Cross-validation of PV Simulation Software

PVsyst ⇔ SAM ⇔ PlantPredict ⇔ PVLIB-Python

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Introduction

Simulation software plays a critical role for planning, optimizing and evaluating PV systems—and for gaining investor confidence. Does it matter which software is used?

Most, if not all, core calculations are based on the same published models (some of them very old!), and most software documentation is open about the models and methods that are implemented. There is apparently no secret sauce!

So in theory, if we simulate the same system with the same model choices and the same assumptions, each software should produce the same results. Or not?

This poster presents our first observations.

Method

A common site with the same system design was selected and simulated with all four programs using the same parameters where ever possible.

To focus on the core models, advanced features such as shading were not used, and discretionary values such as soiling and LID were kept at 0%.

After simulation, CSV files with all intermediate variables were exported and converted to a common nomenclature.

These data were then compared in numerous combinations to identify any differences, and to relate those differences to other variables.

Note: Although many graphs show differences from PVLIB-results, this is certainly not meant to imply that this is the most "correct" one.

Some early observations

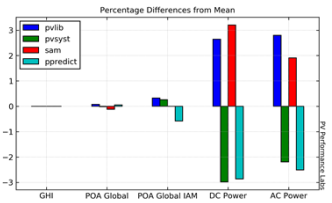
It is actually quite challenging to run identical simulations in all four programs. From reading weather files, to finding and setting the parameters, to interpreting the numerous output values, there always seems to be one that does things a little differently.

The original NSRDB TMY3 files were found have inconsistencies, and with the newer PSM3 files we had to adjust the time stamps in the csv file for SAM. More clarity is needed around the question of whether the weather data represent period averages or samples in time, and how the simulation software distinguishes between those possibilities.

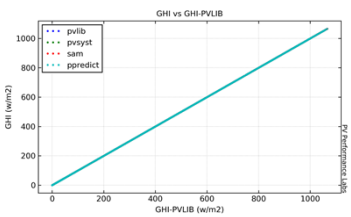
The difference of 5% between the lowest and highest final yield values seems excessive, and may still be caused by some remaining differences in simulation options and/or in the parameter databases.

Simulated Yields

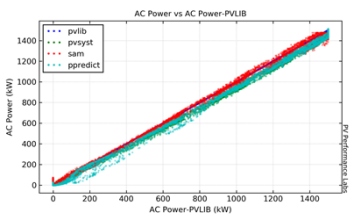
Software	Energy output (MWh)	Difference from mean value
PVsyst	3431	-2.2 %
SAM	3575	+1.9 %
PlantPredict	3420	-2.5 %
PVLIB-Python	3606	+2.8 %



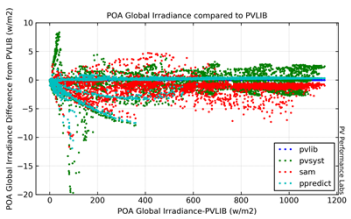
An overview of differences between Softwares at various stages (Stages shown on the x-axis). SAM and PVLIB predict higher, while Pvsyst and PlantPredict under predict AC Power compared to the average.



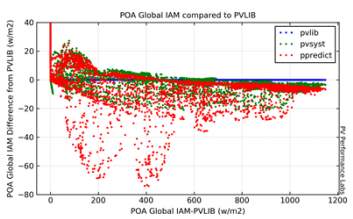
GHI values in the output files are mostly identical, which means the programs use the GHI from the weather data without modification. Only PVsyst shows some detectable, but insignificant differences compared to the others.



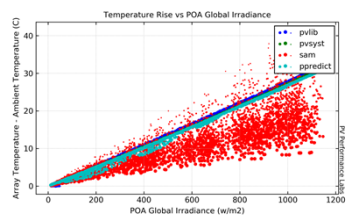
AC energy output varies from +2.8 % to -2.5% from the mean as pointed out in the output table above. The scatter in this plot shows that the deviation is not the same at all time steps and power levels.



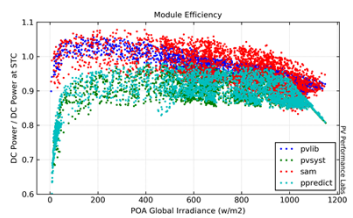
POA Global estimation is done using the Perez transposition model. Differences are clearly visible among the software predictions, and show some interesting patterns. Some, but not all, may be due to differences in sun angles (not shown).



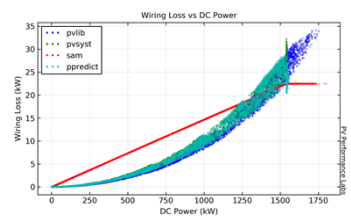
The ASHRAE model is being used in all programs to account for IAM losses. After this calculation the differences have grown further—note the vertical scale. PlantPredict shows quite a few outliers around the range of 200-400 w/m2.



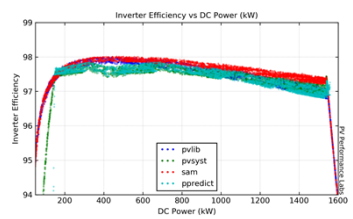
This plot shows differences between cell temperature models. SAM is the odd one out because it includes the effect of wind on the temperature by default.
The marker size is proportional to wind velocity.



The one-diode model is being used to estimate the operating parameters of the PV module. SAM and PVLIB predict much higher module efficiency than PVsyst an PlantPredict. The lower cell temperature for SAM is only a partial explanation.



Resistive wiring losses are normally proportional to I², so we expect to see a curve here. SAM takes a simpler approach and estimates wiring loss to be proportional to power.



The difference in the inverter efficiency between programs is generally less than 0.5%. The power limiting seen on the right also matches, but in the start-up and low-power area on the left some larger differences are visible.

Why could this be useful?

We may find:

- Possible software errors
- Forgotten assumptions
- Differences in the interpretation of published models
- How much influence any model enhancements may have, if applicable
- Reasons to use more than one software

We hope to find that any differences are negligible. In that case all software options would be equally trustworthy, and choosing one would depend more on convenience features, or on the look and feel you like best (or dislike least).

What's missing from this study?

So far, this is a cross-validation study only: no measured system data has been used.

Previous work has shown that the accuracy of a simulation with respect to measured performance depends strongly key assumptions (such as soiling), and that these assumptions depend on the person making them more than the software used.

Never-the-less, comparisons with measured data are essential, and all of the software development teams have internal data sets they use for this purpose. *But*, each team uses *different* validation data sets!

If a common and open collection of measured performance data could be assembled, this would make it much easier for all software teams to demonstrate their software's accuracy, and also for researchers to investigate new and improved models.

Please contact us if you would like to help make this happen.

System description

Site	Albuquerque, NM
Tilt	25
Azimuth	South
Module	FS-390 Plus
Inverter	ABB ULTRA 1500 TL
Modules in series	15
Number of strings	1228
Rated power	1658 kWp
Transposition model	Perez
Soiling losses	0 %
LID	0 %
Mismatch	1.5 %
Wiring	1.5 %