SCE Solar Photovoltaic Program (SPVP) O&M Overview

Rudy Perez

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Existing Solar Photovoltaic Program (SPVP) Overview

- Solar Photovoltaic Program (SPVP)
  - Existing SPVP Program (250 MW UOG + 250 MW PPAs) approved June 2009

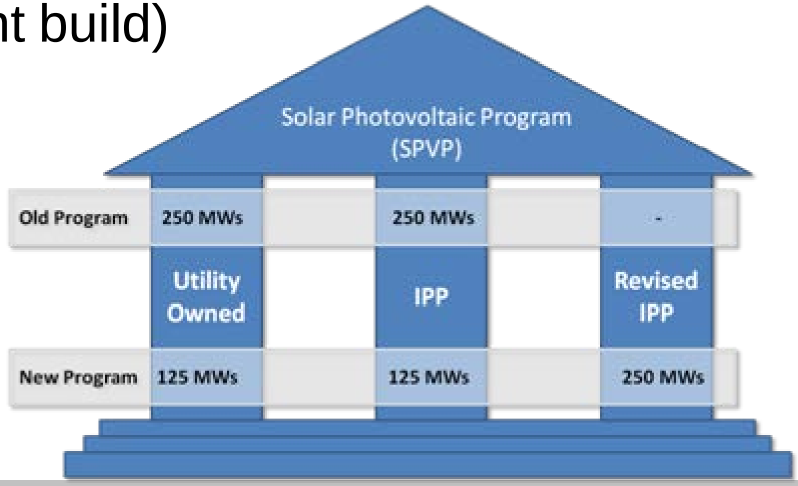
    – 250 MW of Utility-Owned Generation
      – Primarily 1 to 2 MW projects installed on commercial warehouse rooftops, with up to 10% (25 MW) ground-mount
      – 50 MW per year with an average cost of $3.97/Watt ($ '11)*

    – 250 MW from IPP PV Solicitation
      – RAP coordinates annual solicitations for up to 50 MW per year for 5 years
      – Price capped at the utility LOCE, 26 cents per kWH
      – Other terms similar to UOG constraints

*** Reasonableness cap approved in 2008 is $3.85/w dc installed. $3.97/w is escalated to 2011 dollars.**

Petitions For Modification (PFM) to SPVP

- SPVP PFM filed 2/11/2011, Decision received 6/19/12
  - PFM requested:
    - 250 MW cut from the UOG and Original IPP SPVP (125 UOG/ 125 IPP) and create a new 250 MW revised IPP solicitation for competitively priced PV projects in the 1 – 20 MW range
    - Increase the ground-mount allotment to 20% in the UOG and Original IPP to accommodate existing obligations
  - Justifications for PFM
    - Estimated customer savings of $300M PVRR
    - Main SPVP Program goals have been met (i.e. PV market transformation)
    - SCE will continue to share lessons learned with the State and energy industry
  - Second PFM submitted 11/12 to further reduce program to 91 MW (current build)



SPVP Status

- UOG SPVP has 84.3 MW of projects completed and interconnected
  - 23 sites – 22 rooftops and 1 ground-mount (1 to 10 MW sites)
  - There is one project under construction – 6.7 MW Redlands #10
  - Dexus in Perris a 10 MW rooftop – largest single rooftop in the US.
  - Program to complete by YE 2013

SPVP 042 – Porterville

6.77 MWdc - 29,428

Trina Modules

33 acres

10 Satcon Inverters

SPVP 007 - PLD Redlands 3

3.20 MWdc - 10,840

SunPower Modules

446,000 Square ft.

5 Satcon Inverters

Data Needs – Who Needs What

- CAISO – Real-time and Settlements
- GCC – Real-time Operations
- ES&M – Scheduling and Settlements
- Field Engineering – Grid Planning and Development
- O&M – Asset Management and Operations
- Regulatory - Filings
- R&D – What if?

Data Acquisition System - Data Needs

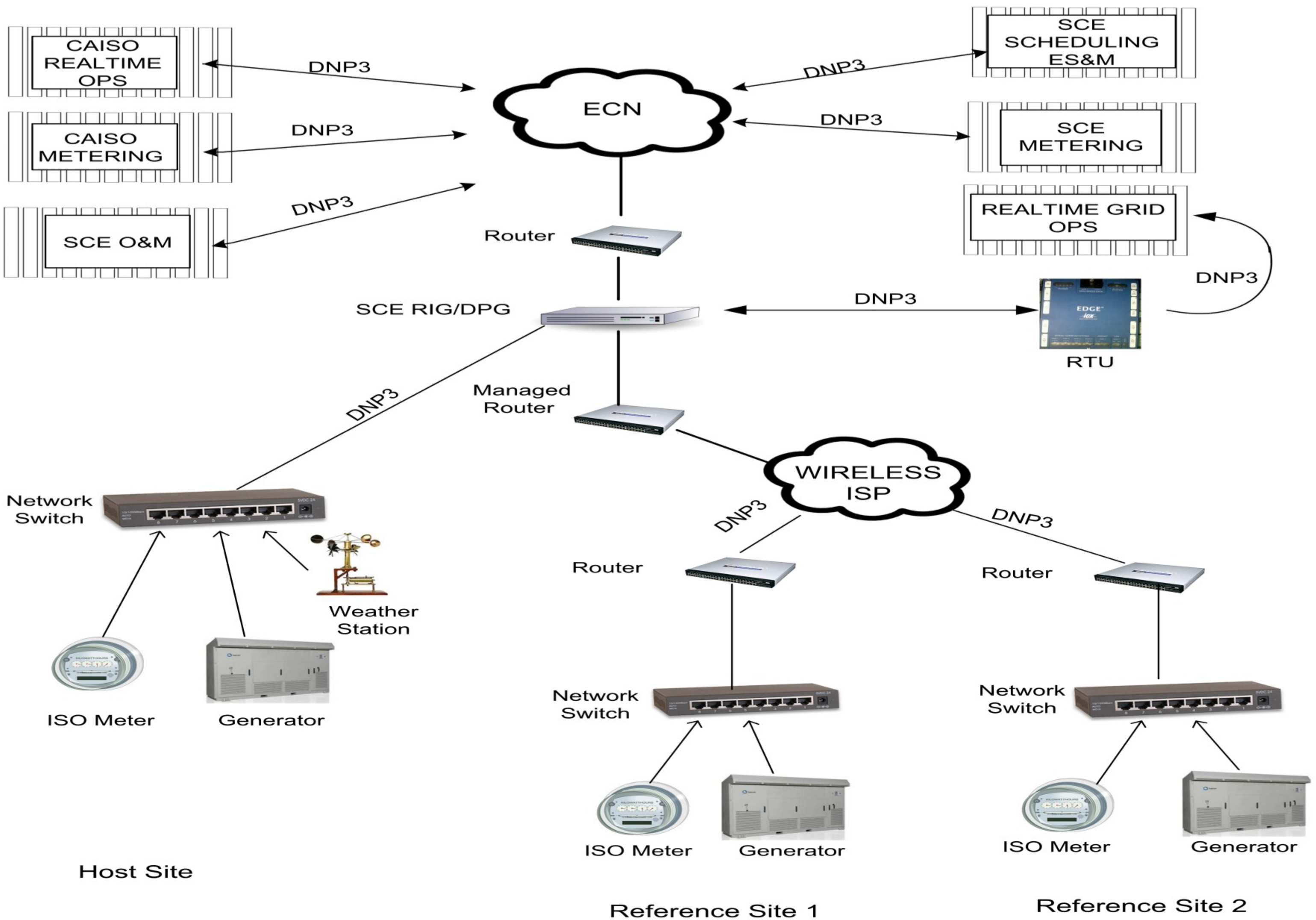
- **SCADA – Site data acquisition**
  - 70 data points per inverter
  - 1 – 16 inverters per site
  - 2 weather stations at 6 sites
  - Meter data from all 25 sites

- **CAISO**
  - 27 data points per site
  - 4 seconds
  - 99.7% reliability
  - ECN connectivity with cyber security

- **Power Systems Controls**
  - 2 data points (Watts and VARs)
  - Weather Station data
  - 4 seconds
  - Circuit specific data

- **ES&M**
  - 2 Site data points (Watts and unit on-line status)
  - 1 Inverter Status point
  - Aggregated data
- **Engineering and R&D**
  - All data points
  - 1 second data

DATA SYSTEM DESIGN

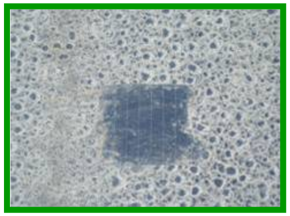


Panel Cleaning and Output Optimization

- 15-25% Degradation in panel output regained after cleaning – depending on panel and tilt. Within 4 weeks output was normally back to original degraded condition
- Costs of rooftop cleanings estimated at $8,000/MW with some waste water environmental concerns
- Economics do not seem to pan out if solar valued at $125/MWH. Pre-Summer cleaning (May) would provide maximum benefits.
- If so, when (which month) does it make the most sense to clean?

Benefits of cleaning

- Energy
- Capacity
- Green energy premium



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Costs of cleaning

- Labor
- Materials
- Waste water routing
- Scaffolding and / or manlift use
- Skylight protection
- Safety monitors

Note: Panels on left are especially dirty due to installation debris, and will be cleaned before project launch

Rooftop Fire Concern and Corrective Action – Risk of Roof-top PV Fires Is Small but damage can be large

- Percentage of CA PV roof-top fires is ~0.2% (based upon incidents reported to fire departments).
- Cal-Fire November 2010 report listed 18 PV roof-top fires in CA over two years (2007-2008). Number of PV projects estimated in CA is >11,000 (data up to 2009).
- SCE risk of roof-top fires may be less due to utility grade design and construction, but our plants are unmanned (if buildings have tenants, then tenants could report a fire).
- May be some additional risk of unmanned plants if less time when people are around to inform the fire department of fires.





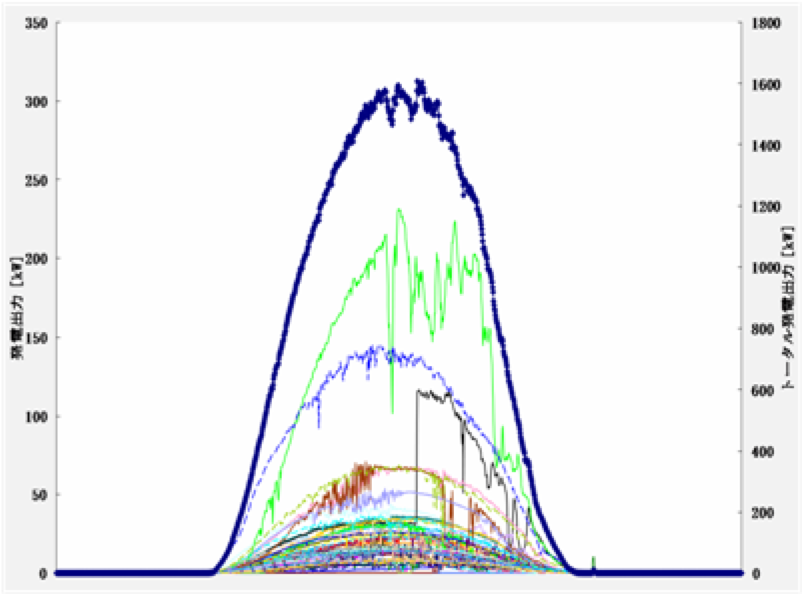
Corrective Action – Installation of Ground Fault Detection System

- Bender RCMS ground fault relays (field tested and proven for all SPVP technologies). 70 years of experience in ground faults.
- Bender telecommunication com unit to coordinate with Operations (Emerson system)
- Bender current transformers to detect ground faults
- Gigavac contactors to isolate fault upon relay trip
- Competitive bid control box
- Standard load center
- Standard control power transformer
- Arc Fault Detection System demos
  - Sensata, Eaton, Solar Bos, etc.

SPVP Integration Concerns

- Grid Control required Remote Control Disconnect Switch at each site
  - Cost of $125K per site
  - Control from Alhambra Control Center
- Penetration Level
  - Originally 15 % circuit rule would have limited SPVP to 1-2 MW per circuit
  - Latest studies allow for up to 8 MW on a circuit if near the substation
  - Dedicated circuits needed if PV exceeds circuit capacity.
  - Costly ($100K/site) Remote Controlled Disconnect Switches current requirement. Inverters can be controlled via internet if deemed reliable
- Active Voltage Regulation –
  - Rule 21, Para D2a – prohibits the generator from any active voltage regulation –
  - Utilities don't want DG units to control voltage is because our "not smart" grid has no way to monitor & control customer generation.
  - Customers will want to be paid for their services and we have no CPUC approved way to do this.
  - Possible solution is to have utility owned generation - even DG- to be treated and considered differently from customer or IPP units.
- System Disturbance Ride-through
  - Rule 21, Para D2b3 – has tight voltage limits which basically prevent any ride thru of a distribution system disturbance.
  - PV systems may have value during disturbances that we want to keep them on-line
- Harmonics
  - Concerns over harmonics from PV Inverters seemed to have allayed, Further study may be needed to guarantee this concern.
- Intermittency – SCE / NREL Study may allay concerns.
  - Overall distributed PV "smoothing effect" reduces impact

Smoothing Effect of Multiple PV



Backup Slides

SPVP O&M Overview

- O&M Overview
  - Roles and Responsibilities
  - Labor Requirements - PLA
  - Output and Scheduling Requirements
- Performance Optimization
  - Panel cleaning
  - Data Monitoring
- Monitoring and Routine Maintenance
  - Warranties – panels, inverters, etc.

- Safety
  - Roofs
  - Electrical
- Key Liabilities
  - Roof Maintenance
  - Insurance Concerns
- Site relationship
- Construction Techniques to aid O&M

Note: SCE budgets $30K/MW per year for O&M costs– excluding site lease costs.

Assumes an internal work force of 11 personnel

Rooftop O&M Challenges

Wrinkles

Ponding

- SCE responsible for to repair damage caused by Solar System as well as moving system out of the way for re-roofing activities.
- 20 to 25 year projects on 10 to 15 year warranty roofs is a concern.
- Roof Wind Loading leads to additional ballast weight concerns
- Seismic Constraints in California are challenging

The primary maintenance challenge is to balance the costs and potential benefits of inspection and ensuing repairs/replacements.

MAINTENANCE OVERVIEW

	Preventative (Pre-scheduled)		Forced (Something breaks)
	Under Warranty	No Warranty	
Primary Issue(s)	Check & replace faulty components before warranties expire	Balance benefits of preventative maintenance and cost of inspection	1. Know when PV installation behaves abnormally in real-time. Inverter Level Monitoring 2. Diagnose cause of abnormal behavior 3. Decide when (or if) to replace broken component

Recommendations	• Schedule component inspections one month before warranties expire*
	• Comply with "active" maintenance provisions in inverter warranties*
	• Establish a time-sensitive process for replacing faulty components
		• Minimize inspection cost (e.g. combine with annual cleaning)
		• Establish cost effective inspection procedures. Typical inspection examples include:
		  • Panel "I-V" curve trace
		  • Fuse replacement
		  • Visual inspection
		  • Inverter service
			• Establish "active alerts" system which notifies operators of site production abnormalities
			• Link notifications to 24-7, 365-day centralized monitoring authority
			• In situations where the cause is not readily apparent, establish inspections dispatch
			• Establish procedure for replacing/repairing damaged components based on C/B analysis
			• *Cost Variables* (component(s) and labor)
			  • *Benefit Variables* (Remaining project life; energy, capacity, and green premium lost)

Ensuring the safety of crew and equipment is the first priority during any maintenance or cleaning activity.

SAFETY OVERVIEW

Primary Risks

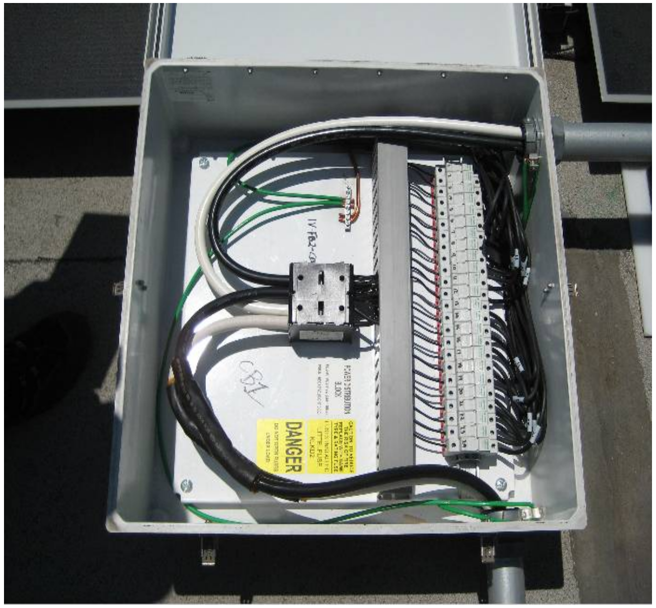
- Bi-directional energy flow on distribution grid downstream of PV rooftop sites
- Working on elevated surfaces (hazards with skylights, man-lifts, and unprotected roof edges)
- Numerous diverse parties (e.g. building tenants and potentially management, various SCE groups) require notification and training on PV safety issues
- Materials hazards during emergency (fire, earthquake)

Current Activities & Next Steps

- Update all distribution grid maps with PV generating sites (e.g. OMS and FIM).
- Continue robust site “Lockout Tagout” procedures.*
- Re-train all relevant crews on bi-directional flow “Lockout Tagout” safety procedures.
- Establish and install safety measures when applicable (e.g. skylight covers, temporary railings, harnesses) to prevent falls.
- Ensure consistent standards, site-specific safety documentation, and the transfer of knowledge from installation to maintenance crews during project “go-live” and interconnection.
- Establish and train a single SCE point of contact for all parties during an emergency.
- Educate local/city first responders and non-SCE building maintenance personnel about PV safety procedures and risks.

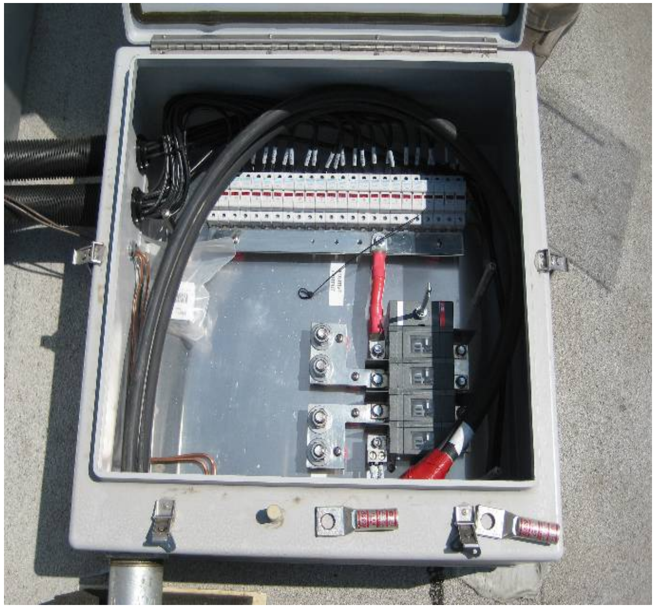
Construction Techniques to aid O&M
Combiner Boxes

Original Design



- No fuse indicators
- Maintenance requires full inverter shutdown
- Must open every string disconnect to perform work
  - About 1400 in 60 boxes

Modified Design



- Blown fuse indicators
- Window in door for visibility
- Isolation switch

Construction Techniques to aid O&M
Raceway Design - Conduit to Cable Tray

Original - Conduit

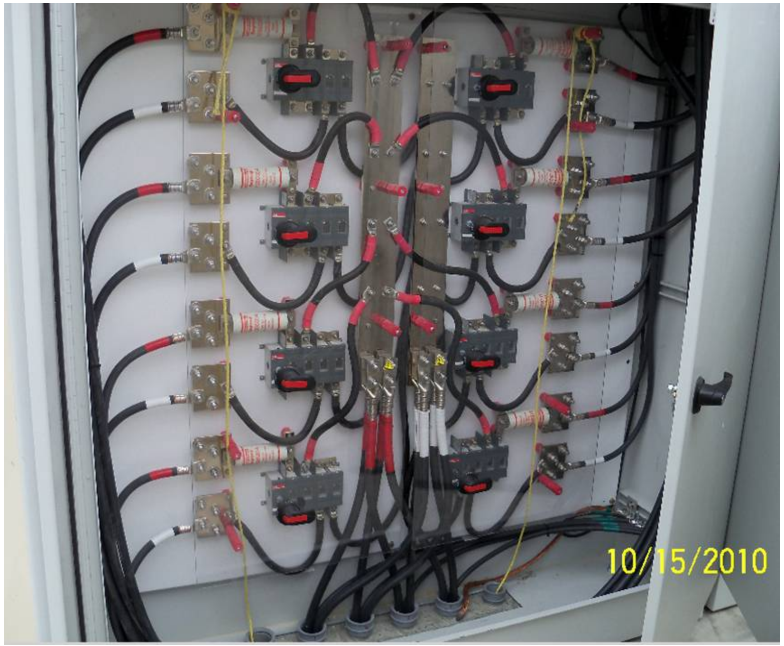
Modified - Cable Tray

Construction Techniques to aid O&M
Master Fuse Box (Recombiner)

Original Design

- Mechanical lugs
- No isolation

Modified Design



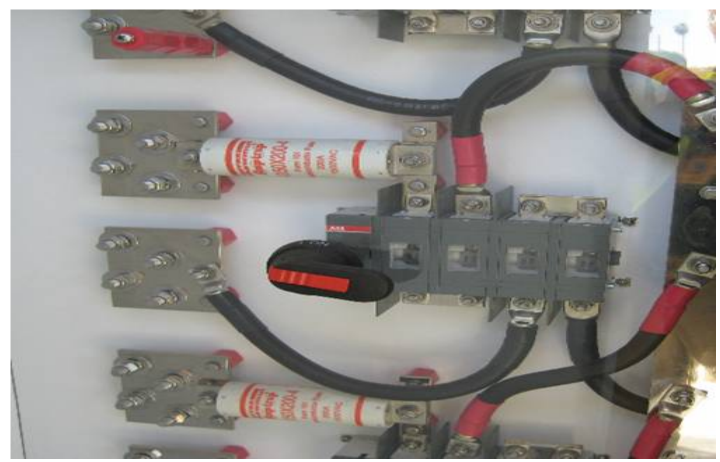
- Isolation switches both poles
- Crimped bolted lugs
- Bolted fuses
- Cable arrangement

Construction Techniques to aid O&M
Fuse Clips

Original Design

Modified Design

Spring Clip Fuses



Bolted Fuses

Construction Techniques to aid O&M Transformer

Original Design

- Dry Type Exposed to Moisture

Modified Design

- Oil Filled