	0.940	+ 0.040

System Availability Derate Factor

PVWatts Definition: *The derate factor for system availability accounts for times when the system is off due to maintenance and inverter and utility outages. The default value of 0.98 represents the system being off for 2% of the year.*

Enphase Guidance: Enphase systems deliver high annual system uptimes. Enphase systems are based on distributed system architecture, eliminating the single point of failure associated with centralized systems. Enphase Systems have no moving parts or filters and require little preventive maintenance. The Enlighten monitoring software enables remote diagnosis—and, often, remote fixes—of issues in advance of maintenance visits, eliminating on-site problem-solving delays. Enphase Microinverters are designed as a simple plug-and-play interface and are easily available through multiple distributors, thereby eliminating the potential for delays due to the availability of specialized labor and equipment common with high-voltage DC systems. The recommended availability derate value for Enphase is 0.998, however, the maximum allowable value for availability in PVWatts is 0.995. *Therefore, the recommended default derate value for Enphase in PVWatts is 0.995, which understates expected availability by 0.003.*

Shading Derate Factor

PVWatts Definition: *The derate factor for shading accounts for situations when PV modules are shaded by nearby buildings, objects, or other PV modules and array structure. For the default value of 1.00, PVWATTS assumes the PV modules are not shaded. Tools such as Solar Pathfinder may be used to determine a derate factor for shading by buildings and objects. For PV arrays consisting of multiple rows of PV modules and array structure, the shading derate factor should be changed to account for losses occurring when one row shades an adjacent row. The figure below shows the shading derate factor as a function of the type of PV array (fixed or tracking); the Ground Cover Ratio (GCR), defined as the ratio of the PV array area to the total ground area; and the tilt angle for fixed PV arrays. As shown in the figure, spacing the rows further apart (smaller GCR) corresponds to a larger derate factor (smaller shading loss). For fixed PV arrays, if the tilt angle is decreased the rows may be spaced closer together (larger GCR) to achieve the same shading derate factor. For the same value of shading derate factor, land area requirements are greatest for 2-axis tracking, as indicated by its relatively low GCR values when compared with those for fixed or 1-axis tracking. If you know the GCR value for your PV array, the figure may be used to estimate the appropriate shading derate factor. Industry practice is to optimize the use of space by configuring the PV system for a GCR corresponding to a shading derate factor of 0.975 (2.5% loss).*

Enphase Guidance: The default shading value for PVWatts is 1.000, assuming no shading is present from peripheral or direct obstructions or from other modules. Like soiling, shading derates vary dramatically based on the particular circumstances of an individual site. Again, Enphase Microinverters maximize the performance of each module, overcoming the production mismatch that occurs from partial shading.

The National Renewable Energy Laboratory's (NREL) Technical Report, *Photovoltaic Shading Testbed for Module-Level Power Electronics*, compared the performance of an Enphase System and a similar system using a string inverter under light, medium, and heavy shade conditions. The study determined that in comparing the results of modeled analysis and actual performance, the Enphase system "indicates a recovery of around half of the overall performance loss due to shade, as predicted by the shading loss site survey." Similarly, a private study commissioned by Enphase calculated that an Enphase microinverter system would recapture over 40% of the performance loss due to shade. Taking a relatively conservative stance, Enphase recommends that shading derate values be adjusted to account for an approximate recapture of 40% of the energy expected to be lost with a string inverter system. For example, we recommend adjusting a shading derate of 0.90 for a standard system to 0.940 recommended value for an Enphase System.

Shading Derate Factors

Shading Derate Factor w/ String Inverter	Enphase Adjusted Shading Derate for PVWatts
1.000	1.000
0.990	0.994
0.980	0.988
0.970	0.982
0.960	0.976
0.950	0.970
0.940	0.964
0.930	0.958
0.920	0.952
0.910	0.946
0.900	0.940
0.890	0.934
0.880	0.928
0.870	0.922
0.860	0.916
0.850	0.910
0.840	0.904
0.830	0.898
0.820	0.892
0.810	0.886
0.800	0.880
0.790	0.874
0.780	0.868
0.770	0.862
0.760	0.856
0.750	0.850

Other Loss Factors to Consider

Module Temperature Variance Mismatch

Module temperatures can vary within an array based on their proximity to the array edge, height above roof, roof coating type, module access to cooling breezes, etc. These temperature irregularities create what most people would call mismatch, but impacts that are not always considered because most people are only considering mismatch due to differences in module manufacturing. This factor accounts for the production loss caused by modules operating at varying efficiencies, as distinguished from module inefficiency due to a uniformly higher temperature across the array. PVWatts does not account for either source of loss. While the impact of this factor will vary based on the characteristics of a given site, Enphase's performance increase may add 0.005 to the overall DC to AC derate factor.

Further Adjustments: Mismatch, DC Wiring and System Availability Derate Values

As noted above, PVWatts has maximum acceptable values for derate factors from Mismatch, DC Wiring, and System Availability that are below the appropriate Component Derate Values for an Enphase System. The combined effect is likely an understatement of the Component Derate Value for Enphase Systems of 0.013 (0.005 +0.003 +0.005). To account for this difference in the overall DC to AC derate factor for PV Watts, a system designer could add 0.013 to the Inverter and Transformer value of 0.965 to get to 0.978, representing the Enphase Microinverter efficiency plus efficiencies not realized for Mismatch, DC Wiring System Availability and Temperature Effects. For PV Design Tools using the Enphase Adjusted Derate Factors, these values may be included in the default values for an Enphase System, with no further adjustments necessary.

Additional References

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5. Deline, C.; Meydbray, J.; Donovan, M.; Forrest, J. "Photovoltaic Shading Testbed for Module-level Power Electronics," NREL, 2012. http://www.nrel.gov/docs/fy12osti/54876.pdf

[i] PVWatts web: http://rredc.nrel.gov/solar/calculators/pvwatts/version1/derate.cgi