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The PV Reliability O&M Database and Data Collection Tool

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Overview

- Background: What is PVROM and why did we develop it?
- Technical overview of PVROM
- Usefulness
- Feedback from the first partner
- How could PVROM support your goals?

Background

- 2008: Sandia recognized the lack of standardized O&M data collection and analysis
- 2008-2009: Developed a standardized O&M data collection tool (PVROM)
- 2009-2010: Developed a Reliability Block Diagram model of a PV system to predict availability and reliability
- 2011-2012:
  - Began outreach to potential users/partners of PVROM
  - Developed a combined Performance and Reliability prediction model
  - Partnered with EPRI
  - Beta test of PVROM with ViaSol
- 2013: Expanding partnerships – currently 3 active users of PVROM, 4th in the agreement phase, 5th in the interest phase

Goals and Objectives Of O&M Projects

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- EPRI and Sandia will focus on identifying and analyzing the technical risks involved in PV operation and maintenance
- Develop a growing partner base with solar industry stakeholders through formalized agreements with organizations and individual companies
- Facilitate increased, accelerated, and broadened data flow
- Integrated research data and combined performance reporting of industry partnership data.

Technical Challenges

- Getting industry data, much of which will be considered to be competitive advantage
- Making it easy for partners to provide data
- Working through standard practices, definitions, and reporting by industry operators. Setting the stage for industry to fulfill this function on its own
- Aggregating reporting for baseline metrics

Why Track O&M?

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- System owners:
  - Uniform organizational investment strategy
  - Uniform performance tracking strategy
  - Different geographical locations (and organizational regions)
  - Common annual fiscal process requires well documented proposals
  - Common (corporate) benchmarking of system production
- Rigorous O&M strategies provide optimal return on investment
- Sandia/EPRI need data for assessing industry-wide trends and developing accurate science/statistics-based predictions of system "ownership metrics"

O&M Data Collection

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- PV System ownership is a cradle to grave commitment
- Different Elements of O&M Data Collection
  - System monitoring; focused on tracking performance/production
  - Incident tracking; focused on tracking downtime and documenting failures/failure modes
  - Cost tracking; focused on documenting expenditures
  - Work orders; focused on managing response to O&M
- Predictability is critical to controlling costs and optimizing production. Tracking O&M is critical to predictability.

Data Collection Tool

- Web-based incident (failure) reporting, analysis, and corrective action system software package (ReliaSoft's XFRACAS™)
- Supports acquisition, management and analysis of system quality and reliability data from multiple sources
- Database resides on Sandia Restricted Network (SRN) server
- Access to database is through Sandia Open Network (SON)
  - Access restrictions (login ID and password) ensure only source users (partners) can access database
  - SNL issues SON login ID and passwords
  - Only system owner, Sandia and EPRI will have access to O&M data
- XFRACAS™ source permissions ensure source users can access only their own data
- XFRACAS™ platform supports both real-time and legacy failure/suspension (or non-failure event) data acquisition, incident record searches and report generation, and export of data for reliability analysis
- Program partners may use other XFRACAS™ capabilities as well

Data Needs for Reliability, Availability, O&M Optimization Analysis

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PVROM Standard Dataset	Reliability	Availability	O&M
Incident Occurrence Date/Time	x	x	x
Bill of Material Part Number	x	x	x
Part Serial Number*	x		x
Part Commissioning Date	x	x	x
Incident Description	x	x	x
Incident Category	x	x	x
Service Response Date/Time			x
Service Completion Date/Time	x		x
Restoration to Duty Date/Time		x	x
Energy Lost (kWh)	x	x	

Discussion point:

What is the minimum data collection criteria for accurate O&M assessments?

PV System Bill of Material

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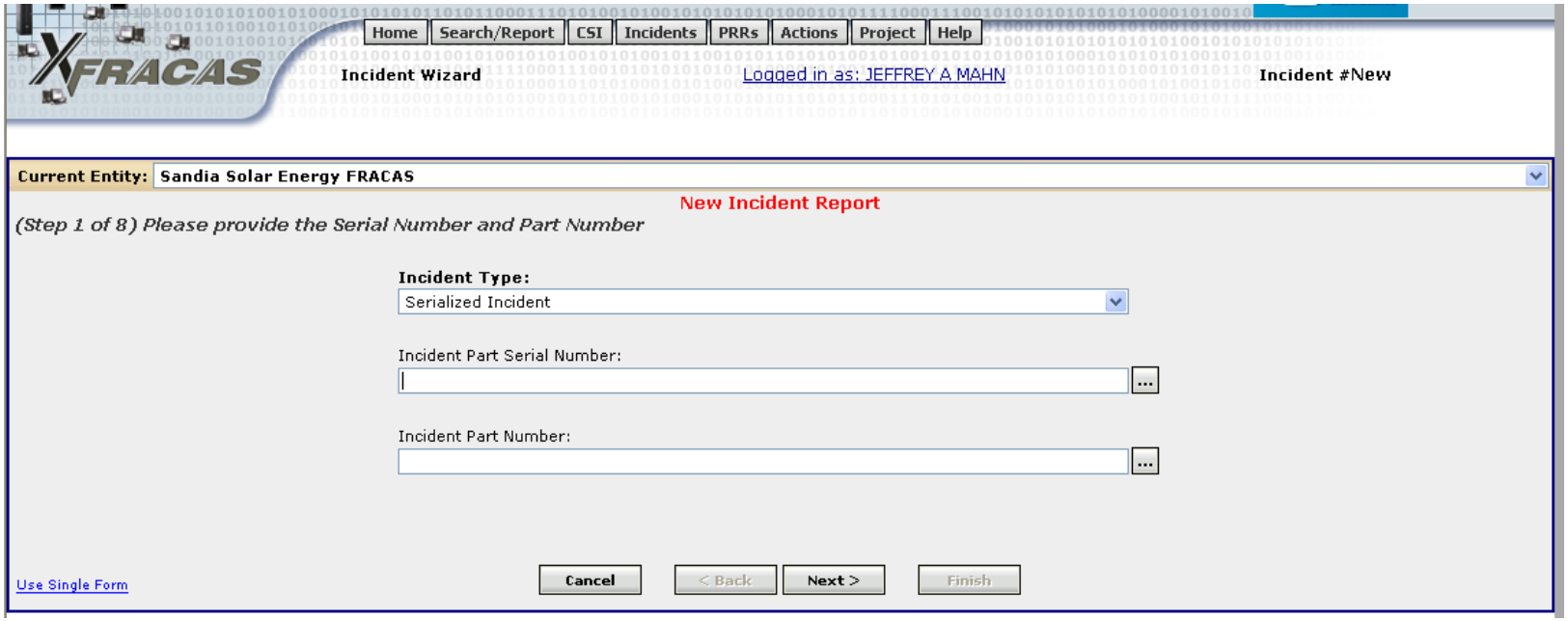
Starting point for collection and analysis of performance data – one BOM for each system power block

Level	Part Number	Part Description	Part Version	Serial Number	Quantity	Build Date	Ship Date	Catalog	Manufacturing Code
1	SGSSS	SGS Solar System Power Block		SGS-1	1	07/13/2001			
2	TXL	480V/34.5kV Transformer		SCL-2	1	07/13/2001			
2	TXS	208V/480V Transformer		TXS-1	1	07/13/2001			
2	ADS	AC Disconnect Switch		ADS-1	1	07/13/2001			
2	DDS	DC Disconnect Switch		DDS-1	1	07/13/2001			
2	ECON	Array Electrical Connections		ECON-1	1	07/13/2001			
2	INV	Inverter		INV-1	1	07/13/2001			
2	LIGHT	Lightning Event		L-1	1	07/13/2001			
2	MOD	PV Module		M-U1-1	1	07/13/2001			
2	MOD	PV Module		M-U1-2	1	07/13/2001			
2	MOD	PV Module		M-U1-3	1	07/13/2001			
2	MOD	PV Module		M-U1-4	1	07/13/2001			
2	MOD	PV Module		M-U1-5	1	07/13/2001			
2	MOD	PV Module		M-U1-6	1	07/13/2001			
2	MOD	PV Module		M-U1-7	1	07/13/2001			
2	MOD	PV Module		M-U1-8	1	07/13/2001			
2	MOD	PV Module		M-U1-9	1	07/13/2001			
2	MOD	PV Module		M-U1-10	1	07/13/2001			
2	MOD	PV Module		M-U1-11	1	07/13/2001			
2	MOD	PV Module		M-U1-12	1	07/13/2001			
2	MOD	PV Module		M-U1-13	1	07/13/2001			
2	MOD	PV Module		M-U1-14	1	07/13/2001			
2	MOD	PV Module		M-U1-15	1	07/13/2001			
2	MOD	PV Module		M-U1-16	1	07/13/2001			
2	MOD	PV Module		M-U1-17	1	07/13/2001			
2	MOD	PV Module		M-U1-18	1	07/13/2001			
2	MOD	PV Module		M-U1-19	1	07/13/2001			
2	MOD	PV Module		M-U1-20	1	07/13/2001			
2	MOD	PV Module		M-U1-21	1	07/13/2001			

Sandia can assist in developing facility/installation BOMs.

Performance Data Entry

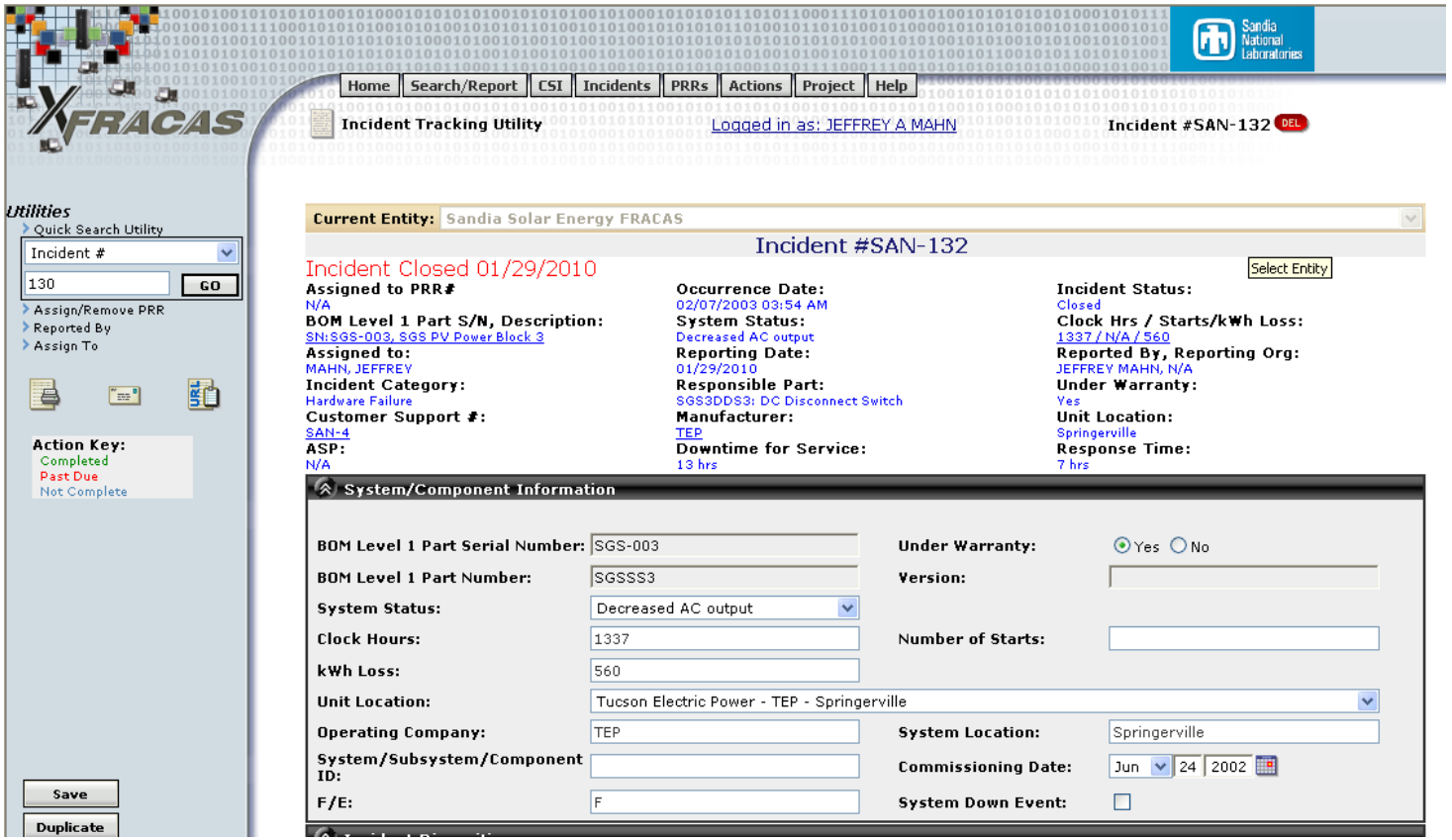
Incident records are initiated with XFRACAS™ Incident Wizard ……



Initial incident data would be entered by O&M personnel at each site.

Performance Data Entry (cont.)

…. and elaborated upon with XFRACAS™ Incident Tracking Utility



Incident status is updated as needed by O&M personnel at each site.

Accessing Data With Queries

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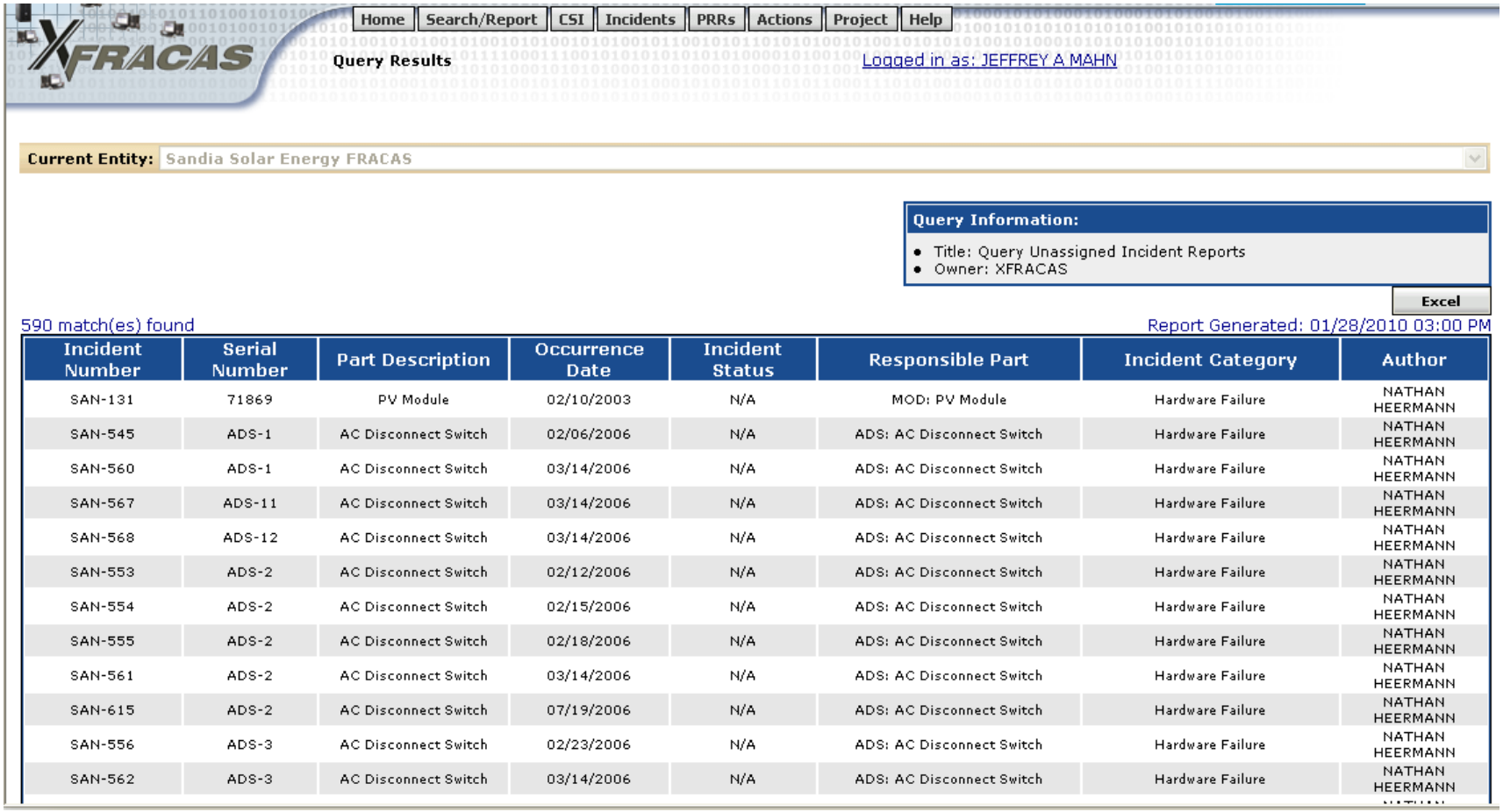
Database information is readily accessible for tracking, analysis, etc.



Home | Search/Report | CSI | Incidents | PRRs | Actions | Project | Help

XFRACAS

Query Results

Logged in as: JEFFREY A MAHN

Current Entity: Sandia Solar Energy FRACAS

Query Information:

- Title: Query Unassigned Incident Reports
- Owner: XFRACAS

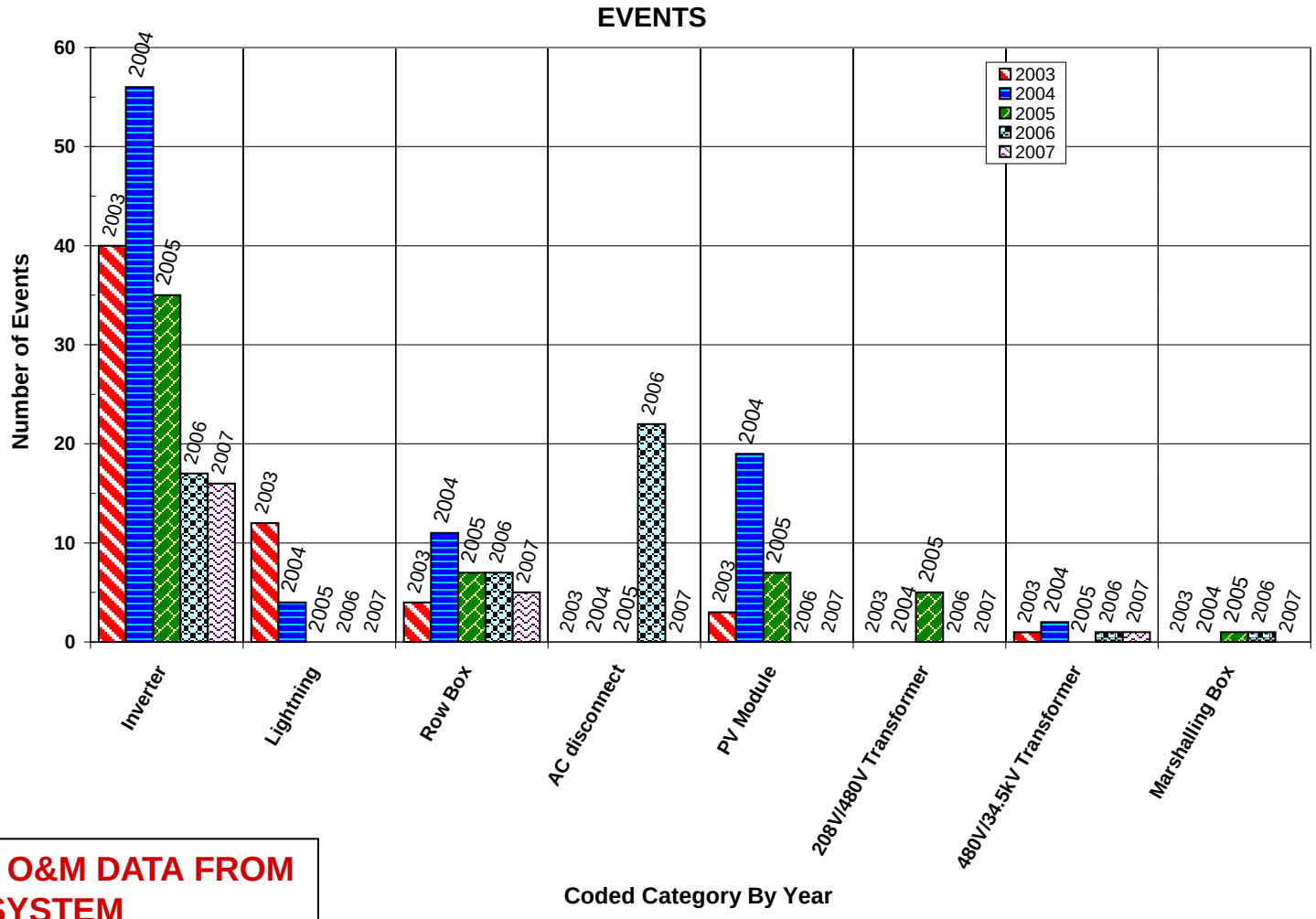
Excel

590 match(es) found

Report Generated: 01/28/2010 03:00 PM

Incident Number	Serial Number	Part Description	Occurrence Date	Incident Status	Responsible Part	Incident Category	Author
SAN-131	71869	PV Module	02/10/2003	N/A	MOD: PV Module	Hardware Failure	NATHAN HEERMANN
SAN-545	ADS-1	AC Disconnect Switch	02/06/2006	N/A	ADS: AC Disconnect Switch	Hardware Failure	NATHAN HEERMANN
SAN-560	ADS-1	AC Disconnect Switch	03/14/2006	N/A	ADS: AC Disconnect Switch	Hardware Failure	NATHAN HEERMANN
SAN-567	ADS-11	AC Disconnect Switch	03/14/2006	N/A	ADS: AC Disconnect Switch	Hardware Failure	NATHAN HEERMANN
SAN-568	ADS-12	AC Disconnect Switch	03/14/2006	N/A	ADS: AC Disconnect Switch	Hardware Failure	NATHAN HEERMANN
SAN-553	ADS-2	AC Disconnect Switch	02/12/2006	N/A	ADS: AC Disconnect Switch	Hardware Failure	NATHAN HEERMANN
SAN-554	ADS-2	AC Disconnect Switch	02/15/2006	N/A	ADS: AC Disconnect Switch	Hardware Failure	NATHAN HEERMANN
SAN-555	ADS-2	AC Disconnect Switch	02/18/2006	N/A	ADS: AC Disconnect Switch	Hardware Failure	NATHAN HEERMANN
SAN-561	ADS-2	AC Disconnect Switch	03/14/2006	N/A	ADS: AC Disconnect Switch	Hardware Failure	NATHAN HEERMANN
SAN-615	ADS-2	AC Disconnect Switch	07/19/2006	N/A	ADS: AC Disconnect Switch	Hardware Failure	NATHAN HEERMANN
SAN-556	ADS-3	AC Disconnect Switch	02/23/2006	N/A	ADS: AC Disconnect Switch	Hardware Failure	NATHAN HEERMANN
SAN-562	ADS-3	AC Disconnect Switch	03/14/2006	N/A	ADS: AC Disconnect Switch	Hardware Failure	NATHAN HEERMANN

Example: Summary of PVROM Component Failures

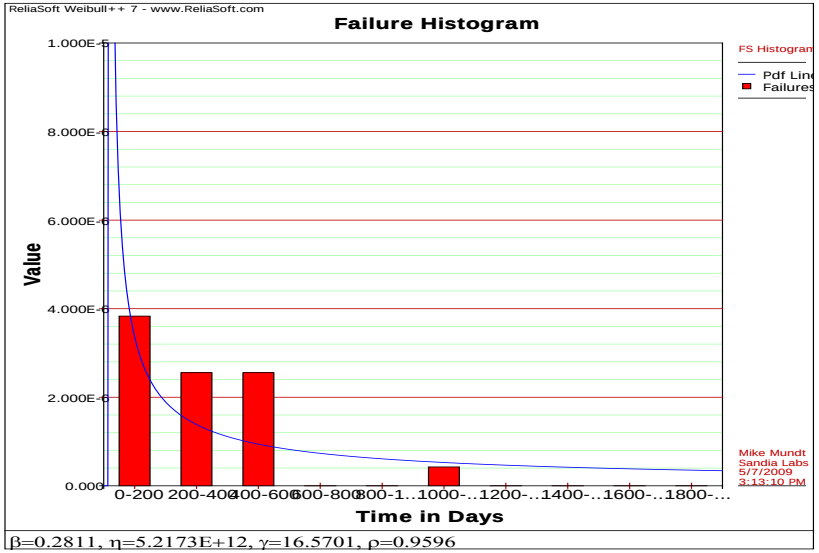


5 YEARS O&M DATA FROM A 4 MW SYSTEM

Analysis of PV Module Failure Data

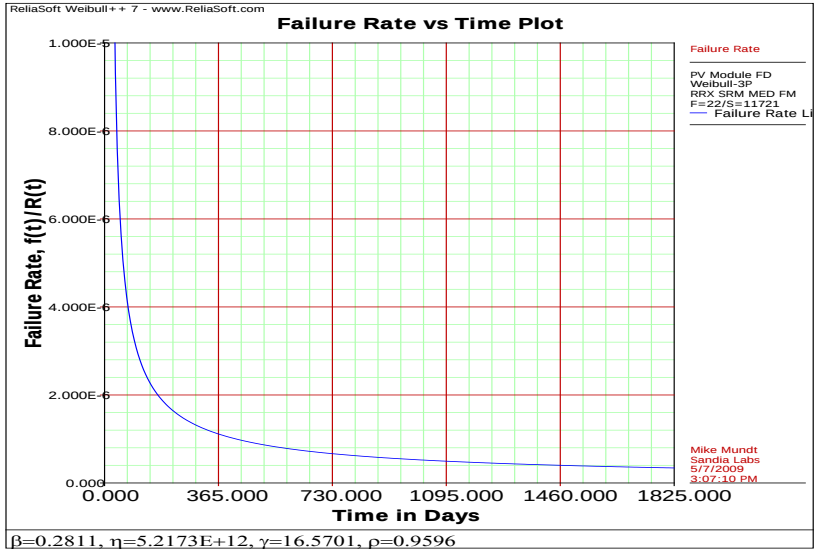
PV Module Failure pdf and Histogram

3P Weibull pdf is reasonable fit to observed failures based on engineering knowledge and goodness-of-fit metrics



PV Module Failure rate vs. Time for 5Years

Accelerated testing needed to determine when failure rate increases due to degradation



These data plots indicate how a PV module failure rate has stabilized following some early failures and remains relatively low for the foreseeable future. Wear-out timing would be established via accelerated stress testing. Similar analyses can be performed for all components, as well as for the entire PV system.

Case Study: Which O&M Approach?

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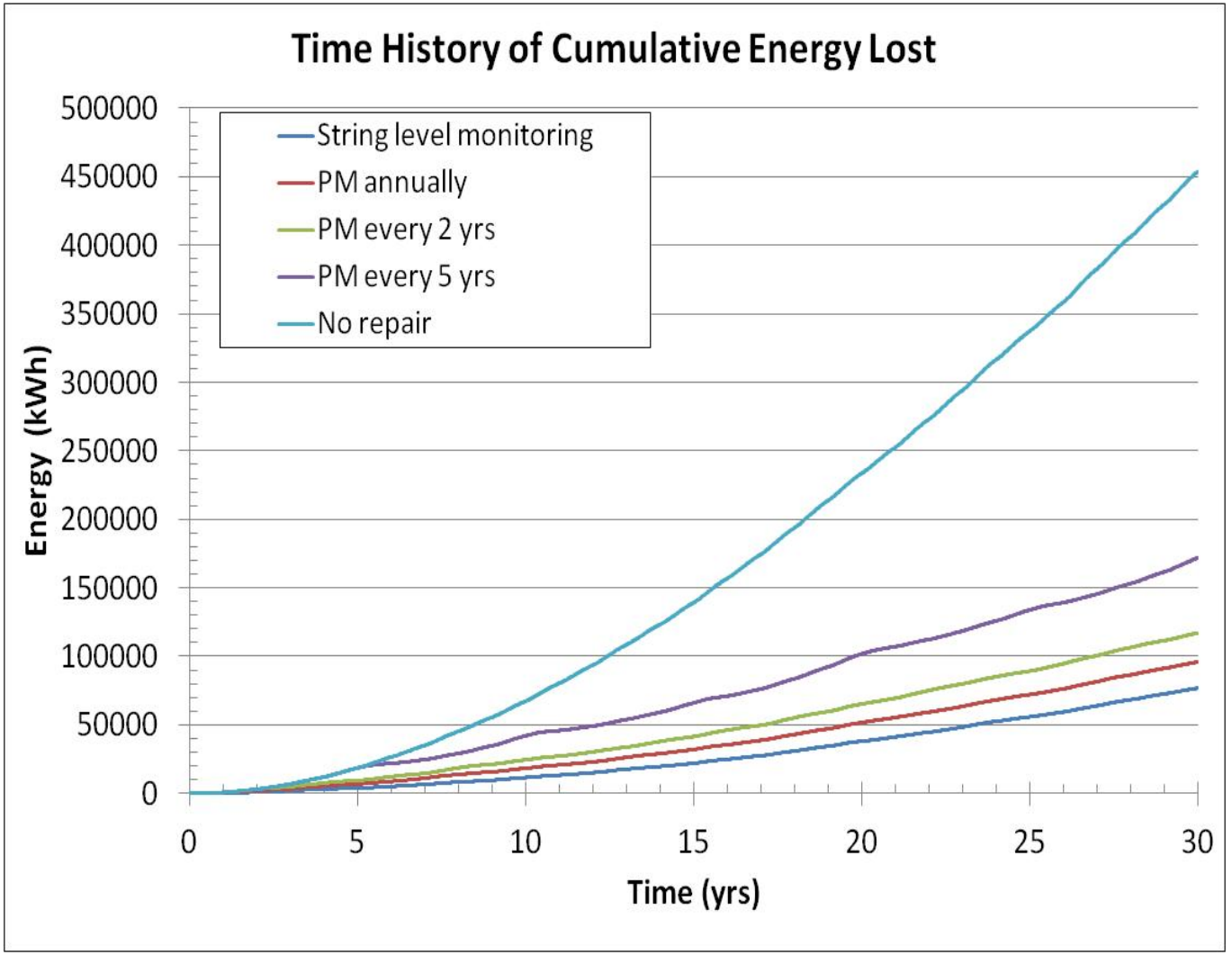
The energy lost due to failures can add up over the life of the system

There is a tradeoff between performance and cost of O&M



Partnership Roles

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- PV system owner adoption of the PVROM database includes:
  - Developing BOMs for each PV facility/installation
  - Entering PV system event data into the PVROM database (ongoing activity) with continuous accessibility to data
  - Providing available PV system legacy data if available
- Sandia will provide necessary PVROM training
  - Assistance in developing necessary BOM's for PV facilities/installations
  - Assistance, as needed, with data collection/entry issues
  - Assistance entering PV system legacy data into PVROM
  - Perform reliability/availability analysis for PV system data and providing results to system owner
- Reliasoft provides additional training on the use of XFRACAS™

Beta Test Results: ViaSol

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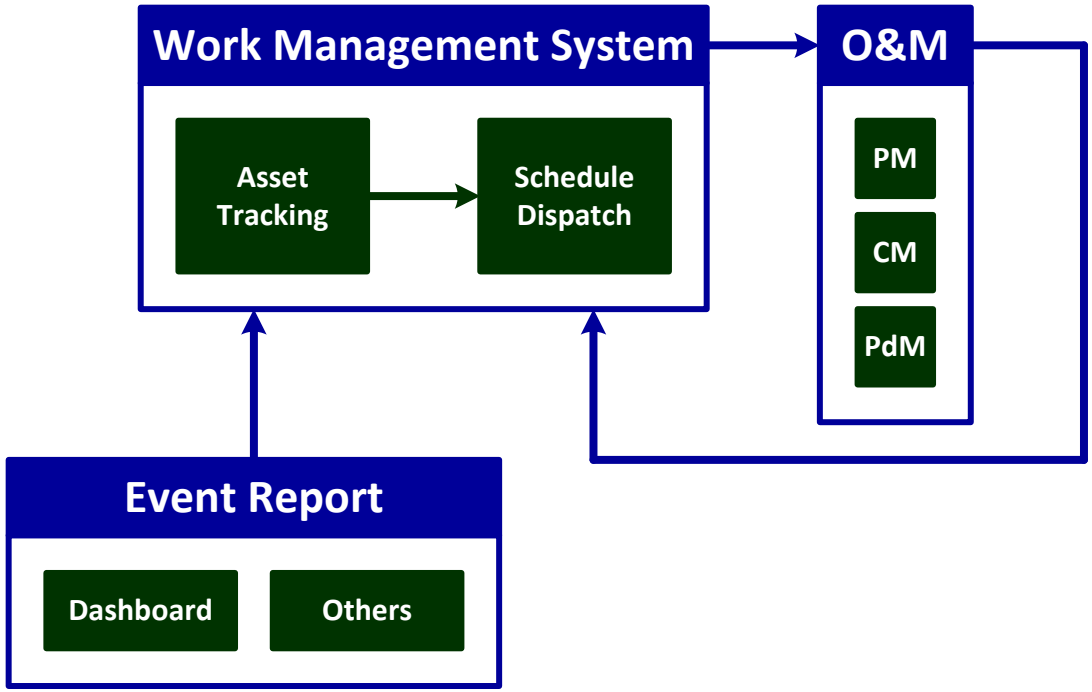
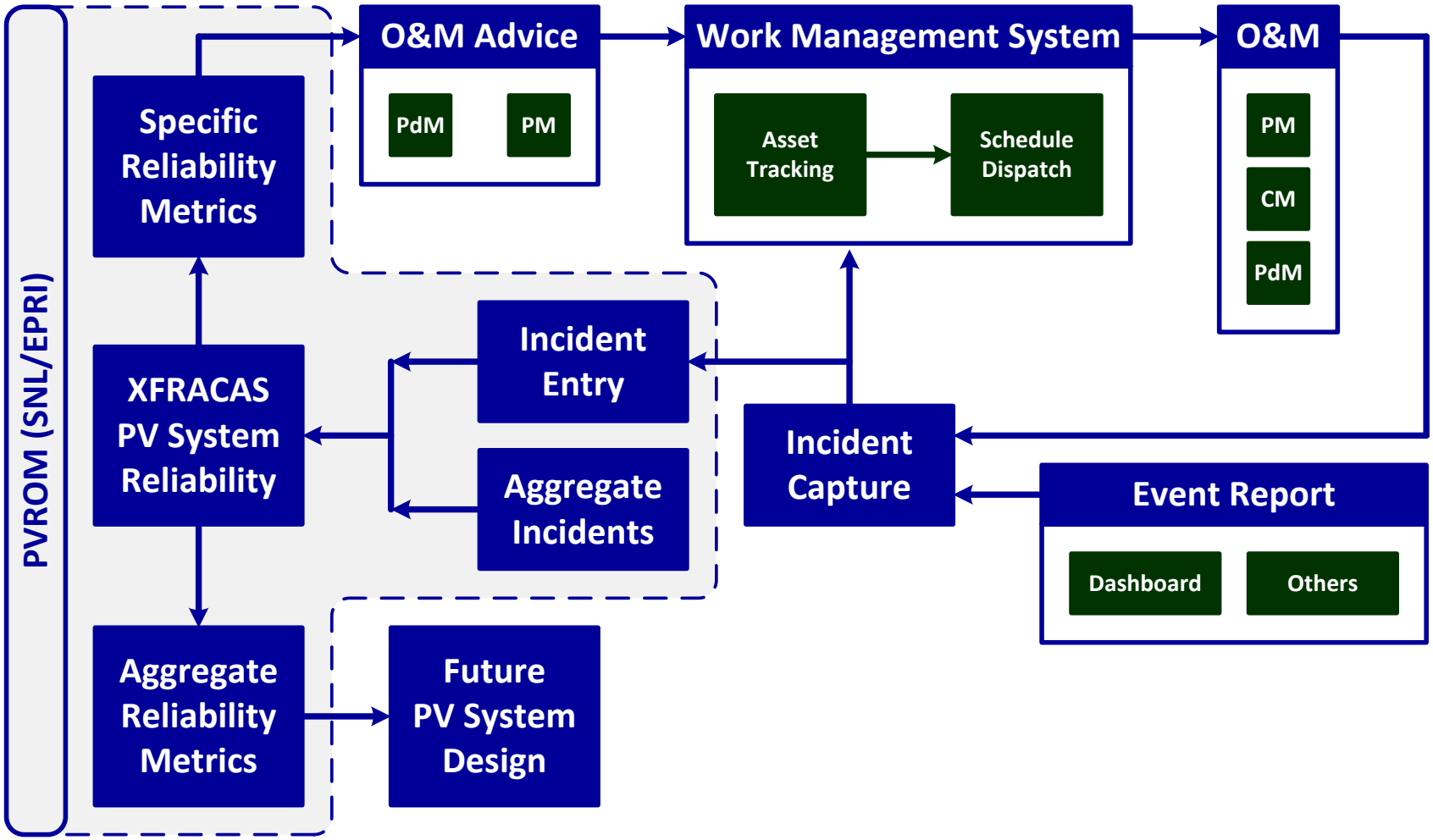
- 2012: First PVROM partner ViaSol tracked implementation time and ease of use
  - Continuous time study to develop and input a BOM
  - Incident capture study
  - Event capture study

Traditional PV O&M Tracking



PV O&M with PVROM



BOM Study

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3 options:

1. Non Serialized Template
   - Determine components to be tracked for reliability
   - Hierarchical: Parent-child levels
   - Each component has to be repairable/replaceable
     - If parent is replaced, all children are replaced
   - No logical (electrical or mechanical) units or empty “containers”
     - Follow SNL guidelines for ease of aggregate analysis
2. Serialized BOM
   - Identify each system component by serial number
     - Actual Serial Number
     - Pseudo Serial Number
   - Assign each component to a level
   - Use system design or as-built drawings

BOM Study

3. Pseudo Serialization
   - Logical
     - Physical location and/or
     - Electrical connection
   - Easy to create and automate
   - Easy to track in XFRACAS
   - Can match asset tags in WMS

BOM Creation Time Study		
As built drawings	4 man-h	2 Engineers
Verification of drawings	12 man-h	1 Engineer + 1 Technician
BOM creation	10 man-h	2 Engineers
Total	**26 man-h**	

XFRACAS Incident Capture

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- Capture incident information at site
  - Typically, not all XFRACAS-relevant information captured
  - Reduce time to gather information
  - Reduce errors in information gathered
  - Difficult to train techs to consistently and correctly gather XFRACAS-relevant data
  - Need to remove “figuring-out-in-field” aspect of data gathering

XFRACAS Incident Capture: Improvements

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- Pictorial Incident Capture Form
  - Reduce the “writing”
  - Reduce guess-work on part of the technician. The technician still has to be trained on the use of the form.
  - Record only pertinent information.
  - Record sufficient information.
  - Allow engineer to accurately deduce the serial number.
  - Allow engineer to work out the incident category, failure type and other XFRACAS information.
  - Help in troubleshooting, repair, and/or replacement of system components.
- Pictorial Incident Capture Form Contents
  - Site Information
  - Date and Time
  - Weather
  - PV Arrays
  - Inverters
  - Trackers
  - Other Sub-Systems

Incident Capture Form

ASU PS5
Field Assessment Form

Rev 02

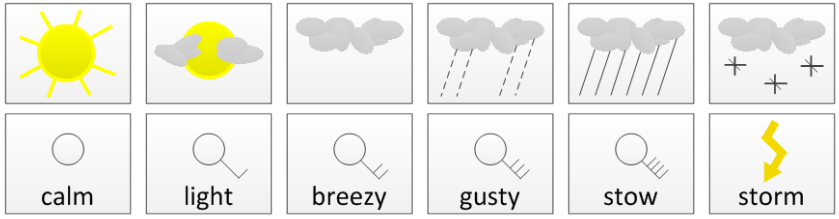
601 South College Avenue
Tempe, AZ 85281

Tech:												☐ AM ☐ PM		
M	Jan	Feb	Mar	Apr	May	Jun								
	Jul	Aug	Sep	Oct	Nov	Dec								
D	0	1	2	3										
	0	1	2	3	4	5	6	7	8	9				
Y	2009	2010	2011	2012								:00	:10	:20
	2013	2014	2015	2016								:30	:40	:50

Start Hour: 12 1 2 3 4 5 6 7 8 9 10 11

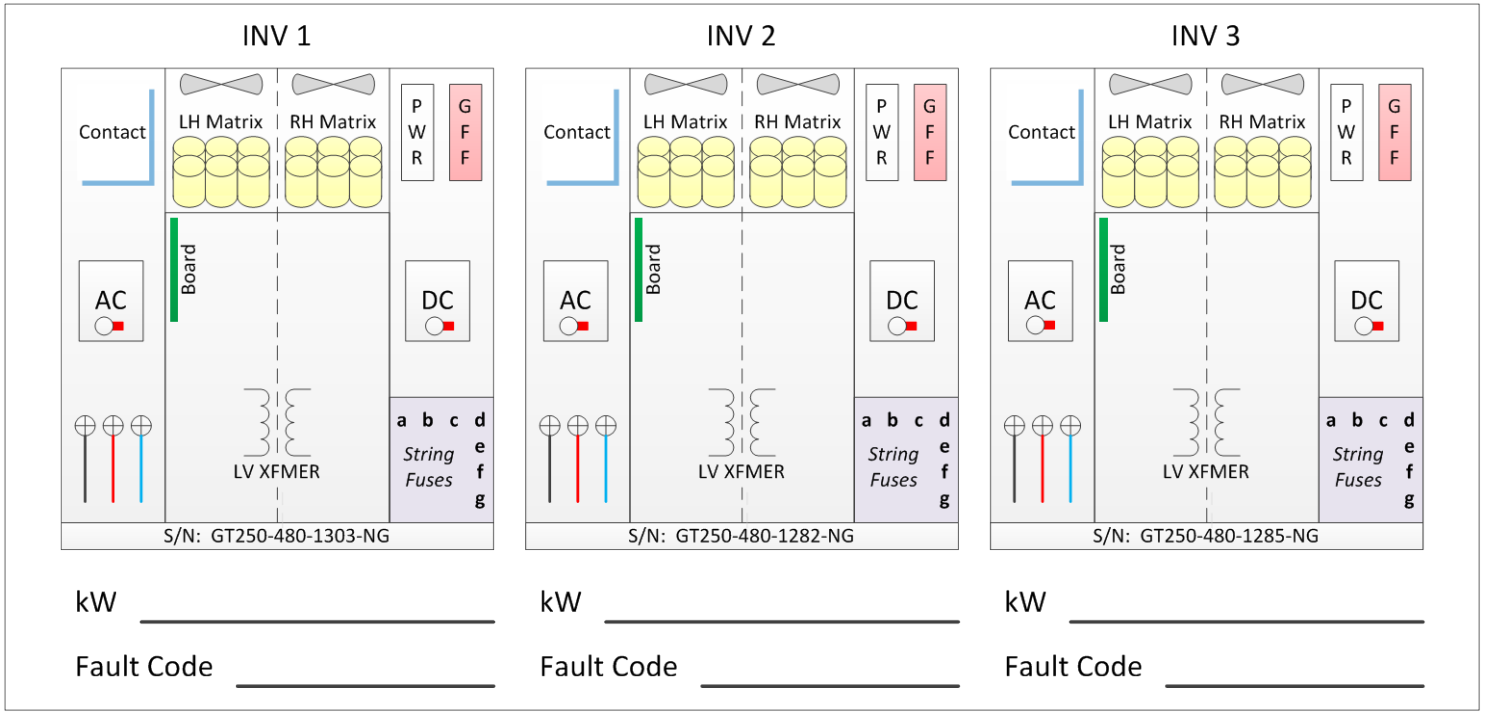
Site Conditions

°F 20 30 40 50 60 70 80 90 100 110



Incident Capture Form

Incident Capture Form



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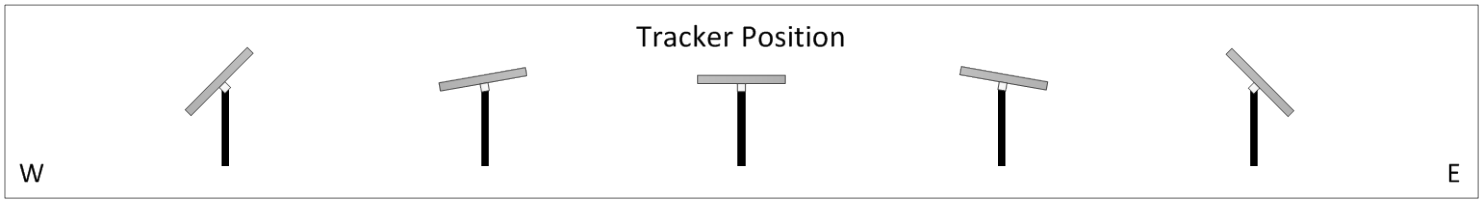
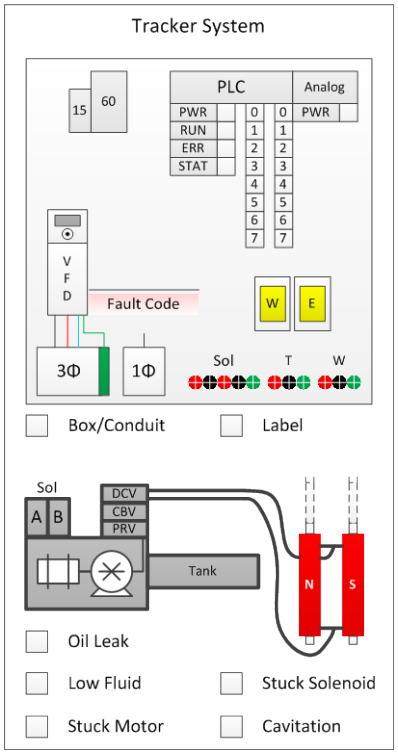
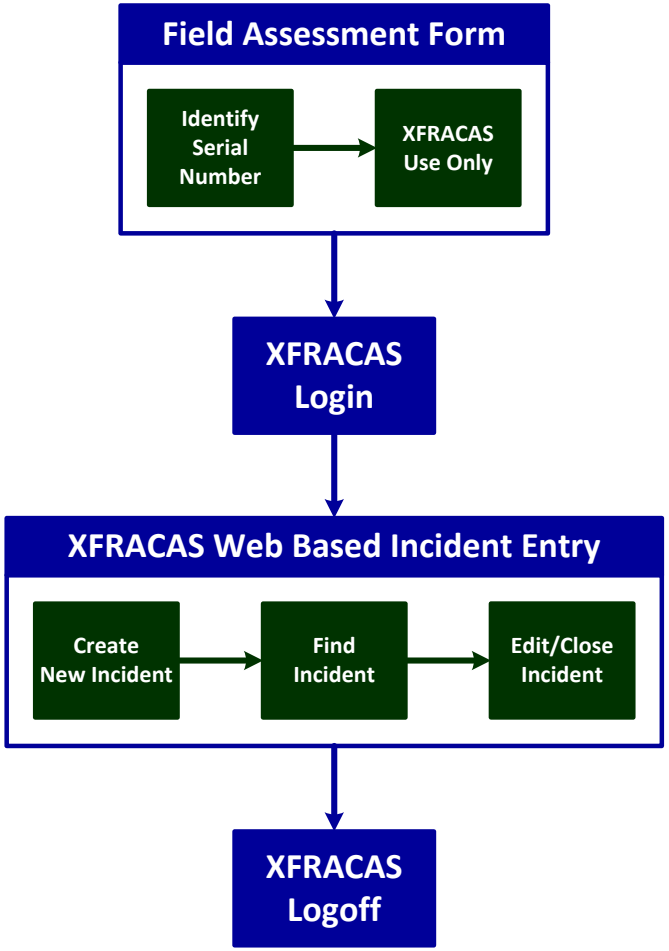




XFRACAS Incident Entry



Incident Entry Improvements

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- [ ] Return to Service
- [ ] Warranty Service Required
- [ ] Further Analysis Required
- [ ] Remove and Replace
- [ ] Repair
- [ ] Scheduled Maintenance

XFRACAS Use Only

Incident Status

- [ ] Open
- [ ] Under Review
- [ ] Closed
- [ ] Closed / Insufficient Data

Incident Category

- [ ] Hardware Failure
- [ ] Planned Maintenance
- [ ] Troubleshooting Issue
- [ ] System Upgrade
- [ ] End of Useful Life Failure
- [ ] Environment-induced Failure/Suspension
- [ ] Vandalism
- [ ] Unknown
- [ ] Grid-induced Failure/Suspension
- [ ] Software problem
- [ ] Hardware upgrade required to operate
- [ ] Lightning-induced Failure/Suspension
- [ ] Software Upgrade Required to Operate
- [ ] Hardware Application Problem
- [ ] Software Application Problem
- [ ] Hardware Upgrade
- [ ] Software Upgrade
- [ ] Equipment Installation Problem

Part Disposition

- [ ] Repair
- [ ] Remove
- [ ] Replace
  - [ ] Unknown
  - [ ] Scrap
  - [ ] Return to Supplier
  - [ ] Return to Engineer

Failure Type

- [ ] Operable
- [ ] Inoperable
  - [ ] PM = Preventive Maintenance
  - [ ] CM = Corrective Maintenance
  - [ ] GI = Grid Induced
  - [ ] LI = Lightning Induced
  - [ ] OI = Other Induced

XFRACAS Incident Entry

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Task	OT_{AVE} (s)	NT (s)	ST (s)
Serial Number	10.77	10.77	**12.67**
XUO	43.55	43.55	**51.24**
Login	12.13	12.13	**14.26**
New Incident	203.33	203.33	**239.22**
Find Incident	16.35	16.35	**19.24**
Edit Incident	244.33	244.33	**287.45**
Logoff	9.99	9.99	**11.75**
Total Standard Time			**635.83**

XFRACAS Incident Entry

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- < 11 minutes to enter an incident
- Approximately 1 to 4 h per month
- Incidents can be queried
- Reports can be generated

Summary

Today we have introduced:

- The importance of PV System O&M
  - Different elements of O&M and the importance of tracking these on PV systems
  - Our perceived value of tracking O&M tracking on PV systems
  - Sandia's data needs for further development of reliability tools
- The basics of Sandia's PV Reliability O&M database
  - Access requirements
  - System BOM creation
  - Data entry
- Roles of each partner in a partnership

Helpful References

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