Cross-validation of PV Simulation Software

PVLIB-Python ⇔ PVsyst ⇔ SAM ⇔ PlantPredict

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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 latest observations for this work in progress.

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%.

The programs offer multiple models to calculate the same aspect of a PV system simulation. To test multiple models, different model combinations were considered and multiple simulations were executed.

The combinations presented here focus on three areas:

1. Models used to determine POA irradiance

2. Models used to calculate module efficiency

3. Models for inverter and wiring losses

The irradiance model combinations use Perez and Hay-Davies diffuse sky models along with ASHRAE and Sandia IAM models.

The module model combinations use PVsyst, CEC and SAPM module models along with PVsyst, NOCT and Sandia cell temperature models. The module parameters were taken from PVsyst, CEC and Sandia databases. To simulate the module models with considered cell temperature models, equivalent U, NOCT, Sandia a and b parameters were calculated.

The inverter model combinations use the PVsyst, Sandia and PlantPredict inverter models. Wiring resistance of 4.03 miliohm with an equivalent fraction of 1.5 % [as per calculations from PVsyst] is considered.

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

System description

Site	Golden, CO
Weather data	NSRDB
Tilt	35
Azimuth	South
Module	FS-275 [CdTe]
Inverter	ABB ULTRA 1500 TL
Modules in series	9
Number of strings	2660
Rated power	1795 kWp
Soiling losses	0 %
LID	0 %
Mismatch	1.5 %

	PVLIB	PVsyst	SAM	PlantPredict
POA: Perez IAM: ASHRAE	17.50 %	17.40 %	--	17.10 %
POA: Perez IAM: Sandia	19.00 %	--	19.80 %	19.60 %
POA: Hay-davies IAM: ASHRAE	15.60 %	15.60 %	--	14.90 %
POA: Hay-davies IAM: Sandia	17.00 %	--	--	17.30 %

Table 1: Annual Irradiance gain from GHI to POA effective irradiance for different sky models and IAM functions.

	PVLIB	PVsyst	SAM	PlantPredict
Module model: PVsyst Uc=29, Uw=0	10.80 %	9.50 %	9.40 %	9.30 %
Module model: PVsyst Uc=20.74, Uw=7.05	10.90 %	9.60 %	9.40 %	9.30 %
Module model: PVsyst Uc=31.86, Uw=2.2	10.90 %	9.60 %	9.40 %	9.30 %
Module model: CEC Uc=29, Uw=0	10.40 %	--	10.60 %	--
Module model: CEC Uc=20.74, Uw=7.05	10.40 %	--	10.50 %	--
Module model: CEC Uc=31.86, Uw=2.2	10.50 %	--	10.60 %	--
Module model: SAPM Uc=29, Uw=0	9.90 %	9.50 %	10.00 %	--
Module model: SAPM Uc=20.74, Uw=7.05	10.00 %	9.50 %	10.10 %	--
Module model: SAPM Uc=31.86, Uw=2.2	9.90 %	9.50 %	10.00 %	--

Table 2: Annual module efficiency for different module models and operating temperature model parameters.

	PVLIB	PVsyst	SAM	PlantPredict
Inverter model: Sandia Parameters: CEC DB Wiring = 4.03 ohm	-4.10 %	--	--	--
Inverter model: PVsyst Parameters: PVsyst DB Wiring = 4.03 ohm/1.5 %	--	-2.80 %	--	--
Inverter model: Sandia Parameters: CEC DB Wiring = 1.5 %	--	--	-5.60 %	--
Inverter model: PlantPredict Parameters: PlantPredict DB Wiring = 1.5 %	--	--	--	-3.60 %

Table 3: Annual inverter and wiring losses. Each software uses a different method.

Results

Each value in the tables below represents a single simulation and availability of that combination for a particular program. A lack of value represents unavailability of that model combinations in that particular program.

Table 1 shows the irradiance gains of the various transposition and IAM model combinations. Figures 1 and 2 show the outputs of ASHRAE and Sandia IAM models.

Table 2 shows the conversion efficiency of various module model combinations. Figure 3 shows the efficiency curve of PVsyst model in the considered programs.

Table 3 shows the DC to AC conversion losses of various inverter and wiring loss models. Inverter efficiency curves in figure 4 shows the difference in the DC to AC conversion modeling approaches of the considered programs.

The additional figures give insights into reasons for the differences in annual gains and losses.
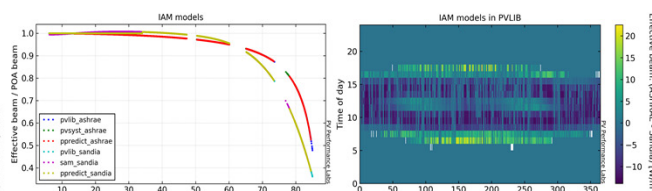
Figure 1: Isolating the IAM behavior. The ASHRAE model implementations are identical while there is some variation among the Sandia model implementations.

Figure-2: This bird's-eye view of the year shows that the small differences at low AOI have a greater influence than the larger differences at high angles.
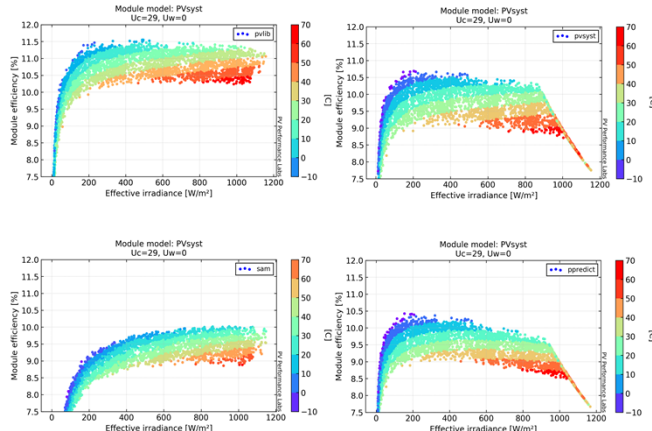
Figure 3: A deeper look into the first row of Table 2. Each software produces a different temperature/efficiency profile from the same set of model parameters.
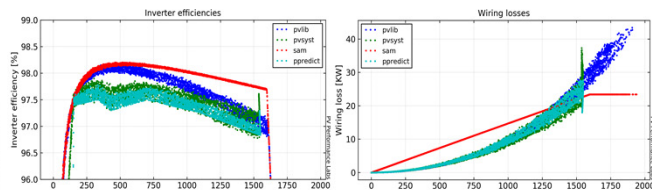
Figure 4: Inverter efficiency curves calculated with different inverter models/software. Inverter parameters are taken from program's respective databases.

Figure 5: Wiring losses in PVLIB, PVsyst and PlantPredict have a quadratic relationship with power compared to a linear one in SAM.