A Review of Modeled Performance of PAN files in PVsyst®

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Introduction

When modeling PV systems in PVsyst® [1], the performance of PV modules is determined by detailed electrical characteristics specified in PAN files. PVsyst® uses PAN file parameters and one-diode model assumptions to generate an IV curve which determines module performance behavior. See Figure 1 for an example I/V curve. PAN files can come from a variety of sources, including PVsyst's internal database, module manufacturers, and third-party module testing labs. They can also be created manually in PVsyst® with default settings and generic performance parameters. Not all of the parameters needed for a PAN file are listed in manufacturer module datasheets. Unlisted parameters include key resistance parameters that can either be estimated with PVsyst's default methods or are provided directly within a PAN file from a manufacturer or third-party testing lab.

These resistance parameters, Rshunt and Rserie, directly impact the module's modeled low-light performance, which can have significant impacts on the final modeled PV system generation. Figure 2 shows example module efficiencies over a range of irradiance levels. This curve is largely determined by the Rshunt and Rserie parameters. The default method for PVsyst ® to determine this curve is to target a relative efficiency @ 200 W/m^2 of -3% [2]. Manufacturers and third-party labs can also provide their own resistance parameters. As the true values of these parameters are not typically disclosed or standardized, the industry generally must accept the values provided in a given PAN file as correct and accurate.

Another often uncertain characteristic of PAN files is the temperature behavior which is related to a heat loss factor U and the muPmpp factor of the PV module. The muPmpp factor is by default an output of the one-diode model but can be corrected to the value provided on manufacturer module specification sheets. Figure 3 shows an example plot of module voltage and maximum power varying with temperature.

To evaluate the performance variability resulting from PAN file specifications, we ran a series of PVsyst® energy models where we tested manufacturer or third-party provided PAN files against ones created with default performance parameters.

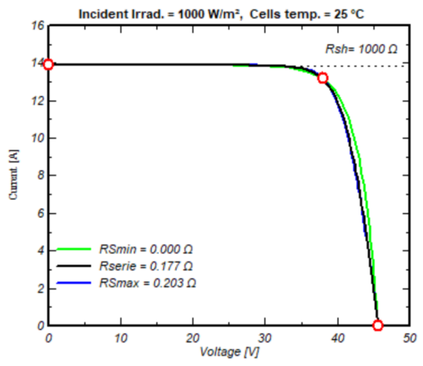

Figure 1: Example I/V curve, PVsyst®

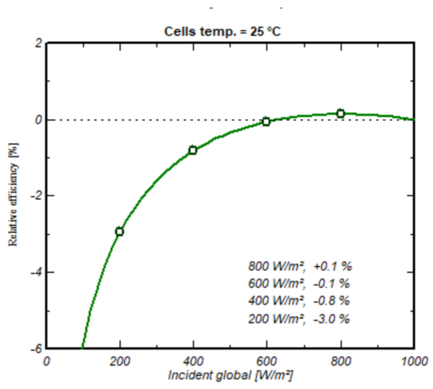

Figure 2: Module relative efficiency versus irradiance level, PVsyst®

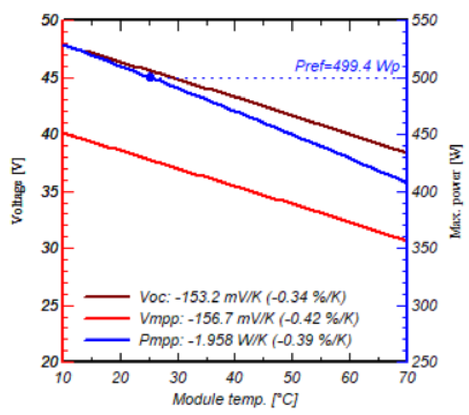

Figure 3: Module voltage and maximum power versus temperature, PVsyst®

Methods

Approach:

We compiled ten PAN files and module datasheets from different manufacturers and then manually created corresponding PAN files for comparison using a combination of module datasheet values and PVsyst default parameters.

Data Source:

The PAN files were initially sourced from module manufactures or third-party testing labs. They cover a combination of Mono PERC, n-type TOPCon, bifacial, and monofacial technologies. We ensured the primary electrical specifications listed in the data sheets matched the provided PAN files and tracked the assumed parameters for later comparison.

PVsyst System Description:

- Single axis tracking, 25% GCR backtracking, 60-degree tracking limit
- 10 MW DC capacity, generic 500 kW inverters, Pnom ratio of 1.25
- Modeled site locations in Maine (cooler, more diffuse irradiance) and Arizona (warmer, more direct irradiance).
- SolarAnywhere® 3.8 solar resource data

Figure 4: Modeled site locations in Maine and Arizona

PAN Performance Comparison:

We tracked and compared the relevant PAN parameters and PVsyst model outputs for both sets of PAN files in both site locations, listed below in Table 1.

PAN Parameters	Outputs
Shunt resistance (Rshunt)	Loss due to irradiance level (%)
Series resistance (Rserie)	Loss due to temperature (%)
Pmpp temperature coefficient (muPmpp)	

Table 1: Tracked PAN parameters and PVsyst outputs

Sensitivity Analysis:

A sensitivity analysis was conducted by independently applying scaling factors to the shunt resistance and muPmpp temperature coefficient in PVsyst's generic Si-mono 500 W Twin half-cells bifacial module PAN file and comparing performance across the range of scaling factors for both site locations.

Results and Discussion

PAN Performance Comparison

Figure 5 plots the PVsyst output of *Loss due to Irradiance Level* between the sampled and default PAN file sets for the Maine site location. It shows a high variability of loss in the sampled PAN file set, while the default PAN file set loss remains relatively consistent around 0.5%. The same trend is shown in Figure 6 for the Arizona site location, although at a lower overall loss due to the warmer climate.

The PVsyst default method for determining resistance parameters seems a reasonable estimate as the default results lie relatively in the middle of the sampled results. However, the variability in non-default PAN file low-light performance, may indicate a need for further standardization of how resistance parameters for PAN files are measured and implemented in the industry. Project designs could unknowingly choose modules that will model and or perform up to 2% lower than others due to inconsistent specifications.

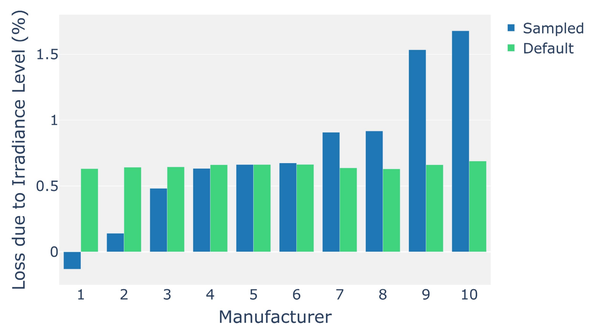

Figure 5: Loss due to Irradiance Level for sampled and default PAN file sets in the Maine site location

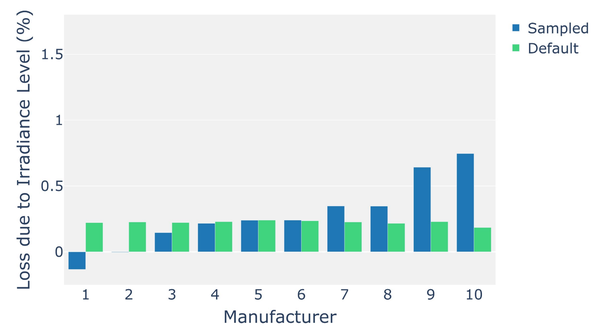

Figure 6: Loss due to Irradiance Level for sampled and default PAN file sets in the Arizona site location

The *Loss due to Temperature* system output is much more aligned between the PAN file sets as shown below in Figures 7 and 8, with the overall losses more significant in the warmer climate of Arizona.

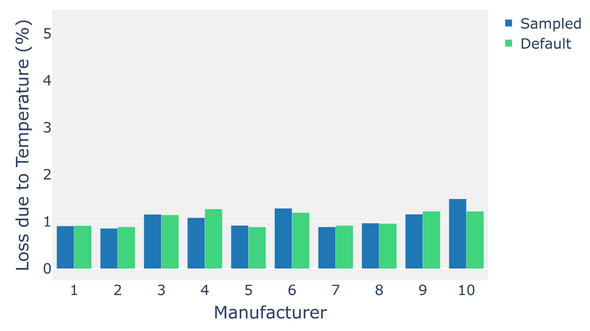

Figure 7: Loss due to Temperature for sampled and default PAN file sets in the Maine site location

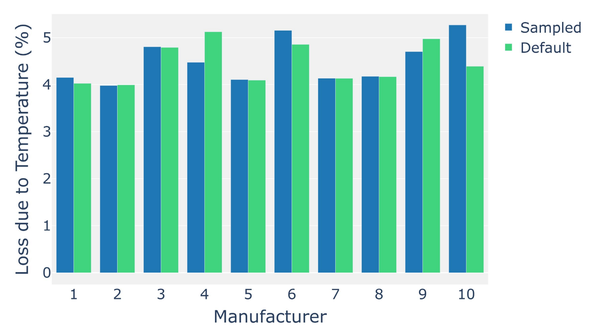

Figure 8: Loss due to Temperature for sampled and default PAN file sets in the Arizona site location

Overall, there is more variability in the low-light performance than the temperature behavior between the PAN file sets. Additionally, the loss impact due to irradiance level is more significant in areas with more total global irradiance and temperature losses are more significant in warmer climates.

Sensitivity Analysis

Figure 9 shows the impact on *Loss due to Irradiance Level* when varying Rshunt for both site locations. The curves exhibit exponential behavior, with a significant loss increase at lower Rshunt values compared to the limited loss decrease at higher Rshunt values. This behavior is more pronounced, with a higher overall loss, for the Maine site location. The exponential nature indicates that a small change in resistance parameters has the potential for a significant change in losses, further reinforcing the conclusion from the PAN file comparison above that there may be a need for standardization of methods to determine these parameters. Figure 10 shows the impact on *Loss due to Temperature* when varying muPmpp. The curve behavior is linear, with a higher overall loss and steeper slope for the Arizona site location. This indicates that variation in muPmpp is more impactful in warmer climates.

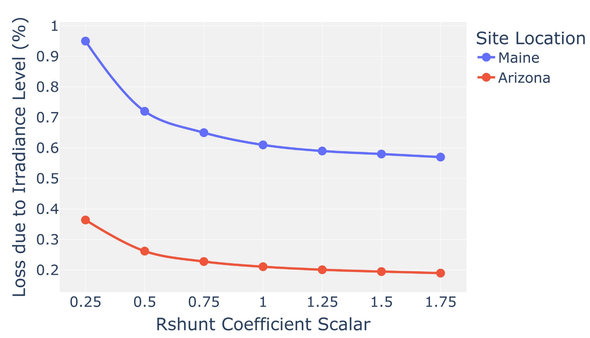

Figure 9: Loss due to Irradiance Level when scaling Rshunt for Maine and Arizona site locations

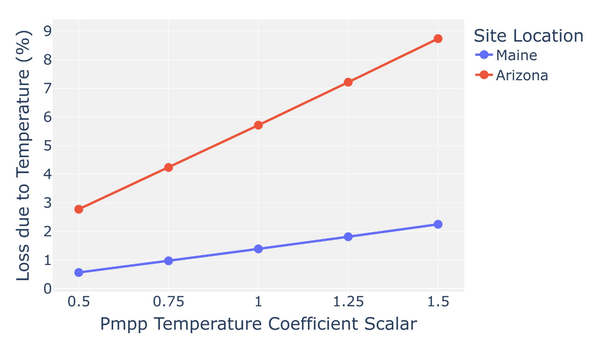

Figure 10: Loss due to Temperature when scaling muPmpp for Maine and Arizona site locations

Conclusions:

Our analysis highlights the impact of PAN file parameter variations on modeled PV system performance. Differences in resistance parameters primarily affect low-light behavior, leading to variation in irradiance-related losses that are more significant in areas with more total irradiance. The PVsyst default method for low-light behavior provides a reasonable estimate, but the differences in PAN files suggest a need for more scrutiny on key parameters throughout the industry.

References:

1. PVsyst – Photovoltaic Software. PVsyst SA, Satigny, Switzerland. https://www.pvsyst.com/
2. "Rseries and Rshunt determination procedure", PVsyst 7 Help Documentation. PVsyst SA, Satigny, Switzerland. https://www.pvsyst.com/help-pvsyst7