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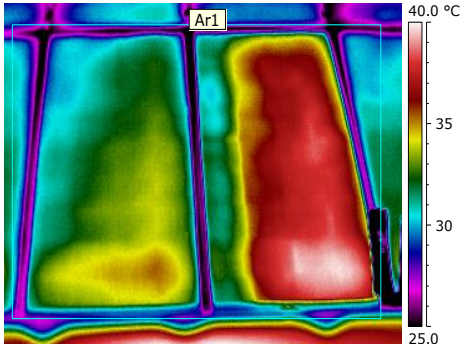

SAM Webinars 2017: PV Reliability Performance Model in SAM

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Janine Freeman – National Renewable Energy Laboratory

December 7, 2017

SAND2017-13406 TR

U.S. DEPARTMENT OF ENERGY

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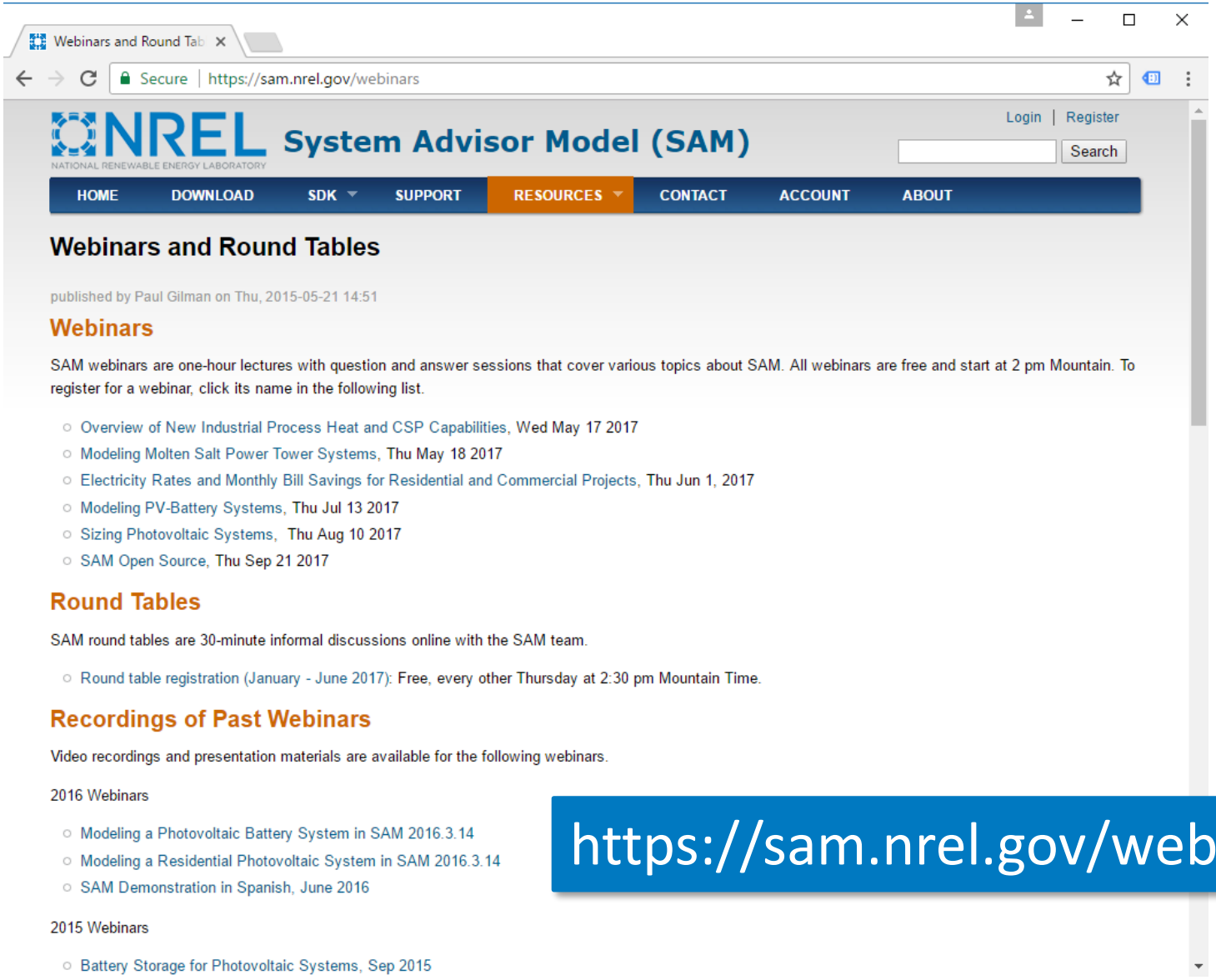
We will post a recording of this webinar on the SAM website

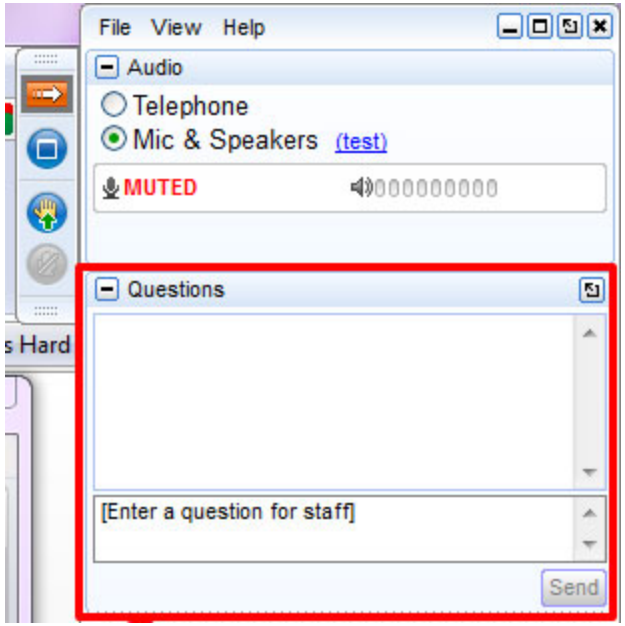


https://sam.nrel.gov/webinars

Logistics

If you have a question or comment:

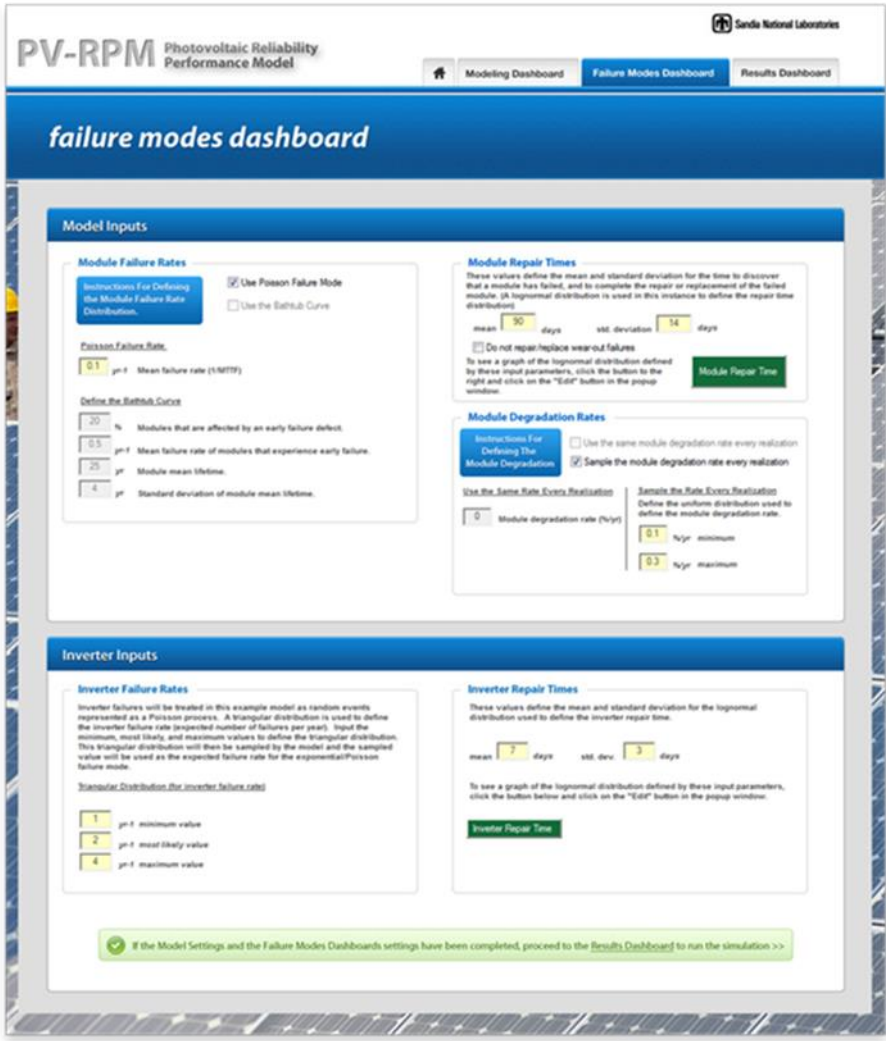
- Type it in the Questions box.
- Click the “Raise hand” button.
- We may unmute your phone so you can ask your question or follow up.



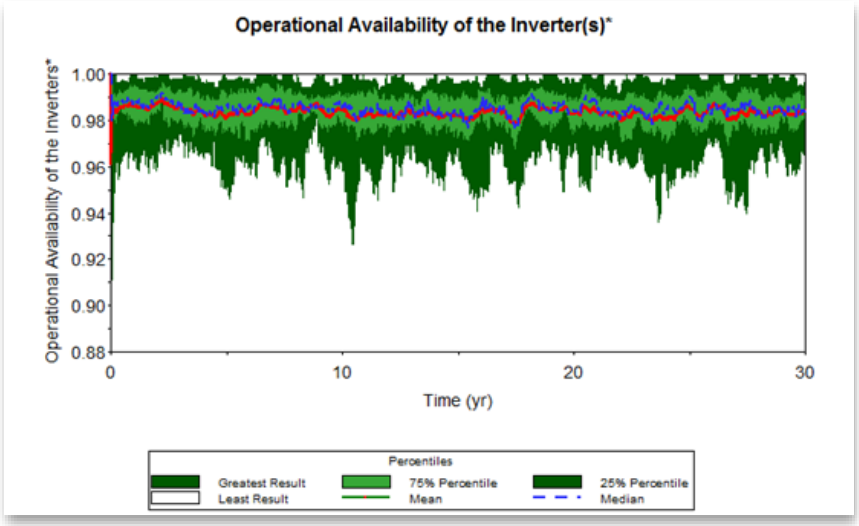
Outline

- Introduction
- What is PV-RPM and why would I use it?
- Setting up a simulation
- Demonstration
- Analyzing Results
- References

What is PV-RPM and why would I use it?



- Developed by SNL in 2010 as a proof-of-concept to evaluate PV performance impacts from probabilistic ‘events’ (faults/failures) impacting modules and inverters



- Goldsim player platform – limited evaluation capabilities (system configuration and failure mode types)

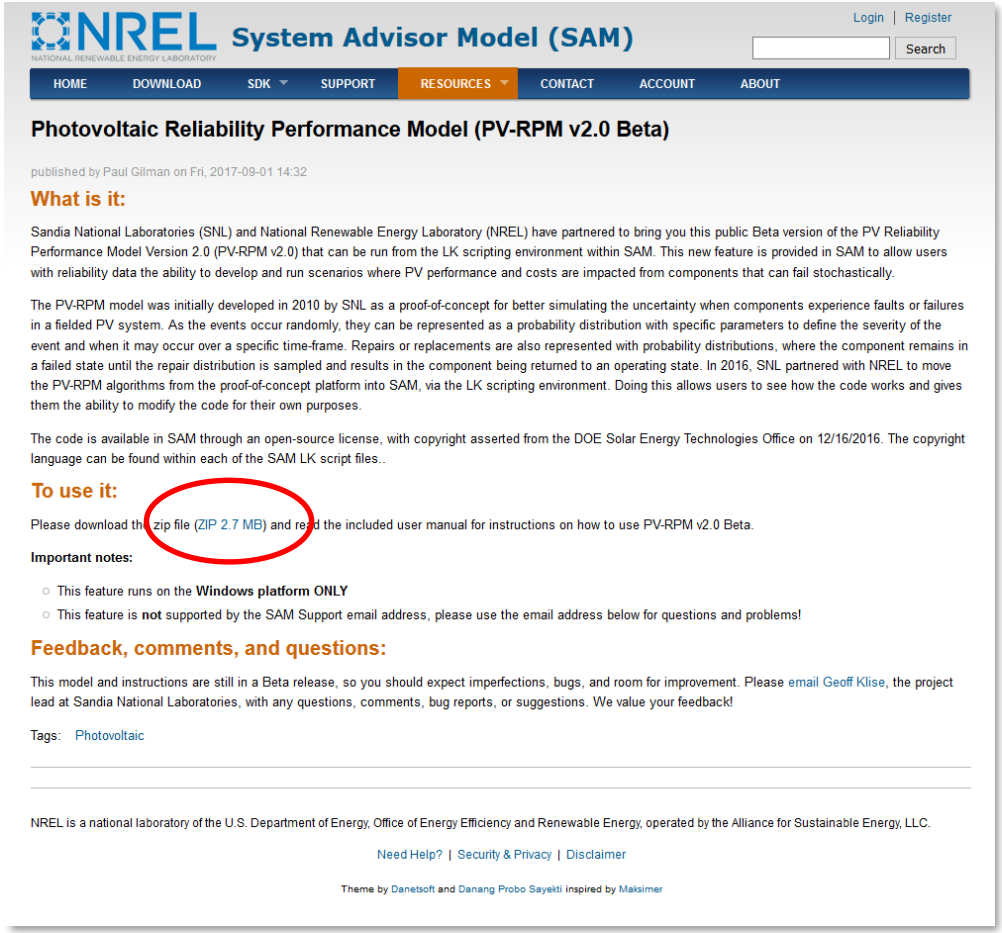
What is PV-RPM and why would I use it?

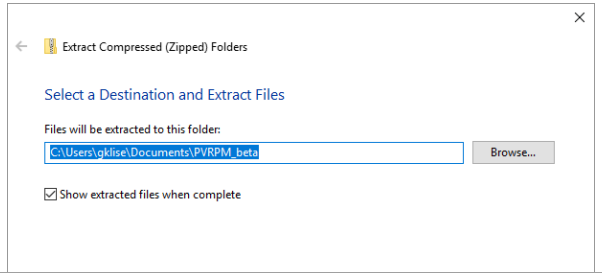
- Are you interested in how the failure of the following components impact power production, maintenance costs and LCOE?
  - Module
  - String
  - DC Combiner
  - Inverter
  - AC Disconnect
  - Transformer
  - Tracker
  - External Grid Impacts

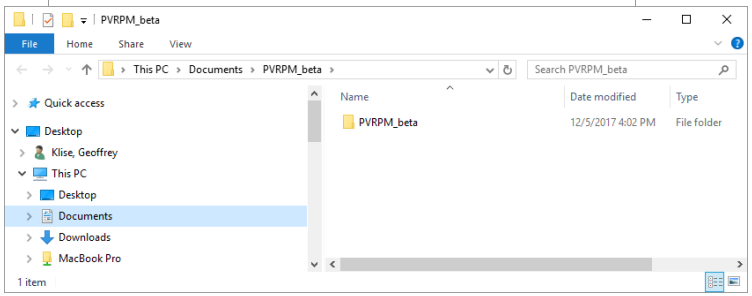
Setting up a simulation

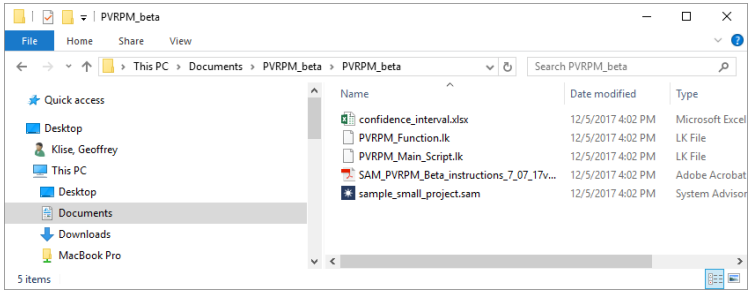
Where to download PV-RPM for SAM

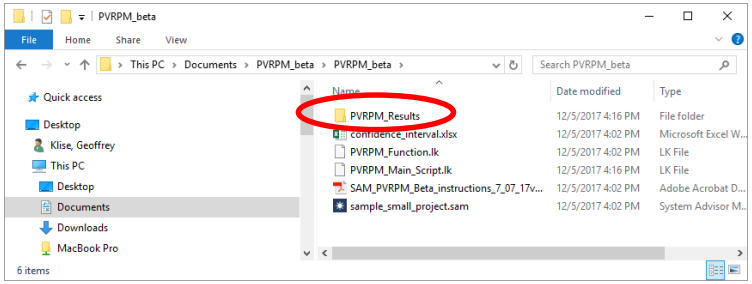
https://sam.nrel.gov/pvrpm











Default system parameters for PV-RPM

Table 2 – Small system input parameters

Model Input Steps	User Choice
Location and Resource	
TMY	USA AZ Phoenix (TMY2)
Albedo – Sky Diffuse Model - Irradiance	0.2 / Perez / DNI and DHI
Module (CEC database)	
Manufacturer and Model	SunPower SPR-X21-355-BLK
Temperature Correction	NOCT
Inverter (CEC database)	
Manufacturer and Model	SMA America: SB3800TL-US-22 (240V) CEC 2013
System Design (4 kWdc)	
Modules per String	6
Strings in Parallel	4
Number of Inverters	2
Tracking	Fixed
Tilt (deg)	20
Azimuth (deg)	180
Ground Coverage Ratio	0.3
Shading	None
Losses (Only Subarray 1)	
Irradiance - Soiling	5% for each month
Module Mismatch	2%
Diodes and Connections	0.5%
DC Wiring	2%
AC Wiring	1%
Lifetime	PV simulation over analysis period
Module Degradation Rate	0%[i]
Enable lifetime daily DC Losses	Check Box Not Selected[i]
Enable lifetime daily AC Losses	Check Box Not Selected[i]
Financial Parameters	
Analysis period[ii]	5 years

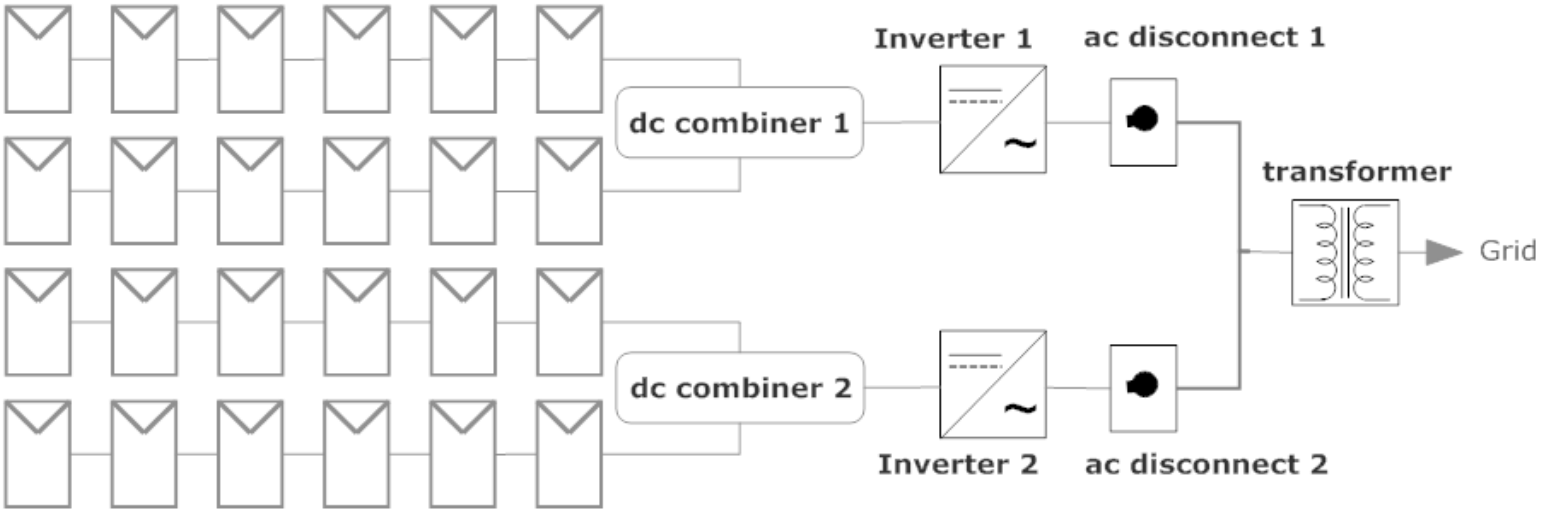
i – this will be defined in the script and discussed in a later section.

ii - Even though there are no loan, tax, insurance or salvage costs analyzed by the PV-RPM model, the analysis period needs to be set on this page, and the financial parameters chosen will affect SAM's calculation of the LCOE.

Layout of default PV system

Defined in main SAM window
- # of modules
- Modules per string
- Strings in parallel
- # of inverters

Defined in LK “Main Script”
- # of combiners
- # of transformers
- # of trackers
- Calculated AC disconnect – 1 per inverter



Probability distributions used in SAM

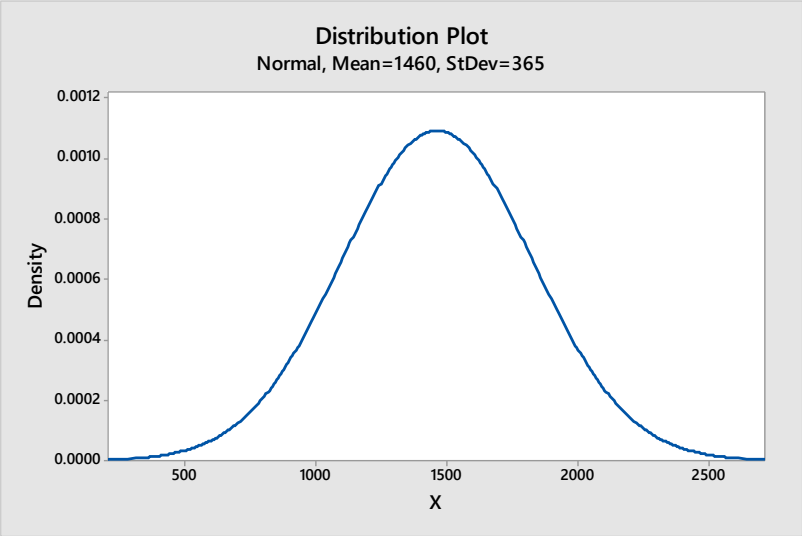
Table 1 – SAM LHS available distributions

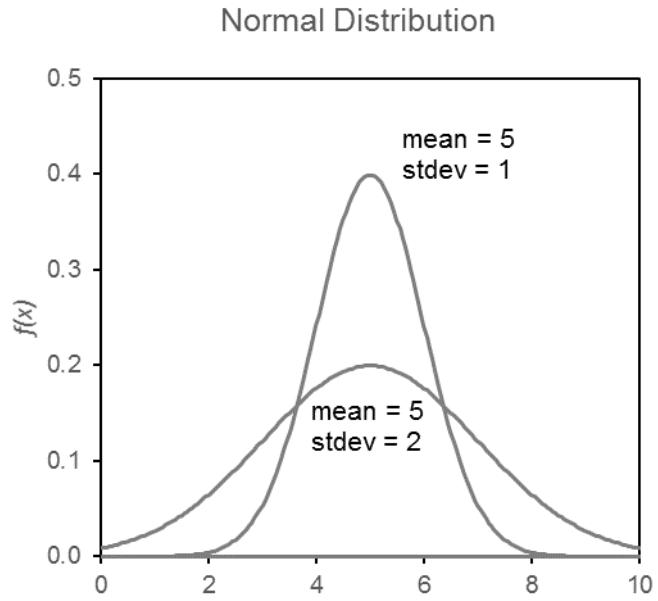
Distribution	First Parameter	Second Parameter	Third Parameter
Uniform	Min	Max	
Normal	Mean (mu)	Std. Dev. (sigma)	
Lognormal*	Mean	Std. Dev.	
Lognormal-N	Mean	Std. Dev.	
Triangular	A	B	C
Gamma	Alpha	Beta	
Poisson	Lambda		
Binomial	P	N	
Exponential	Lambda		
Weibull	Alpha or k (shape)	Beta or Lambda (scale)	

*The Sandia LHS library included in SAM requires mean and error factor inputs into lognormal function. The Lognormal-N function requires the mean and standard deviation of the UNDERLYING normal distribution. However, we anticipate that most users will have the mean and standard deviation of the actual lognormal distribution. Therefore, the LHS function implemented in the PV-RPM script translates from input mean and standard deviation to the error factor before calling the lognormal LHS function. The translation equations used can be found at https://dakota.sandia.gov/content/latest-reference-manual, Keywords>Variables>lognormal_uncertain.

Distribution Examples

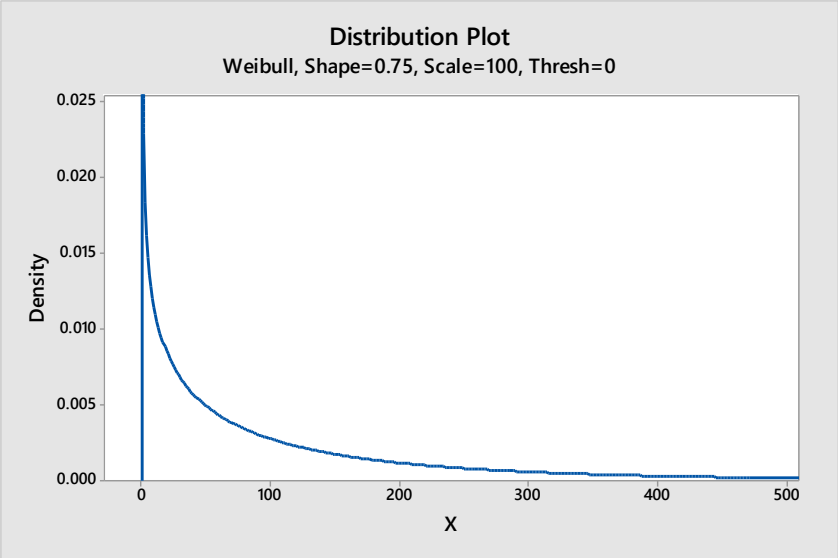
```
//failure mode 1: normal failures
                meta.module.failure[0].distribution = 'normal';
                meta.module.failure[0].parameters = [4 * 365, 1 * 365];
//mean, std, years converted to days
```

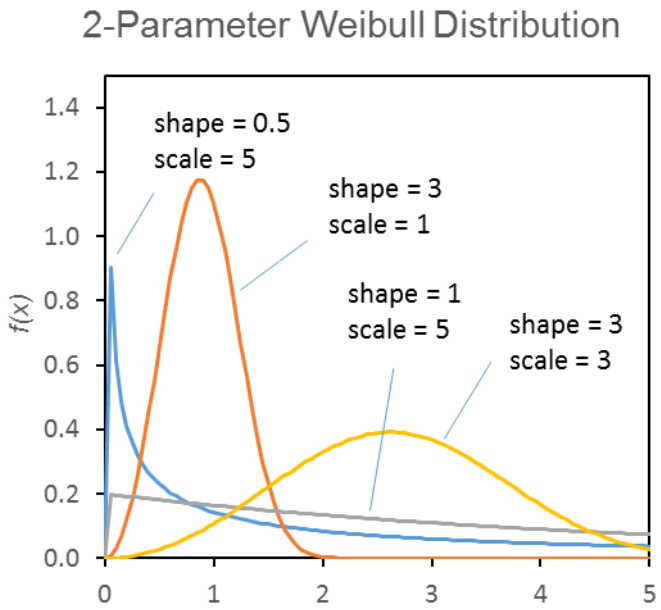




Distribution Examples

```
//grid failures
        meta.grid.failure[0].distribution = 'weibull';
        meta.grid.failure[0].parameters = [0.75, 100]; //slope
(shape factor)- unitless, mean- days
```

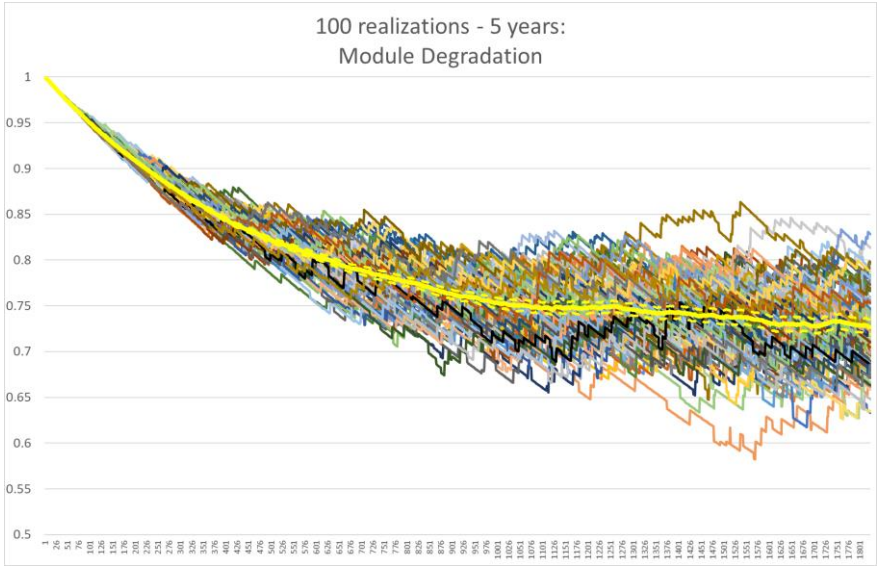


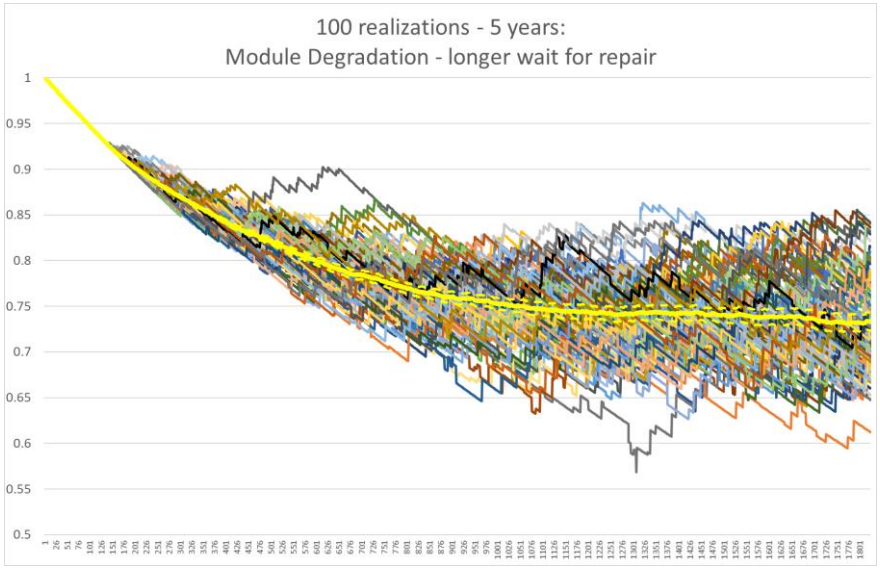


Demonstration

Analyzing Results

Degradation Analysis – accelerated example





20% module degradation rate, 5-year analysis with 100 realizations on base 4 kW (24 module) system.

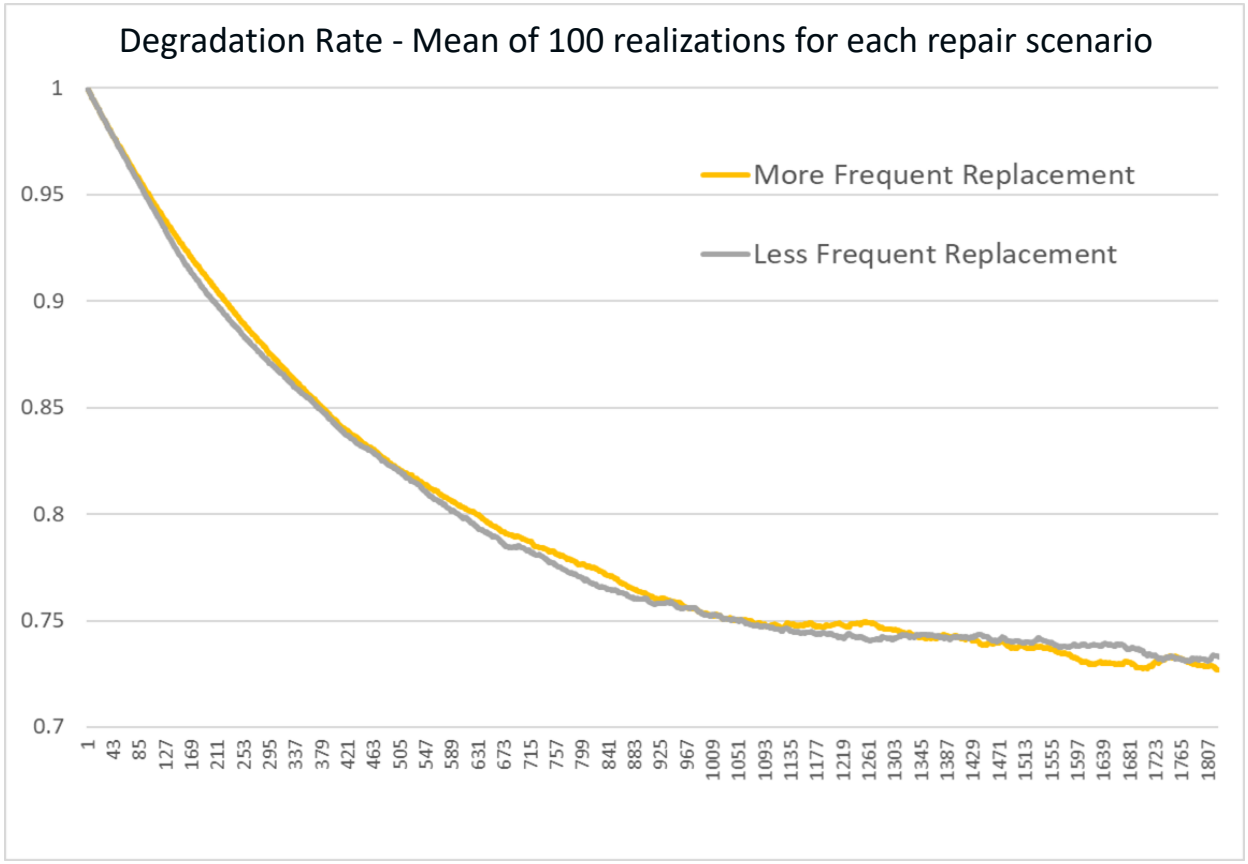
- Default “lognormal” *repair* distribution for modules. Two failure distributions, one ‘normal’ (increasing failure rate), and one ‘exponential’ (constant failure rate).
- Mean (60), Standard Deviation (20) [days]

Plot shows Mean of 100 realizations plus upper and lower 95% confidence interval

- Changed repair distribution for modules
- Mean (200), Standard Deviation (20) [days]

Plot shows Mean of 100 realizations plus upper and lower 95% confidence interval

Degradation Analysis – accelerated example



More frequent replacement:

- Mean of 48 module failures over 5 years
- Mean Availability 0.93

Less frequent replacement:

- Mean of 57 module failures over 5 years
- Mean Availability 0.73

References

- User manual – available in PV-RPM download
- https://sam.nrel.gov/pvrpm
- Sandia PV-RPM validation report http://energy.sandia.gov/download/41153/
- PV-RPM three system comparison (proof-of-concept) http://energy.sandia.gov/wp-content/gallery/uploads/SAND2012-10342_final.pdf
- Reliability and Availability study (proof-of-concept) http://energy.sandia.gov/download/20994/

Thank you

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