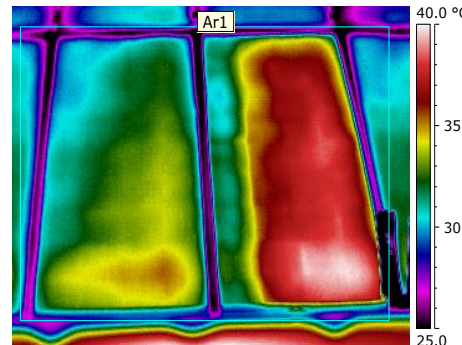


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# PV Reliability Operations Maintenance (PVRM) Database: Data Collection & Analysis Insights

*Intersolar North America*

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July 14, 2015



Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

# Reliability Impacts Asset Value

## Present Value of future costs

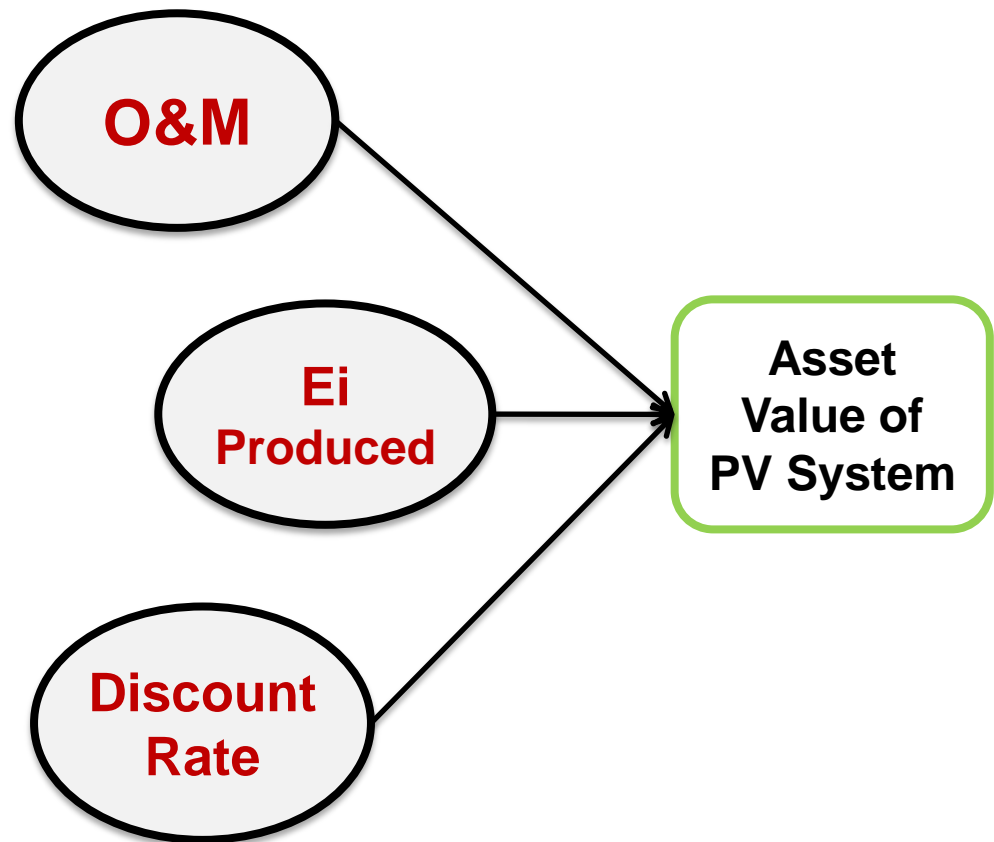
- **Issue:** High degree of uncertainty

## Present Value of anticipated energy production

- **Issue:** How much will be lost from all anticipated and unanticipated downtime

## Time Value of Money

- **Issue:** What is the basis for risk free rate and risk spread?  
Very sensitive parameter



If performance history and reliability database reveals an underperforming and/or poorly maintained asset, financing costs may increase, seller will receive less, buyer spends time and money to remediate issues

- Understanding how and when system components fail
- Training workforce to understand importance of quality data collection
- When failure modes known, when to perform preventative maintenance based on mfg. recommendation or site history
- Smart sparing strategy for anticipated component/part failures
- Reveal new failure modes with newer system architecture

# What is PVROM?

- **Fault, failure and event data collected by PV system/plant owners and operators**
- Data entered into serialized database with hierarchical relationships
  - Preventative and corrective maintenance
  - Component repairs and replacement
- Reliability statistics developed from events, faults, and failures

# Current PVROM Process

- Recruit partners (joint SNL, EPRI effort)
- Sign 3-way NDA
- Establish server accounts on SNL network
- Set up Bill of Material in correct format for new or existing PV system
- Train user on data entry and troubleshooting
- Analyze data using reliability engineering methods

# PVROM History

1999

Industry – NGO – Co-op – DOE – SNL partnership

- Baseline reliability and cost data collected
  - **Solar home lighting, water pumping, grid-tied and off-grid**
- MS Access relational database
- Qualitative data collection focus
- Goal of identifying trends that impact lifetime costs
  
- APS residential off-grid lease
  - 5-6% O&M cost, % of installed cost
- **14 year O&M history of 77 PV water pumping systems**
  - MTBF of 17 months
  - Pumps 78% of failure costs

## Reliability Study

September 2002 Release

- SOLAR HOME/AREA LIGHTING SYSTEMS
- WATER PUMPING SYSTEMS
- GRID-TIED SYSTEMS
- OFF-GRID RESIDENTIAL SYSTEMS
- SYSTEM OPTIONS (List Failure Modes, All System Report, Customer Requests)
- UTILITIES (Refresh, Retire, Delete, Import/Export)
- CLOSE DATABASE

Data fields in this color (light blue) are considered the required minimum information.



Los datos que se encuentran en campos de color azul son imprescindibles y deberán ser llenadas.

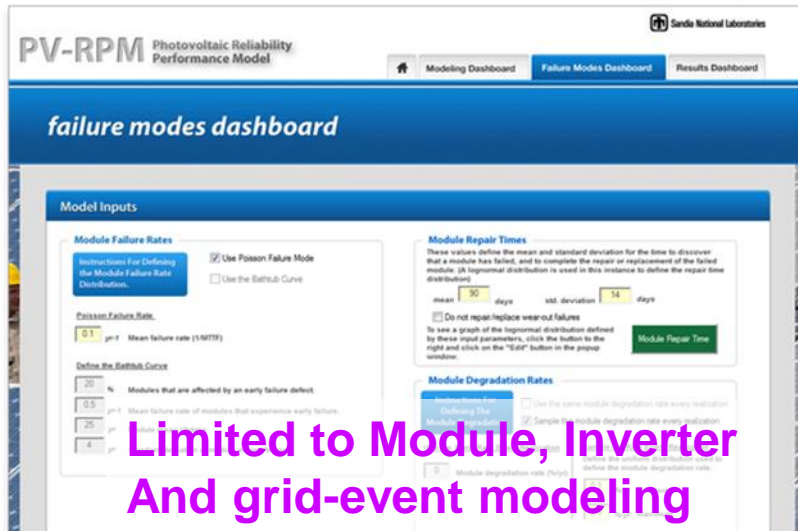


# PVROM History

2007

## Utility – DOE – SNL partnership

- 4.7 MW Springerville Generating Station
- 7 years of reliability data
- First implementation of robust reliability data collection, using XFRACAS for PVROM data collection**
- Provided foundation for proof-of-concept reliability performance model, PV-RPM

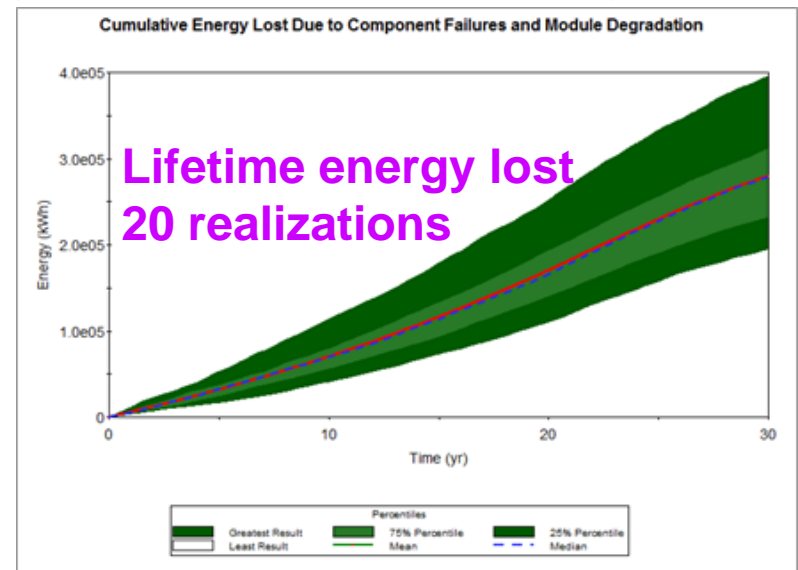


2010

Limited to Module, Inverter  
And grid-event modeling

## Tucson Electric Power - Arizona

Number of Sites	26
Total Nameplate Power (MW)	4.6
Total Modules	11,700
Total Inverters	26
Total Line Items	11,863
Total Incidences	452
Observation Time (months)	84



# PVROM Current Efforts

2012

## PV System Representative – DOE – EPRI – SNL partnership

- EPRI as partner to facilitate utility partnerships with SNL
  - Outreach to *many* owners, operators, O&M providers
  - Started with ~31 MW of large DG and utility-scale systems (38 sites)
  - Currently collecting data on ~2.2 MW nameplate
  - New partner would like to start soon: ~200 MW of new nameplate
- 
- Quantitative, reliability engineering focused
  - Long-term data collection is ideal for revealing trends, insights and event/fault/failure distributions
  - Using all data collected to inform PV-RPM model for financial projections beyond proof-of-concept capabilities

# Data Partner Summaries

## Arizona - Fixed

Number of Sites	<b>30</b>
Total Nameplate Power (MW)	<b>0.45</b>
Total Modules	<b>2,017</b>
Total Inverters	<b>33</b>
Total Line Items	<b>3,041</b>
Total Incidences	<b>26</b>
Observation Time (months)	<b>16*</b>

*\*Current and historic events are currently being entered*

## Insights

- Standardized data entry improved technician reporting
- More detail later this year after data analysis

## Challenges

- Multiple sites, still entered into XFRACAS with paper forms
- Difficult to estimate kWh production lost

# Data Partner Summaries

## Arizona - Tracking

Number of Sites	2
Total Nameplate Power (MW)	1.75
Total Modules	8,100
Total Inverters	7
Total Line Items	9,077
Total Incidences	40
Observation Time (months)	29^

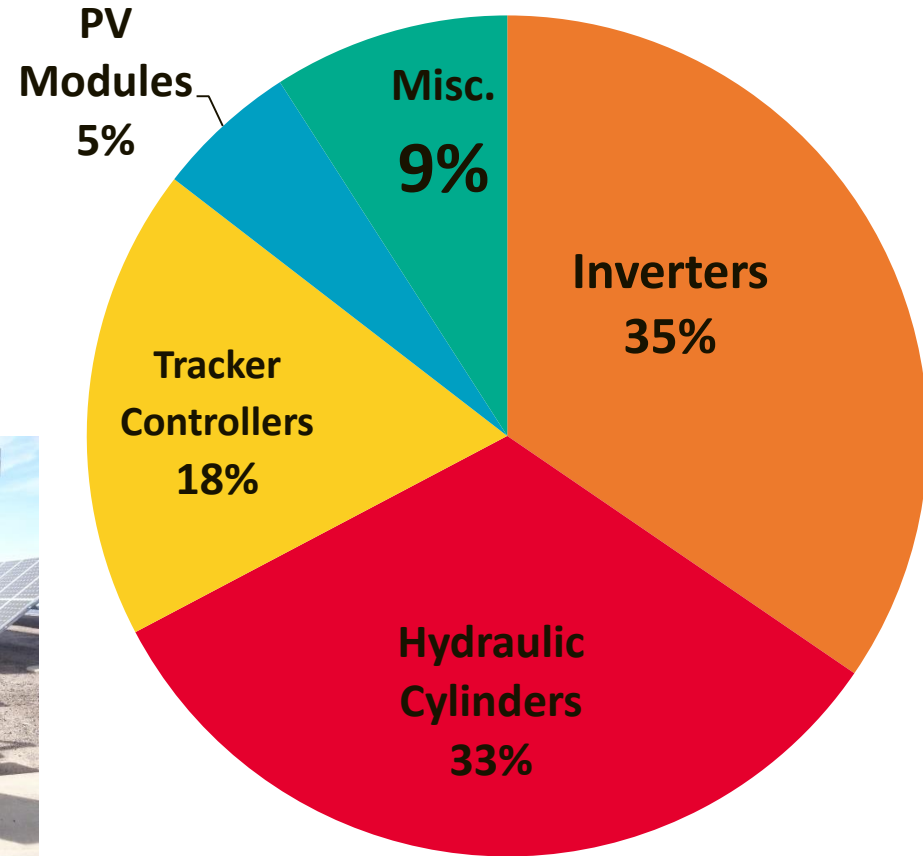
*^This site recently stopped participating*

Insights	Challenges
<ul style="list-style-type: none"> <li>MTBF decreased for hydraulic Cylinder, led to discovery of failure induced by incompatible fluid/seals</li> </ul>	<ul style="list-style-type: none"> <li>Ownership change halted PVROM participation</li> </ul>

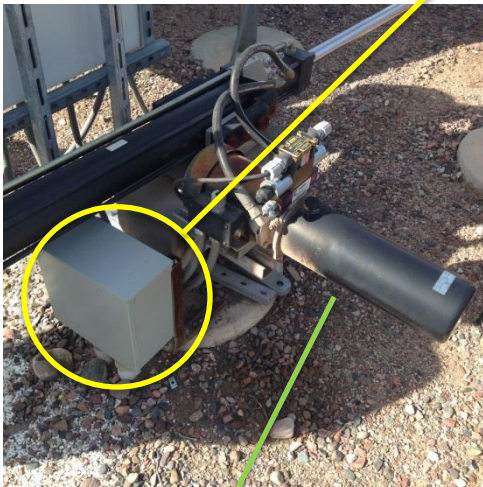
Component	MT Between Maintenance Actions (hours)	MT Between Failure (hours)	MT To Repair (hours)
Inverter	5,000	9,000	8.0
Hydraulic Cylinder	30,000	30,000	12
Large Transformer	50,000	50,000	8.0
PV Module	100,000	100,000	2.0

# Tracking system events/faults/failures

- Hydraulic cylinders and inverters constitute 68% of failures
- Modules are only 5% of recorded failures



**Controllers**



**Hydraulic Cylinders**



**Inverters**

# Data Partner Summaries

## California - Fixed

Number of Sites	6
Total Nameplate Power (MW)	29
Total Modules	425,022
Total Inverters	29
Total Line Items	468,782
Total Incidences	5
Observation Time (months)	4 <sup>^</sup>

<sup>^</sup>Participation ended in early 2015

## Challenges

- Complex BOM entry due to interest in fuse and sub-component level tracking
- Staffing changed multiple times, had to train each new person and get access to SNL server
- An efficient process was not developed due to staff availability. Other company priorities did not leave time for data entry

# PVROM Analysis - Example

- **Non-repairable failure distribution parameters**

Component	Distribution	1 <sup>st</sup> Model Parameter	2 <sup>nd</sup> Model Parameter
AC Disconnect Switch	Lognormal	$\mu = 7.048$	$\sigma = 3.863$
Photovoltaic Modules	Weibull	$\beta = 0.825$	$\eta = 4.498 \times 10^6$
480/34.5 kV Transformer	Weibull	$\beta = 0.668$	$\eta = 2,554$

Notes:  $\beta$  (Shape Parameter of Weibull Distribution),  $\eta$  (Characteristic Life of Weibull Distribution),  $\mu$  (log-geometric mean of the Lognormal Distribution),  $\sigma$  (log-geometric standard deviation of the Lognormal Distribution). Model parameters based on time metric of **days**.

- **Repairable failure distribution parameters**

Component	Beta (Shape)	Lambda (Scale)
DC Disconnect Switch	0.470	0.0496
Array Electrical Connections	1.239	$3.486 \times 10^{-5}$
Inverter – Corrective and Preventative Maintenance	1.029	$2.264 \times 10^{-3}$
Inverter - Induced Outages	1.041	$4.799 \times 10^{-3}$

# Benefits of PVRROM to Existing Data Partners

- Determined ways to pseudo-serialize PV system components as serial numbers were not collected during installation
- Prompted studies on time for barcode scanning of PV modules during O&M activities, and time to enter data into PVRROM
- Insight into PV tracker failure based on reliability growth/decline analysis
- Realize there is a better way than paper-based field data collection
- Awareness that detailed tracking provides a strong basis for root cause analysis
- Knowledge transfer for how to perform statistical analysis with data collected

# Overall Challenges

- NDA process can take up to a year
- Participating company needs a champion for ensuring data collection and input takes place
- Need for long-term data collection for more accurate statistical representation
- Reliability data collection and analysis will take additional up-front investment

# Benefits of PVROM to Industry

- SNL and EPRI have developed rigorous process for data collection that can support reliability analysis
- Use of this “process” provides a technical basis that can be used to better inform manufacturers of different system and environmental impacts
- Provides statistical measure of reliability growth or decline as a result of preventative and corrective maintenance policy
- The highest, or lowest level of repairable/replaceable parts can be analyzed (whole inverter to replaceable inverter components)
- Develop sparing strategies to optimize equipment available on-site and potential acquisition and delivery time
- Provides focus on maintaining the equipment, which is important when O&M contracts may or may not have specific “Equipment Availability” guarantees

# Current Publications

- EPRI/SNL 2013 Status report

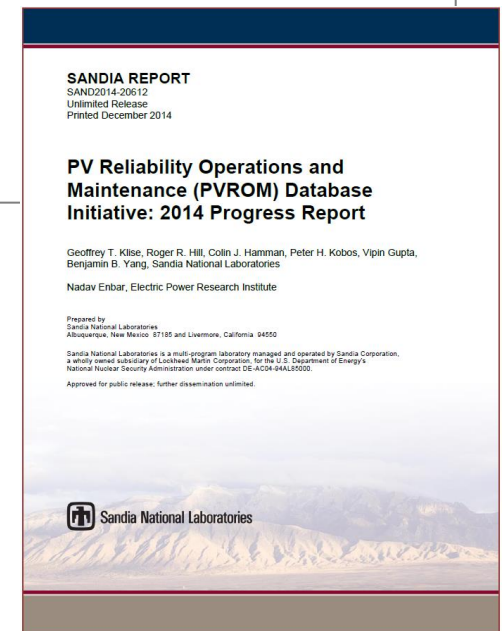
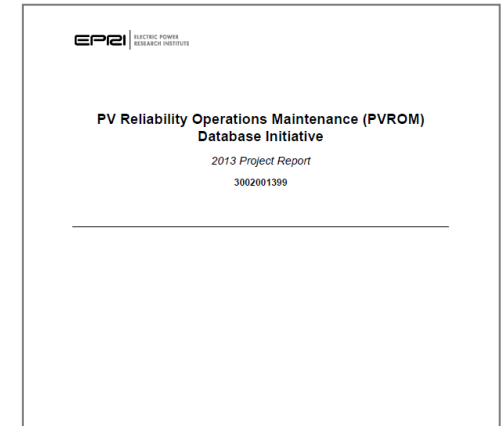
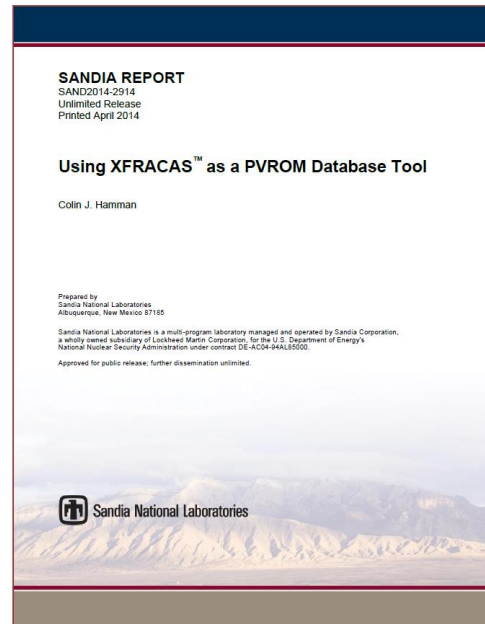
<http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002001399>

- Using XFRACAS as a PVROM Database Tool

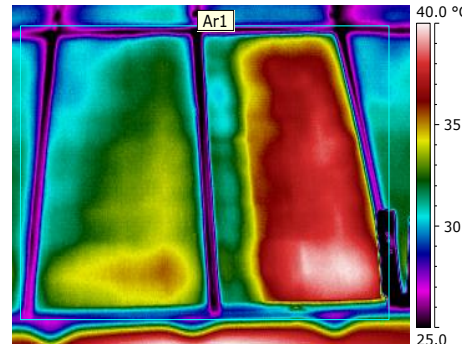
<http://energy.sandia.gov/wp-content/gallery/uploads/SAND2014-2914-XFRACAS-as-PVROM-Tool.pdf>

- PV Reliability Operations And Maintenance (PVROM) Database Initiative 2014 Progress Report

[http://energy.sandia.gov/wp-content/gallery/uploads/dlm\\_uploads/SAND2014\\_20612\\_PVROM.pdf](http://energy.sandia.gov/wp-content/gallery/uploads/dlm_uploads/SAND2014_20612_PVROM.pdf)



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**Thank You**  
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