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TESTING — CERTIFICATION — INNOVATION

PAN Files from IEC 61853-1 Test Data:
Why Using Datasheet I-V Values is a Bad Idea

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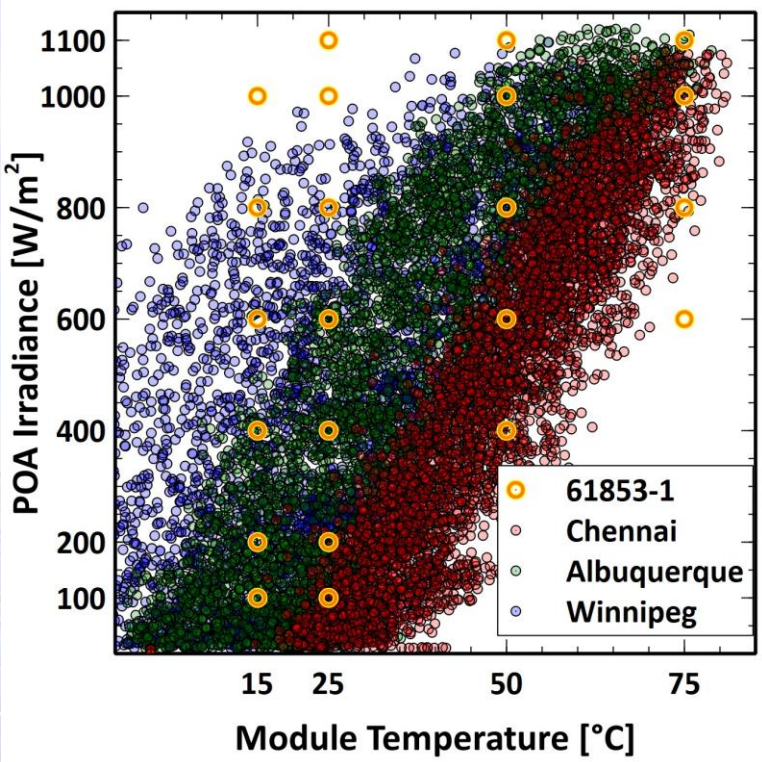
IEC 61853-1 Performance Matrix Test

- IEC 61853 series of standards aim at annual-energy-yield-based rating of PV modules, and define the relevant tests.
- IEC 61853-1 specifies I-V curve acquisition at multiple temperature and irradiance points, capturing majority of field operating conditions:

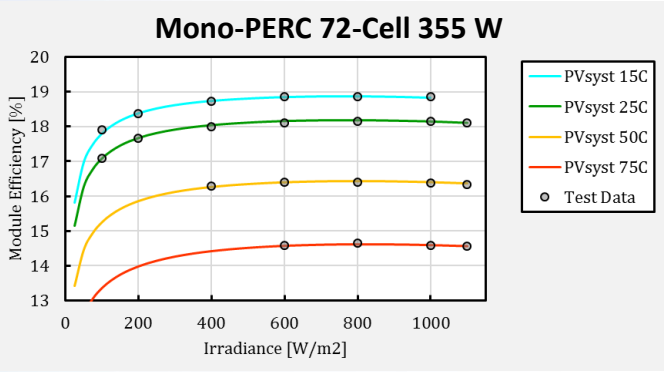
T [°C]	Irradiance [W/m²]
15	100, 200, 400, 600, 800, 1000
25	100, 200, 400, 600, 800, 1000, 1100
50	400, 600, 800, 1000, 1100
75	600, 800, 1000, 1100



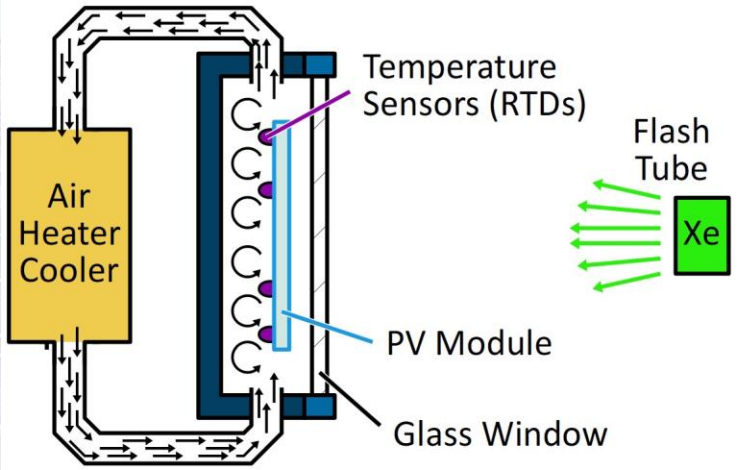
- At least 3 samples are tested.

61853-1 with Isothermal Flasher

- CFV uses a Class $A^+A^+A^+$ flasher with integrated thermal chamber to obtain accurate 61853-1 data.

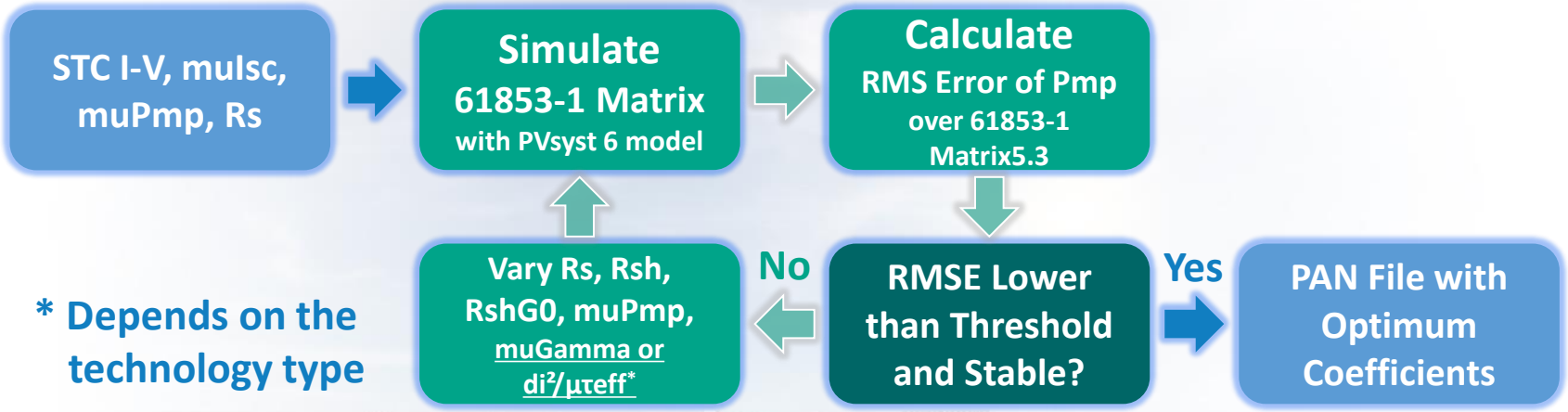


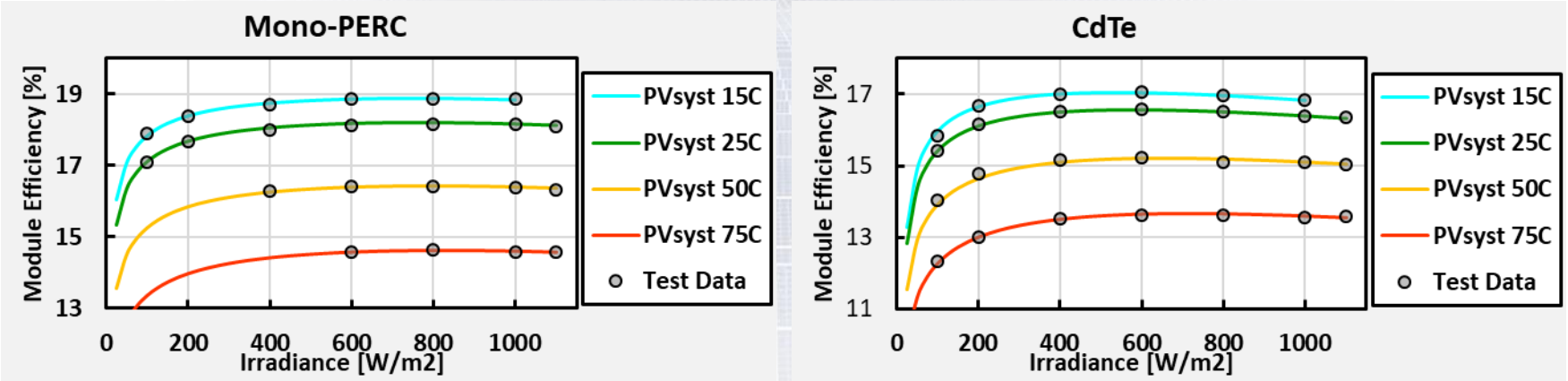
- The "isothermal" method is the state of the art for 61853-1 measurements.
- Measurements are made when 4 temperatures sensors are within ±0.5°C of the setpoint.



Creating PAN Files with PANOpt®

- **PANOpt®, CFV's in-house-developed software, analyzes the test data to generate optimized PAN files for PVsyst 6.**





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Practical Issues

1. **Creating PAN files for higher power classes**
   - Per customer request, we create PAN files for up to 2 power classes (+10 W) above the tested class. This is a standard practice in the US.
   - We scale 61853-1 Pmp values with a gain factor that gives the target power rating at STC. Scaled values are then used for PANOpt®.
   - Is data scaling justifiable? Will it overestimate the yield gains for higher power class if the higher power is achieved with lower Rser?
2. **Whether or not to use datasheet STC values**
   - By default, we use measured STC Isc, Voc, Imp, Vmp values when creating PAN files, instead of using the datasheet values.
   - Some customers push back and request that we use datasheet values instead, on grounds that project developers want to see datasheet values in PAN files.
   - What is the effect of using datasheet STC values instead of the measured values?

Data Scaling: Worst-Case Example - 1

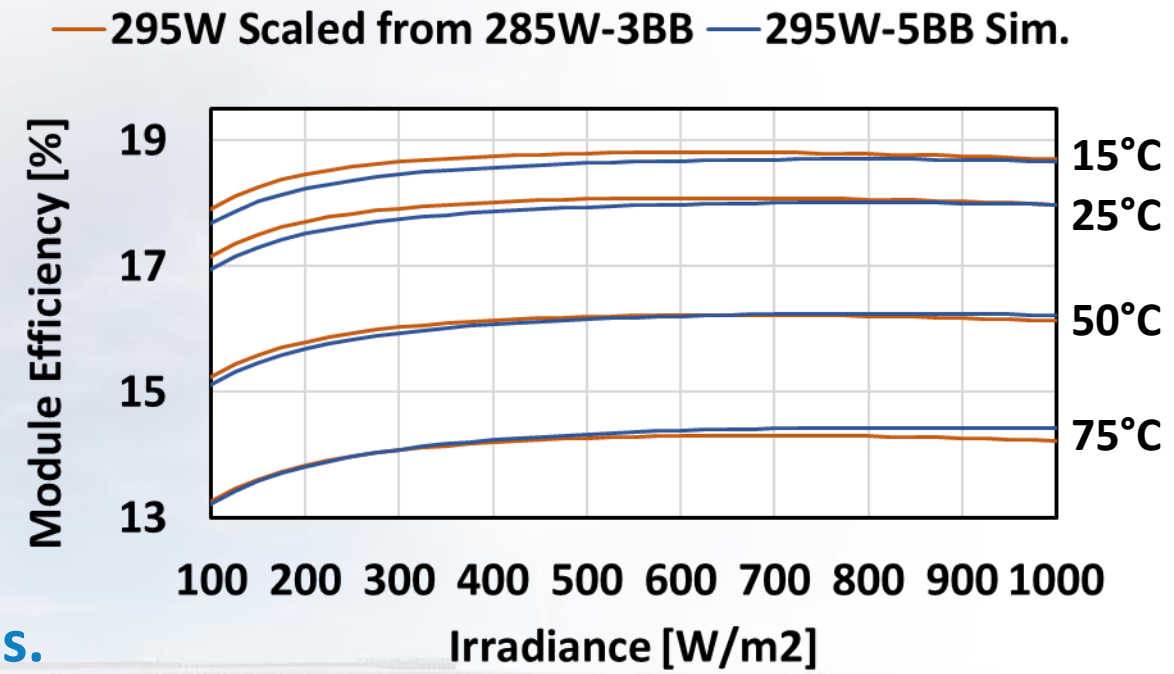
- A realistic worst-case example is when a manufacturer increases the number of BBs without changing model name:
  - Based on 61853-1 data on 285W 60-cell mono-PERC modules with a 3BB design, a PAN file for 295W power class was prepared.
  - The manufacturer then combined 5BB design, larger wafer, and process improvements to actually produce 295W mono-PERC.
  - Developers had done estimations with 295W PAN file scaled from 285W-3BB, but 5BB modules will be delivered.

295W PAN File from Scaled 285W-3BB Data	Characteristics of 295W-5BB Product
Rser = 0.310 Ω, muPmp = -0.41%/°C	Rser = 0.260 Ω, muPmp = -0.39%/°C
Isc = 9.627 A, Voc = 40.04 V, Imp = 9.059 A, Vmp = 32.56 V	Isc = 9.563 A, Voc = 39.76 V, Imp = 9.009 A, Vmp = 32.74 V

- How different is the scaled 295W PAN file from the actual 295W product in terms of performance and annual yield?

Data Scaling: Worst-Case Example - 2

- 15°C and 25°C curves show difference at low irradiance.
- 50°C curves almost overlap. Lower Rser leads to lower muPmp, offsetting the low-irradiance loss.



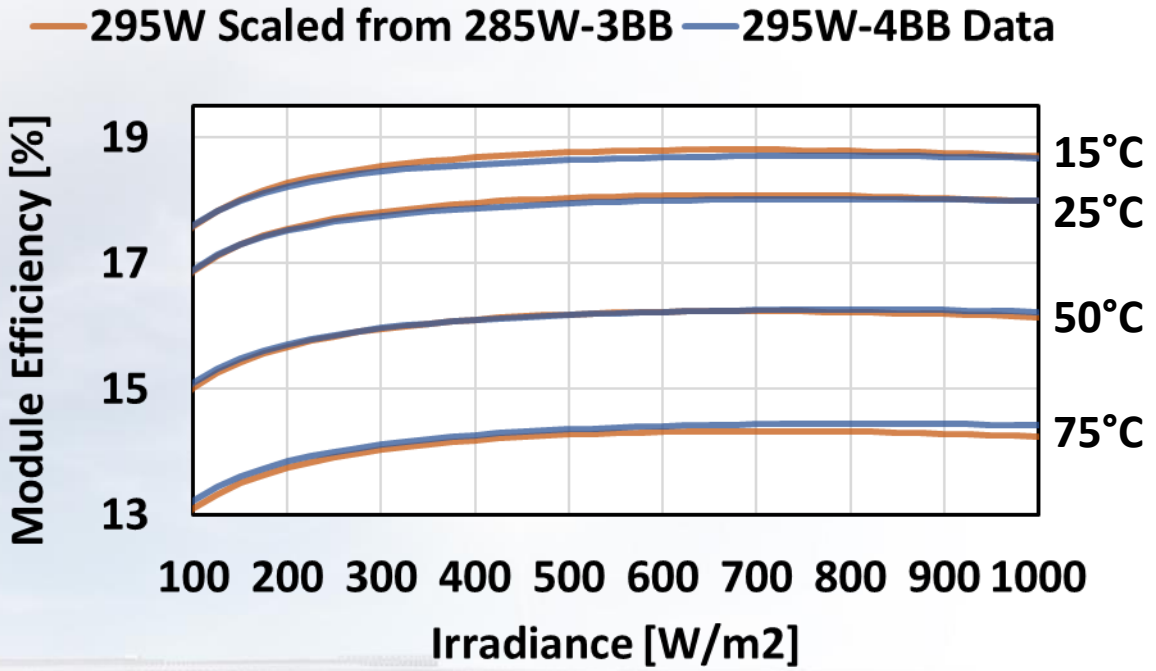
- PVsyst simulation of 100 kW system in Albuquerque:

295W PAN File Scaled from 285W-3BB	EArray = 222.3 MWh
295W-5BB	EArray = 222.0 MWh (0.13% difference)

- This was a hypothetical case, but we have a real example.

Data Scaling: Real Case

- We had done PAN file testing on two mono-PERC products from one manufacturer: 285W with 3BB, and 295W with 4BB.
- 295W curves scaled from 285W-3BB nearly overlapped with measured 295W-4BB curves.
- PVsyst yields were identical.



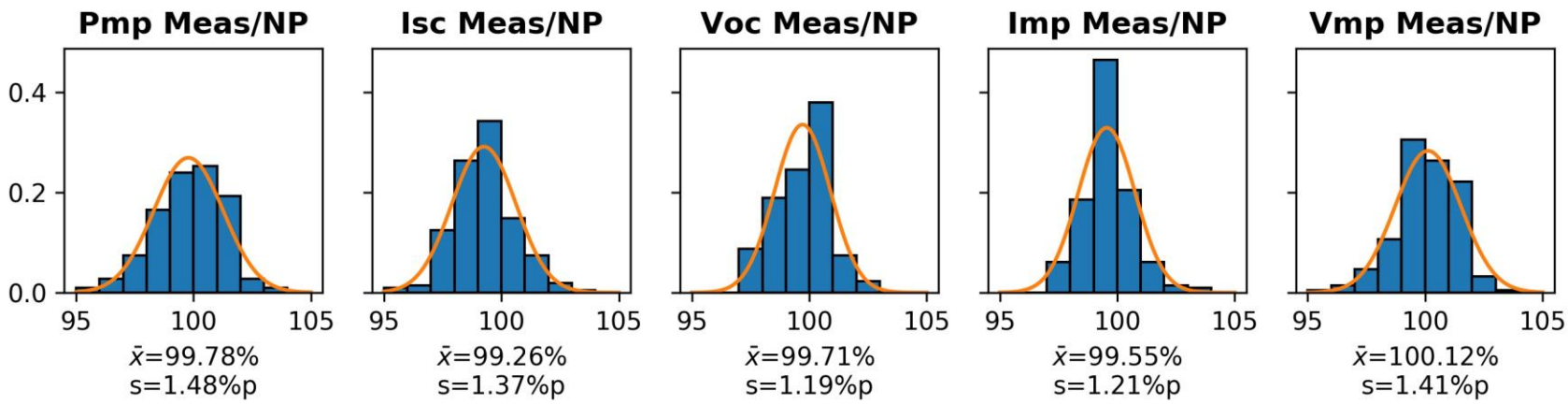
295W from Scaled 285W-3BB Data	EArray = 222.0 MWh
295W from 295W-4BB Data	EArray = 222.1 MWh (0.03% difference)

Data Scaling: Main Findings

- While it is theoretically possible to overestimate the yield of a higher power class module by using scaled data from a lower power class, in practice this does not happen.
- For the mainstream Si module design, major Rser improvements that do not require new model names come from using more busbars (3BB → 4BB or 5BB).
- Increasing the number of BBs lowers Rser, but not enough to move up 2 power classes (+10 W). Other changes such as larger wafer or cell process improvements are needed, whose effects are uniform across the irradiance range.
- Rser lowering via more BBs also lowers muPmp, which offsets the lower low-irradiance response.
- Drastic changes such as half cell or shingle require new model name, and so we would not do data scaling for such cases.

Datasheet STC Values vs Measured - 1

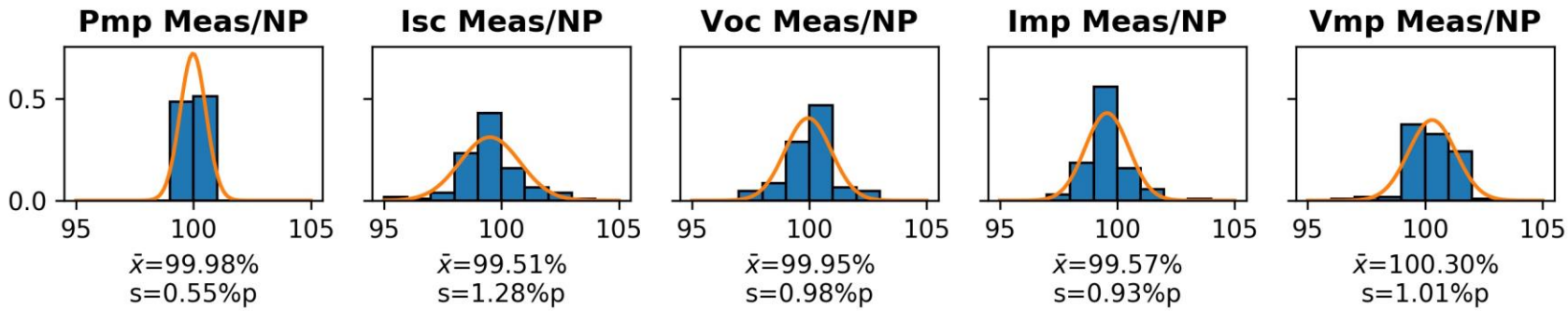
- Shown below are STC I-V measurements at CFV on Si modules over last 2 years, as ratios of the datasheet values.
  All modules received > 5 kWh/m^2 of light.



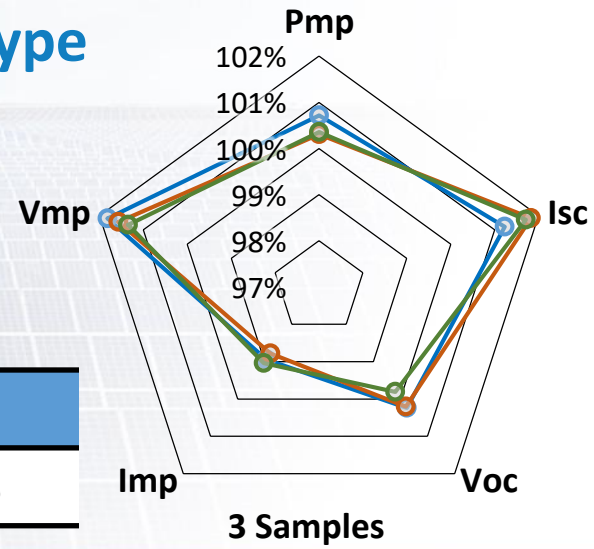
- The distributions look reasonable. If we just focus on modules in 99-101% Pmp range, we should get tighter distributions, right?

Datasheet STC Values vs Measured - 2

- **Not really. Even for samples in 99-101% Pmp range, measured Isc, Voc, Imp, and Vmp can be quite different from datasheet.**



- **Example: a 72-cell mc-Si 315Wp module type**
  - **Three samples had STC Pmp measured at 100.5% of rated value.**
  - **Isc, Voc, Imp, and Vmp were significantly different from the datasheet values.**



Isc	Voc	Imp	Vmp
101.6%	100.1%	98.9%	101.6%

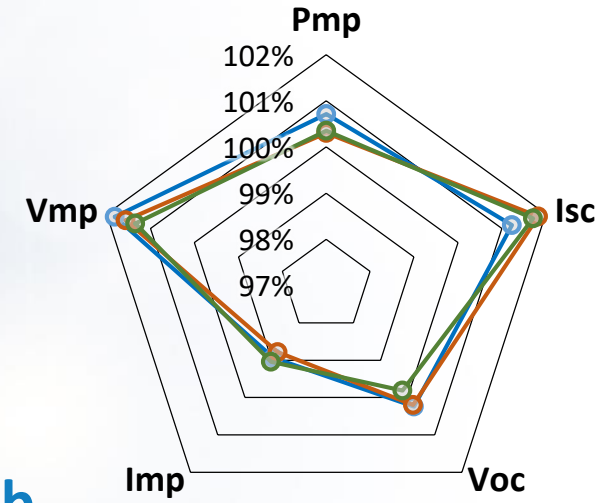
Datasheet STC Values: Effect on Yield?

- When strongly requested by the customer, we prepare PAN files with the datasheet STC values, with only Isc and Imp scaled to get the rated power, if necessary.
- Single-diode model is surprisingly flexible. We can usually find Rser, Rsh, and muPmp values that give us small RMS error of Pmp over the 61853-1 matrix. This "best-effort-with-datasheet-values" PAN file also gives nearly identical yield as the PAN file using the measured STC values.
- Simulation of 120 kW_{DC} / 100 kW_{AC} system in Albuquerque, using PAN files for the 315 W module from previous slide:

Best Effort PAN File wit Datasheet Values	EArray = 241.5 MWh
PAN File with Measured Values	EArray = 241.4 MWh

Datasheet STC Values: Hidden Errors

- Not so apparent are the hidden errors in array voltage and current calculations.
- Forcing datasheet values will result in consistent errors in array DC voltage and current calculations.
- STC values measured with a Class $A^+A^+A^+$ flasher in an ISO 17025-accredited test lab are always better estimates of the module population than the datasheet values.
- There are some “myths” in the industry about the authority of the datasheet values that need to be debunked.



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Debunking Myths about Datasheets

1. “Datasheet STC values are production averages.”

   False.
   Datasheet STC values are prepared for certification, before any attempt at mass production. Datasheet STC values seldom get updated after production starts!

2. “Datasheet STC values are checked during certification.”

   Mostly False.
   Certifiers check if STC measurements are within ±5% only. Also, test data on one power class is used to certify higher classes (up to +10%).

3. “Datasheet STC values are target specifications.”

   False.
   Manufacturers care about Pmp, as it is the warrantied item. Only a very few care about the accuracy of other values.

Recommendations for Developers

- **Don't just ask for PAN files. Get the reports too.**
  - Good labs (like CFV!) explain in the report detail how the PAN files were prepared. Measurement data are also included.
  - Reading the report will give you a better understanding of the risk in using a particular PAN file.
  - If you see a PAN file report without measurement data, raise a flag. Complain to manufacturer, test lab, and/or lab accreditation body.
- **Budget for some due-diligence testing.**
  - Most of the performance testing originates from the supplier side (module manufacturers).
  - There should be more customer-side testing taking place. There are lot-to-lot, factory-to-factory variations in Pmp distribution.
- **Be comfortable using measured STC values instead of the datasheet values. There's really no good reason to use the datasheet STC values.**

Summary

- IEC 61853-1 testing has been standardized, but the process of making PAN files is not.
- US-based labs have developed a practice of using scaled data to provide PAN files for higher (not-yet-available) power classes. Despite criticism, scaled PAN files for ±10 W power classes are surprisingly accurate for the mainstream Si design.
  - Since 2017, CFV marks PAN files made from a different power class by putting in “Scaled from 000W” in the Data Source field. Those made from the data on matching power class are marked “Tested Class”.
- Datasheet STC values (Isc, Voc, Imp, Vmp) are often given too much weight by developers, considering how little attention is actually given by manufacturers and certification bodies.
- Measured STC values should be used whenever available, to not reduce errors in voltage and current calculations.