



Russell Neal, SCE

NREL HIGH PENETRATION PV PROJECT AT SOUTHERN CALIFORNIA EDISON

SCE SPVP Program Status

- SCE SPVP has 84 MW of projects completed and interconnected. One additional 7 MW rooftop in construction
- Total of 24 sites – 23 rooftops and 1 ground-mount (1 to 10 MW in size)
- One project, Dexus in Perris, is a 10 MW rooftop
 - Largest single solar rooftop in the US
 - Interconnected onto one 12 kV customer circuit.
- Future plans call for 2 additional rooftops (12 MW) and 2 ground mounts (18 MW)
- Program to complete by YE 2014

Completed SCE SPVP Projects

SPVP 005 - PLD Redlands 1

3.39 MWdc - 10,680

Sunpower Modules

468,000 Square ft.

5 Satcon Inverters



SPVP 007 - PLD Redlands 3

3.20 MWdc - 10,840

SunPower Modules

446,000 Square ft.

5 Satcon Inverters



SPVP 042 - Porterville

6.77 MWdc - 29,428

Trina Modules

33 acres

10 Satcon Inverters



Completed SCE SPVP Projects

SPVP 006 - PLD Ontario 2

2.55 MWdc

11,088 Trina Modules

562,000 Square ft.

4 Satcon Inverters



SPVP 009 - PLD Ontario 3

1.41 MWdc

8,131 Trina Modules

369,000 Square ft.

2 Satcon Inverters



SPVP 008 - PLD Ontario 4

2.85 MWdc

12,376 Trina Modules

681,000 Square ft.

4 Satcon Inverters



SPVP 012 - PLD Ontario 5

.77 MWdc

3,360 Trina Modules

241,000 Square ft.

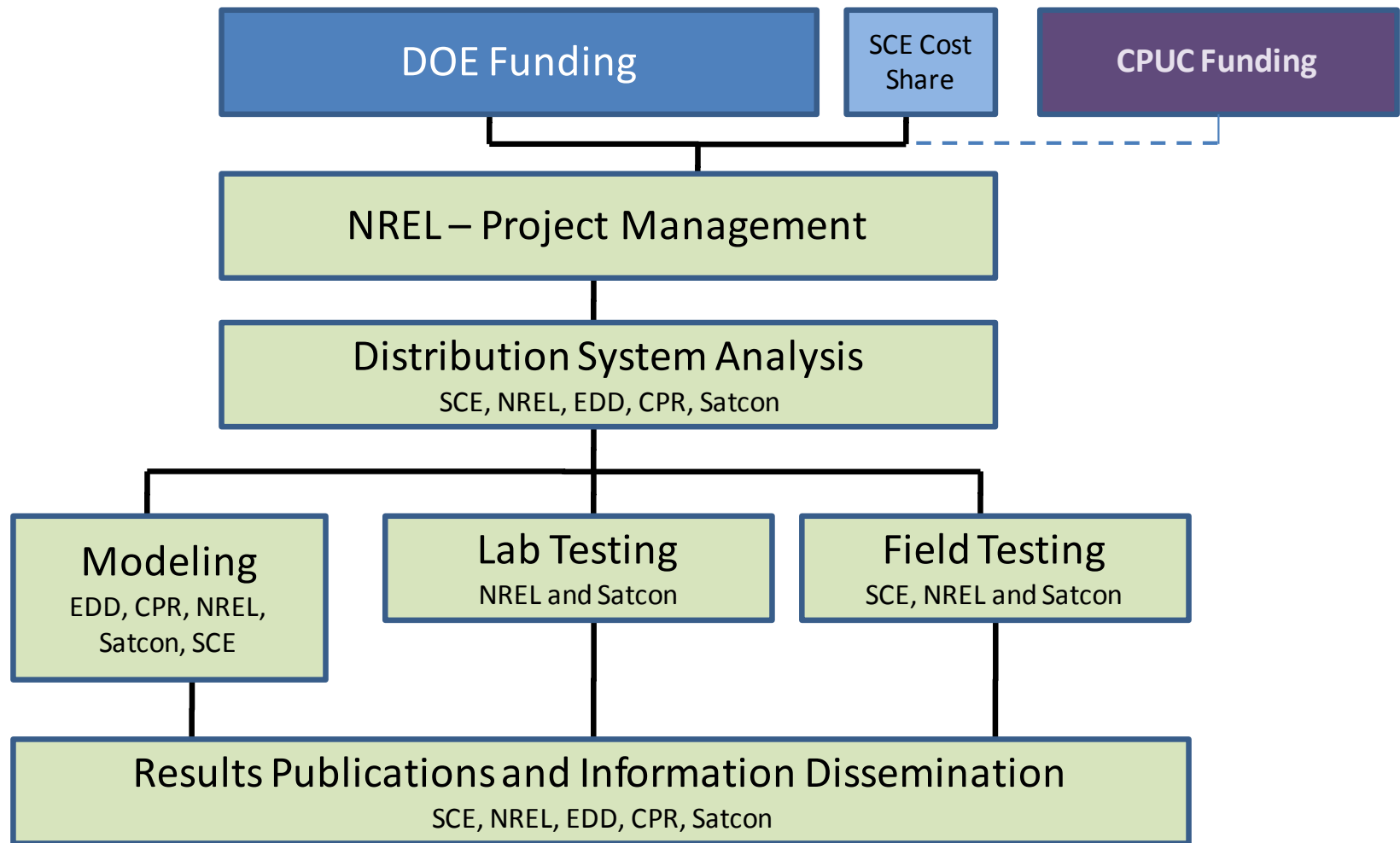
1 Satcon Inverter



NREL Project

- Study impacts and mitigations
- Combined DOE and CPUC/CSI funding
- Model three circuits with SPVP impacts
- Develop active inverter mitigations
- Field test and measurements
- Guidebook for deploying HPPV on distribution circuits

Approach and Tasks



State of the Project

- Circuits selected
 - > Fontana 12 kV, 3.5 MW PV
 - > Porterville 12kV, 5 MW PV
 - > Palmdale 12 kV, 3 MW PV (3rd party)
- Supplemental instruments being deployed
- Inverter modification options investigated
 - > Issue: Satcon bankruptcy
 - > Alternatives: PF switching, Other controls

Thank You!

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Barry Mather Ph.D., NREL

MODELING, SIMULATION, TESTING AND DEMONSTRATION OF A 500KW COMMERCIAL ROOF-TOP PV SYSTEM ON SCE'S DISTRIBUTION SYSTEM

Project Sponsors and Team Members

Project Sponsors:



Project Team Members:



High
Penetration

2013

Feb 13-14, San Diego, CA

Focus Areas

- Distribution system modeling and simulation for high-penetration PV scenarios
- Identifying the effects of high-penetration PV and developing methods to mitigate these effects
- Advanced inverter functionality development and testing
- High-penetration PV demonstration

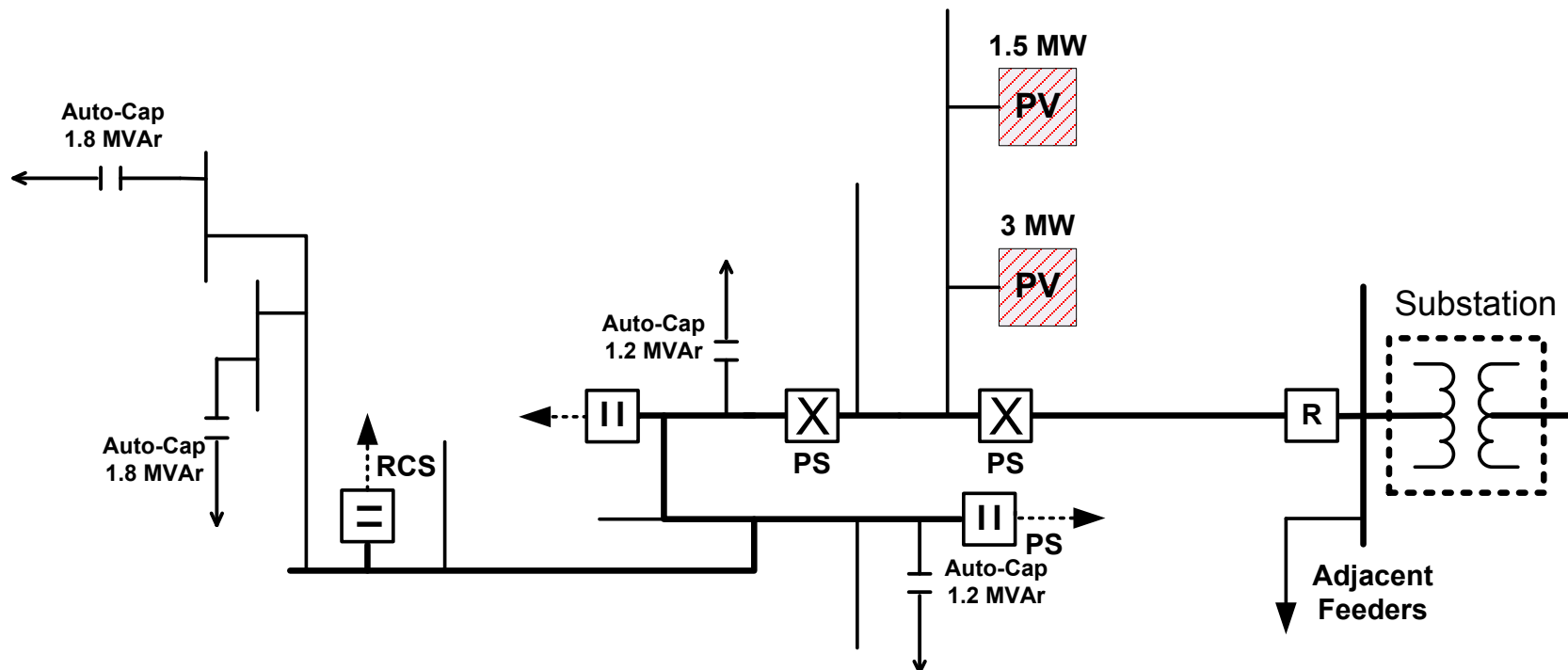
Key Project Deliverables and Activities

- Modeling of High-Penetration PV Distribution Circuits (x3)
 - > Report on Methods for Hi-Pen PV Integration Studies
 - > Report on Recommended Mitigation Methods for Hi-Pen Circuits
 - > Verification of Circuit Models/PV Impacts Using Collected Data
 - > Report on Quasi-Static Time-Series Modeling for Hi-Pen PV
- Demonstration of Advanced PV Inverter Functionality to Mitigate PV Impacts
 - > Development of Advanced Functionality Specifications
 - > Laboratory Testing of Adv. PV Inverters
 - > Demonstration of Adv. PV Inverters in SCE system

Key Project Deliverables and Activities Cont.

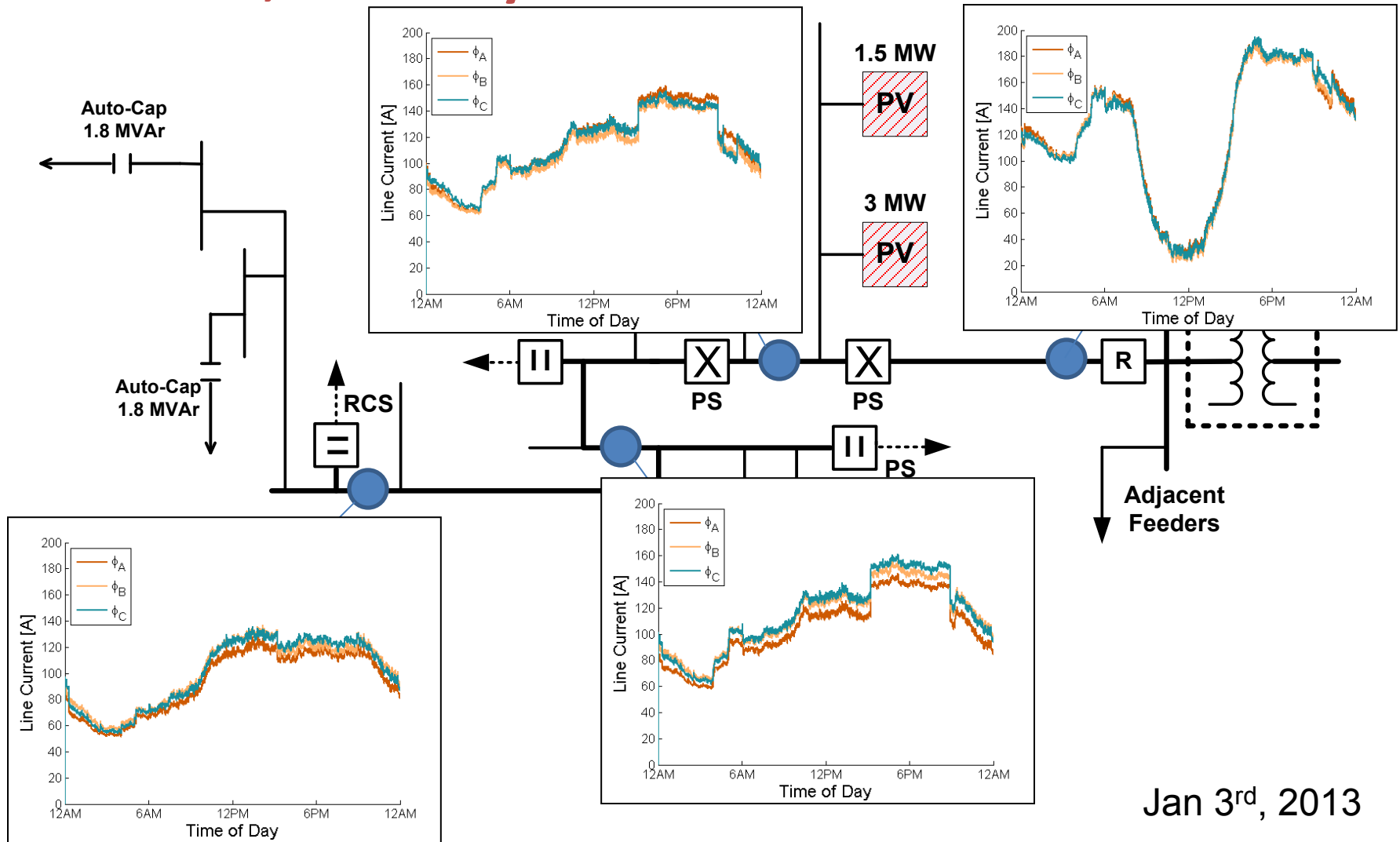
- Publish a Handbook on Distribution Interconnected High-Penetration PV Integration

Fontana, CA Study Circuit



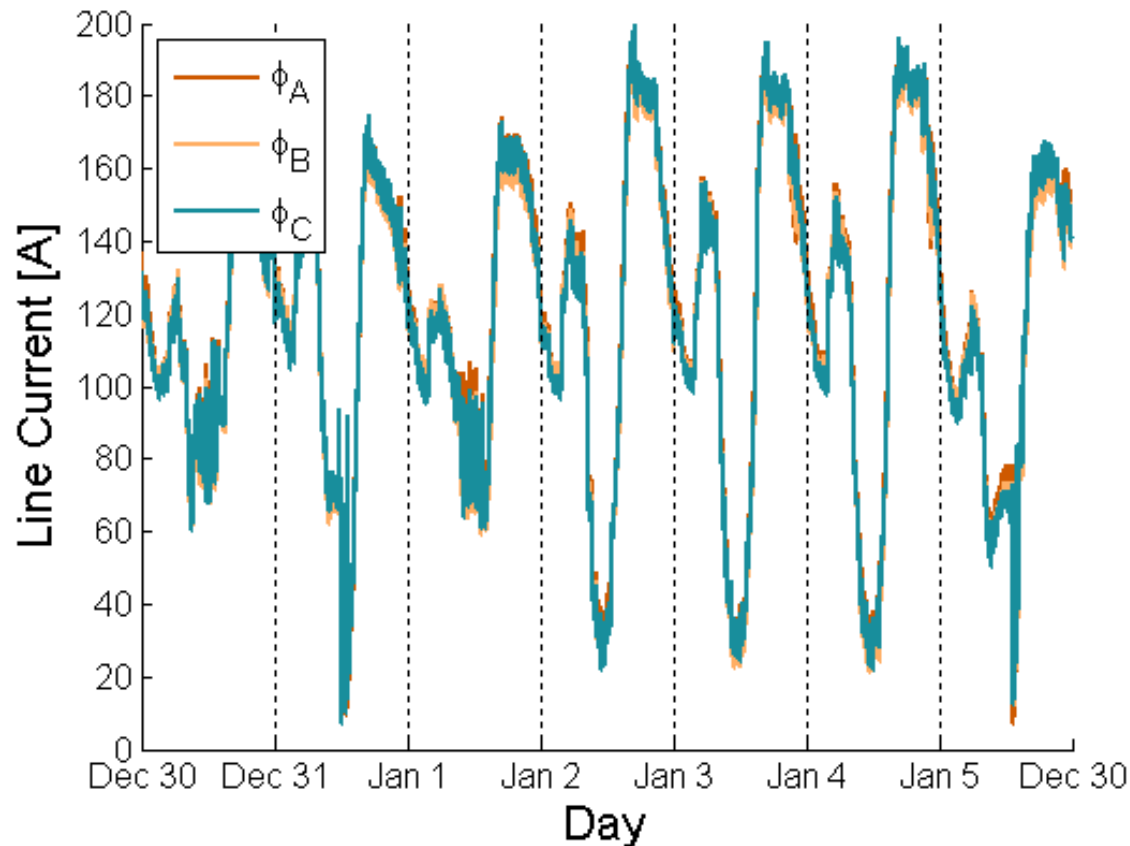
- 12 kV circuit, 7.8 miles, commercial/warehouse loads
- PV AC rating: 4.5 MW, reverse power flow conditions possible
- Circuit voltage regulation by switched capacitors

Fontana, CA Study Circuit – Circuit Power Flow



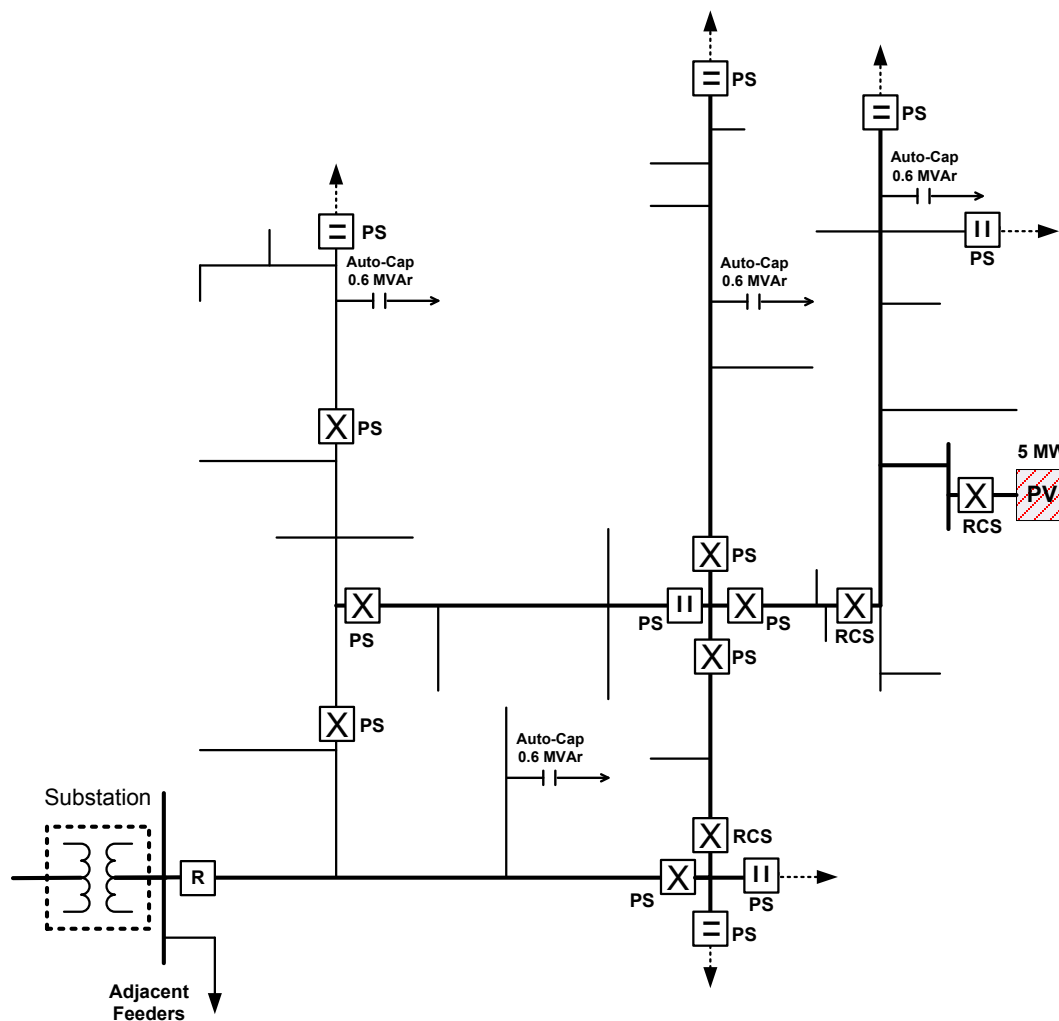
Jan 3rd, 2013

Fontana, CA Study Circuit – Substation Power Flow



- Reverse power flow through the “express” part of the circuit is likely common on clear shoulder season days

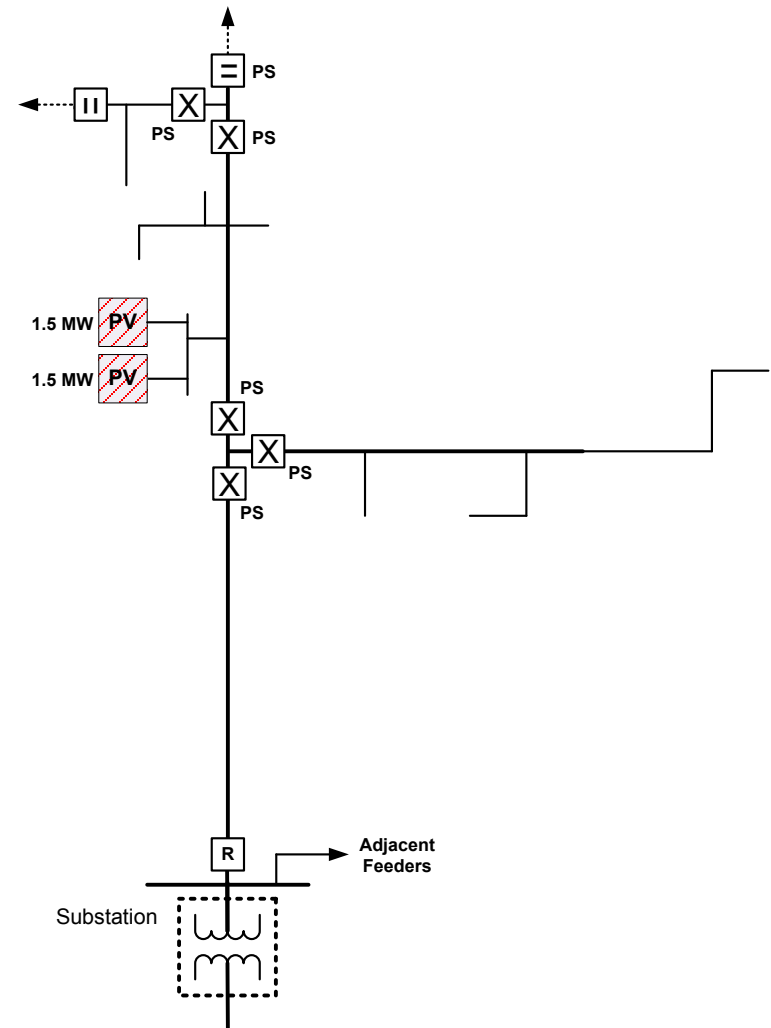
Porterville, CA Study Circuit



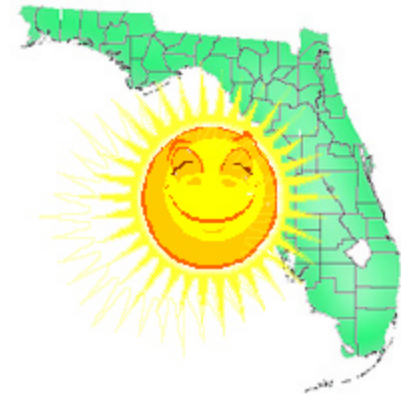
- 12 kV circuit, 47.2 miles, rural, lightly loaded/ water pumping loads
- PV AC rating: 5 MW
- Reverse power flow common
- Voltage regulation via switched capacitor banks

Palmdale, CA Study Circuit

- 12kV circuit, less than 5 miles of total circuit length, very lightly loaded, nearly an “express circuit”
- PV AC rating: 3 MW
- Reverse power flow conditions present during daylight hours (when clear)
- Current voltage regulation issues may prompt operating the PV inverters at a lagging power factor



500kW PV Inverter Testing – Collaboration



- The SCE Hi-Pen PV Integration Project teamed with FSU CAPS – SUNGRIN Team to complete this Power Hardware-in-Loop (PHIL) evaluation of a 500kW Satcon PV Inverter operating in advanced functionality modes

Figure 10 is a line graph showing the relative PV array power output over a 16-minute period for two wind speed conditions: Moderate (solid line) and High (dotted line). The y-axis represents 'Relative PV Array Power Output' from 0 to 1.0, and the x-axis represents 'Time (min.)' from 0 to 16. The Moderate wind speed curve starts at 0.3, rises to 1.0 by 1 minute, and remains relatively stable with minor fluctuations. The High wind speed curve starts at 1.0, drops to 0.4 by 1 minute, and then fluctuates significantly between 0.3 and 1.0 for the remainder of the test.

RTDS Simulation Space

PV Array Model

$V_{dc,ref}$ $I_{dc,ref}$ $V_{dc,in}$ $I_{dc,in}$

Distribution Sys. Model

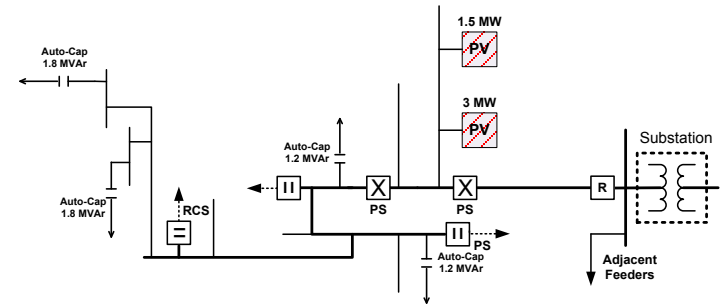
$I_{ac,inj}$ $V_{dc,pcc}$

VVS (PV Array Emulation)

PV Inverter (DUT)

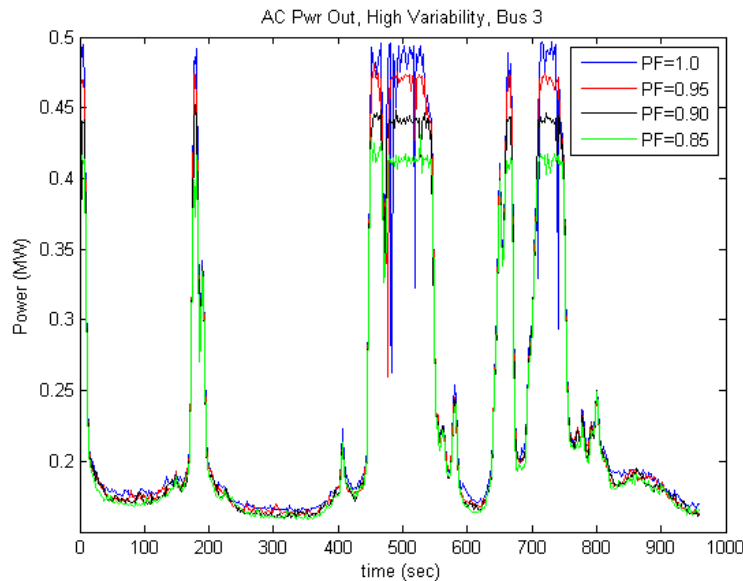
480:4160

VVS (AC Grid Emulation)

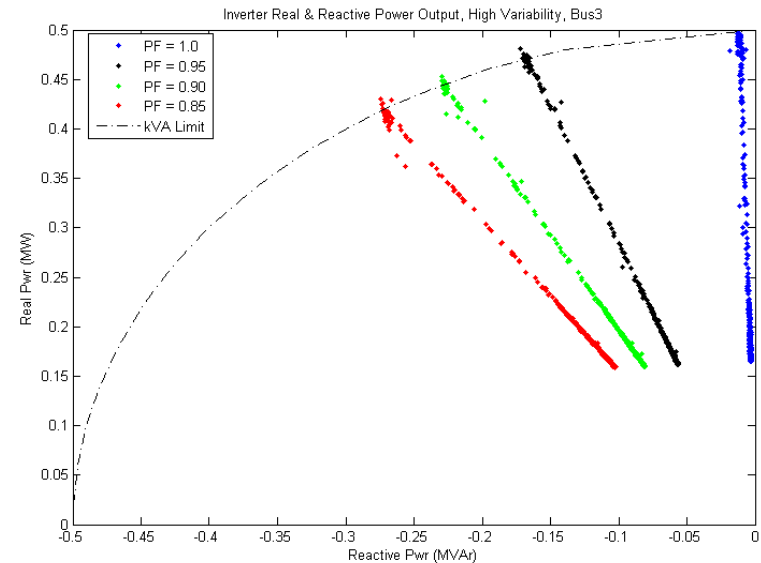


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500kW PV Inverter Testing - Results



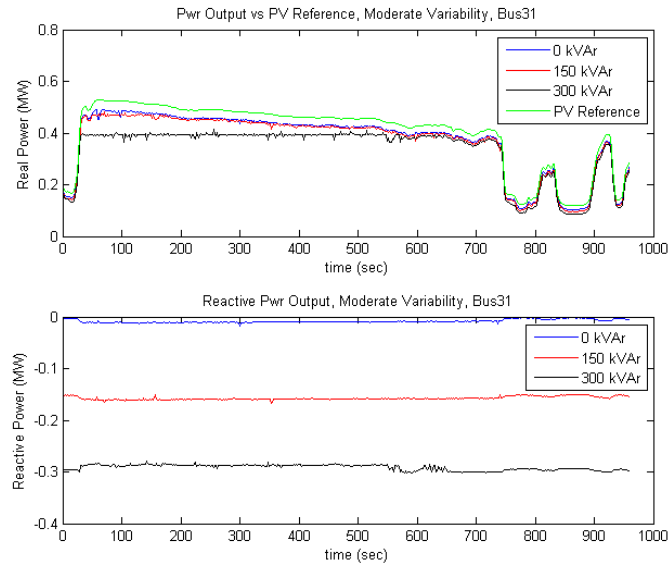
PV inverter power output
for various PF set points



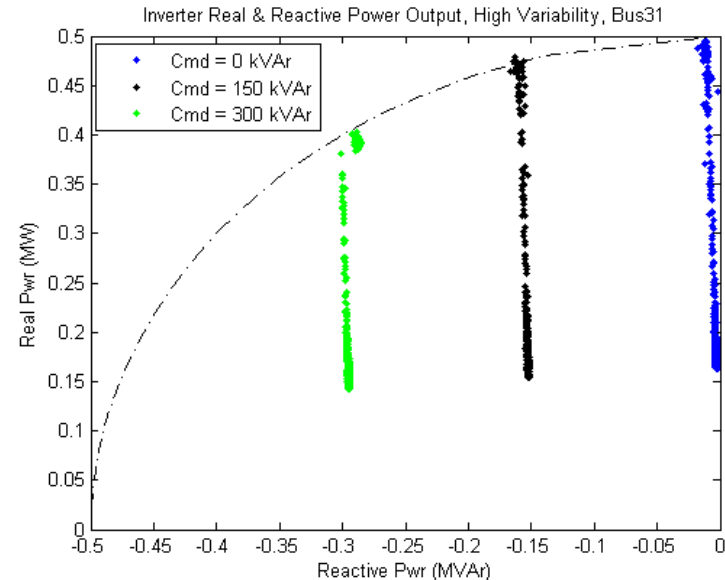
P-Q plot of PV inverter output
for various PF set points

- Conclusion: the PV inverter tracked a PF set point very well over highly variable solar resource profiles.

500kW PV Inverter Testing - Results



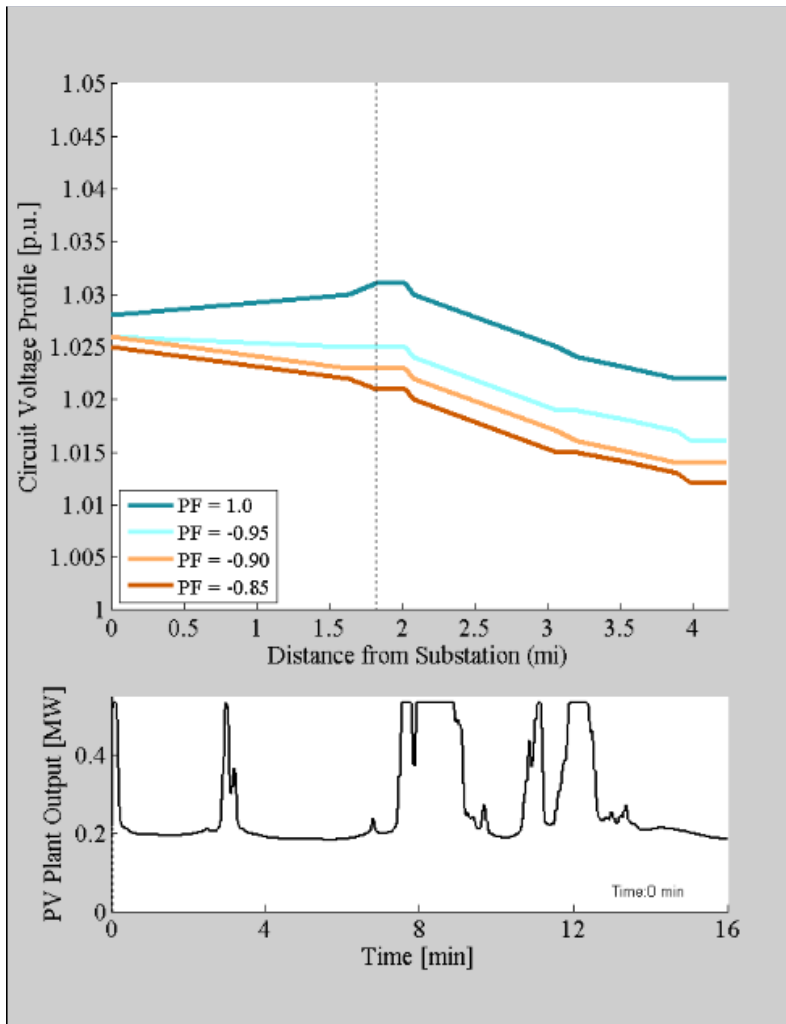
PV inverter real and reactive power output for various PF set points



P-Q plot of PV inverter output for various PF set points

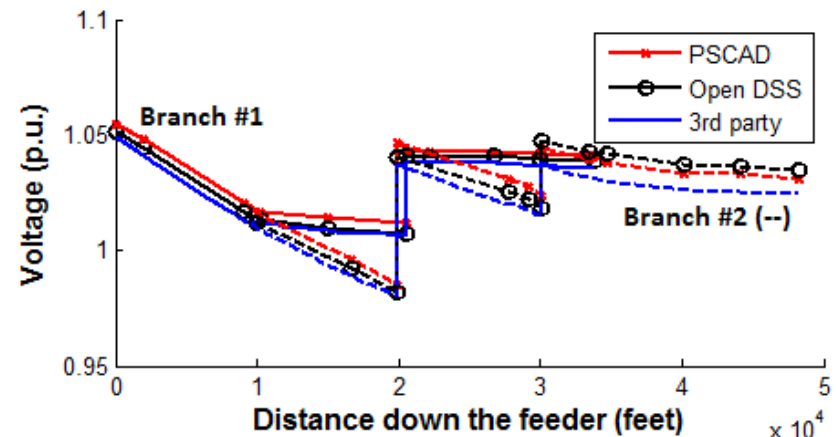
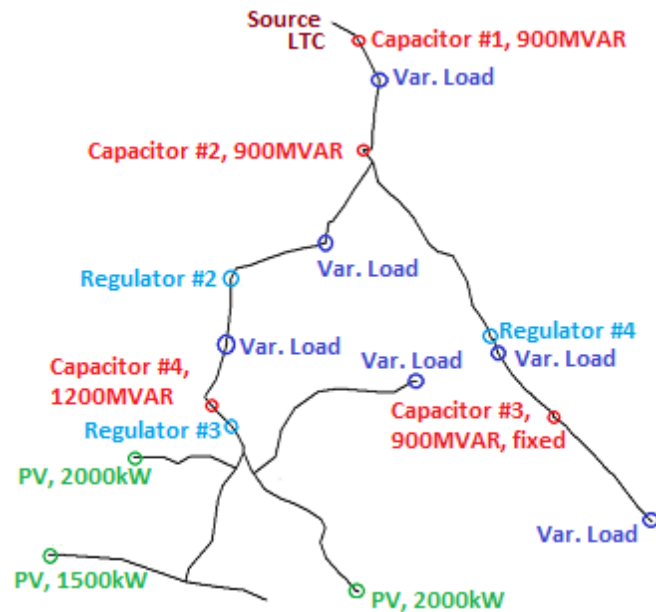
- Conclusion: the PV inverter tracked a constant VAr set point very well over highly variable solar resource profiles. Some modifications to “foldback” algorithm need to be addressed

500kW PV Inverter Testing - Results



- Fontana, CA circuit model, 2MW PV system consisting of 4 x 500kW Satcon PowerGate Plus Inverters
- Results shown for “high-variability” resource
- Constant PF operation at 0.95 lagging reduces voltage profile impact due to PV

Comparison: Time-Series vs. Transient Simulations



- Tests Quasi-Static Time-Series Analysis at multiple time steps
- Follow-on study is being completed for volt/VAr controls

			PSCAD	OpenDSS					
				5s	10s	15s	30s	40s	50s
Load tap changer		Max	5	6	5	5	6	5	5
		Min	4	5	5	5	5	5	5
		# of actions	1	1	0	0	1	0	0
Reg. #3	A	Max	7	6	6	6	6	6	7
		Min	4	3	3	3	3	4	4
		# of actions	7	6	7	5	8	2	7
	B	Max	4	4	4	4	4	4	4
		Min	1	2	1	1	1	2	1
		# of actions	8	5	6	5	6	2	7
	C	Max	2	2	1	1	1	1	1
		Min	-1	-1	-1	-1	-1	0	0
		# of actions	8	6	6	4	8	1	4
Cap. #1	Opening time (s)	489	495	-	-	470	-	150	

Please contact:

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Q &A AND DISCUSSION

THANK YOU