Renewable Grid Integration Research in the U.S.

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UNSW – IEA PVPS Task 14 Workshop Sydney, AU

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Presentation Overview

- Photovoltaic solar integration on distribution systems in the U.S.
  - High-penetration PV grid integration projects
  - Advanced screen development for distribution interconnection
- Wind and solar integration on the U.S. Western Interconnection
  - WWSIS II
  - WWSIS III
- IEEE 1547 revisions
  - IEEE 1547a
  - Future full revision

NREL/SCE Hi-Pen PV Project

Project Background:

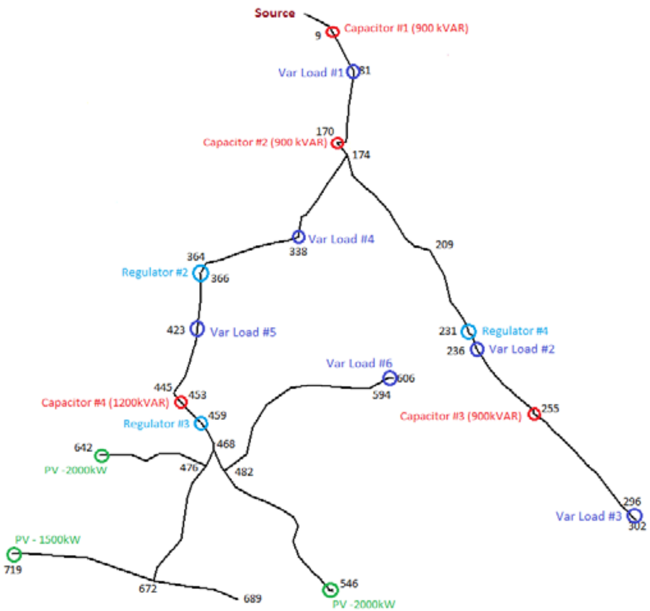
- SCE is installing 250 MW of PV by 2015
- Most are large rooftop systems (1-5MW)
- All are connected to the distribution system

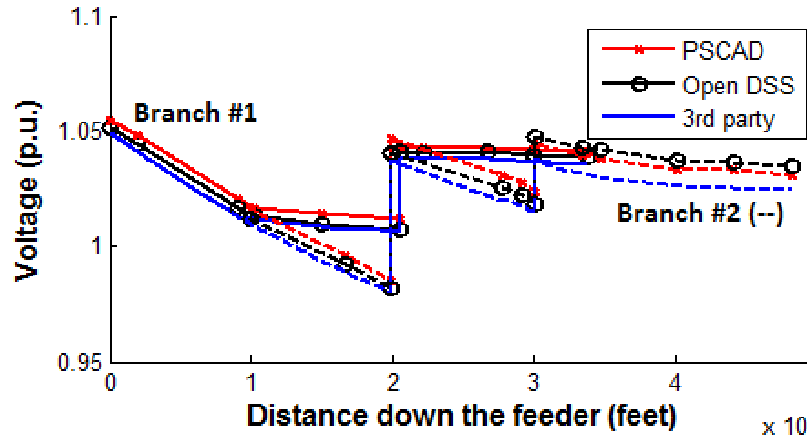
Project Motivation:

- Accelerating and disseminating the experiences gained from high-penetration PV integration on the SCE system to the wider distribution engineering community would accelerate the rate of PV interconnection in a safe, reliable and cost-effective manner

Comparison of Quasi-Static Time-Series and Transient Simulation Analysis Techniques

IEEE 8500 node test feeder model



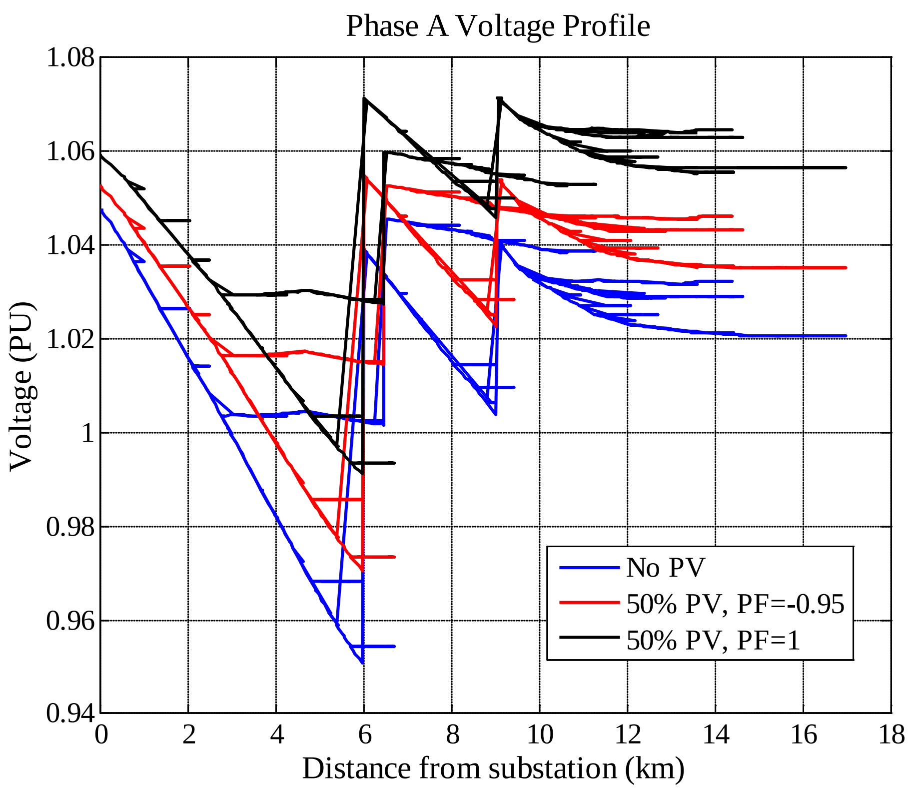


- Evaluated quasi-static time-series analysis results at multiple time steps over a 16 minute period
- Analysis run times are on the order of 5 hours for PSCAD and 5 seconds for OpenDSS

			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

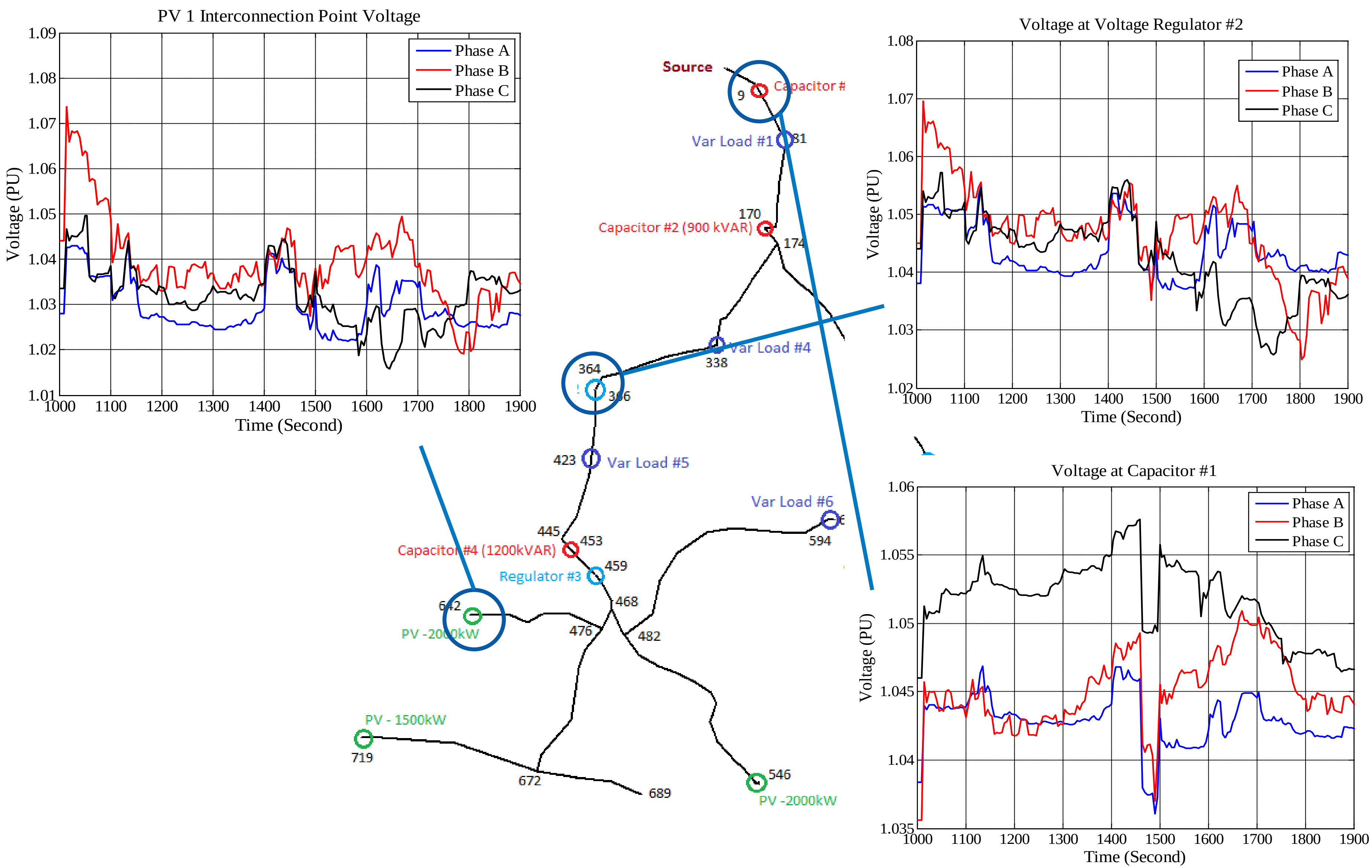
See: D. Paradis, F. Katiraei and B. Mather, “Comparative analysis of time-series studies and transient simulations for impact assessment of PV integration on reduces IEEE 8500 node feeder,” IEEE PES GM, Vancouver, Canada, July, 2013

Inclusion of PV Mitigation Controls



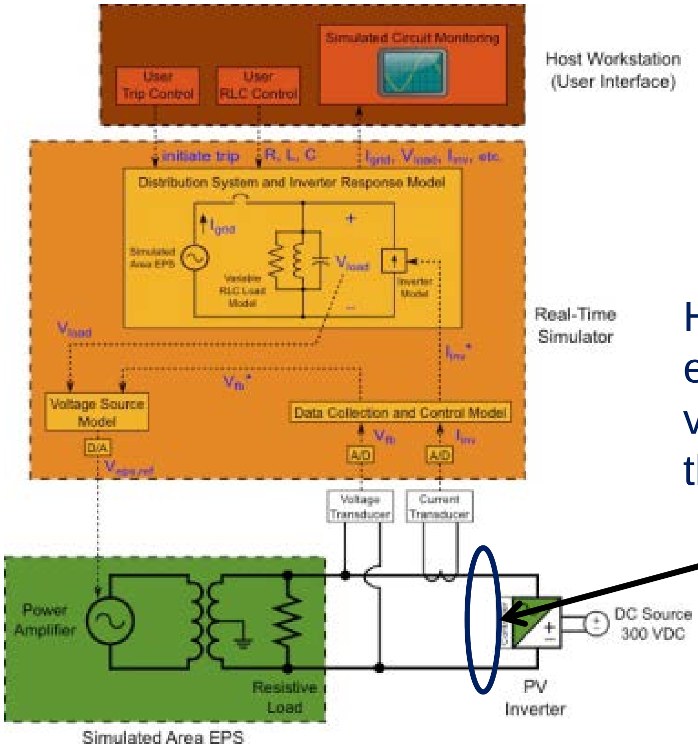
- A snapshot analysis is shown for three voltage profiles of the 8500 node test feeder with varying PF control implemented

Inclusion of the Control Dynamics

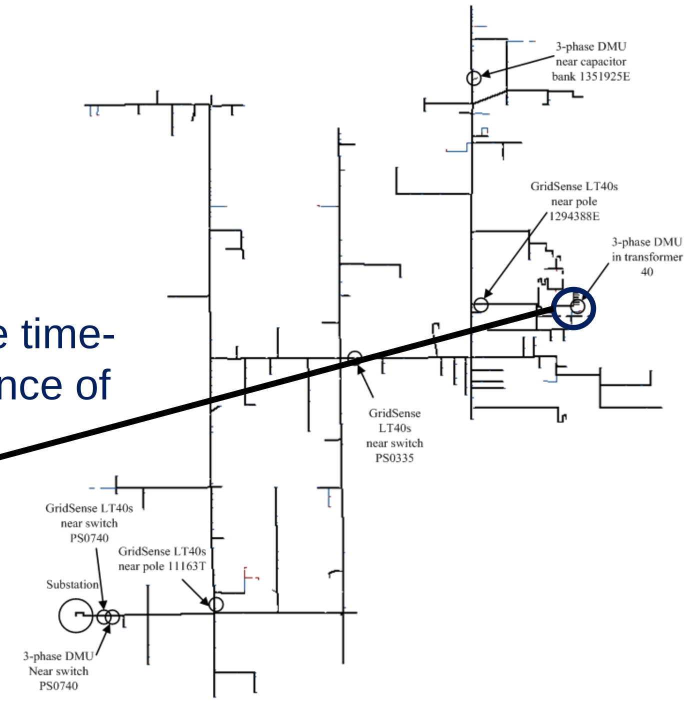


Anti-Islanding Testing via PHIL

PHIL Implementation



Dist. Cir. Model

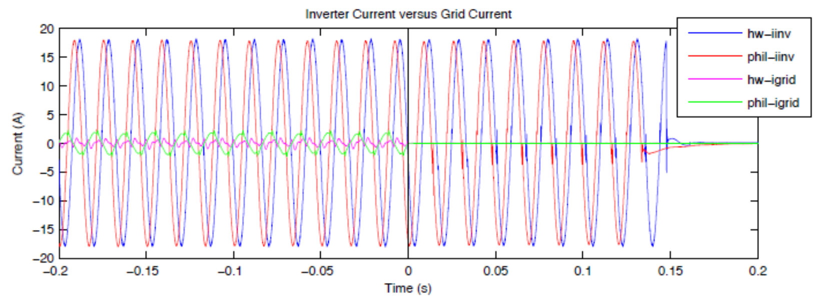


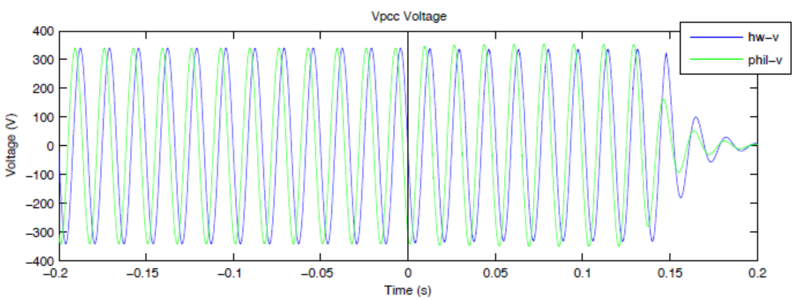
High-bandwidth emulation of the time-varying impedance of the PCC

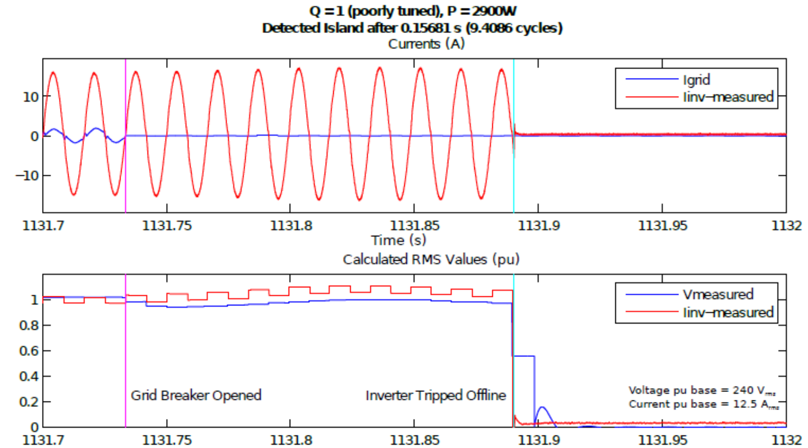
- By modeling the distribution system point of common-coupling (PCC) complex impedance with a higher bandwidth than the PV inverter’s anti-islanding function, it is possible to evaluate the PV inverter’s performance as if it were installed on the distribution circuit

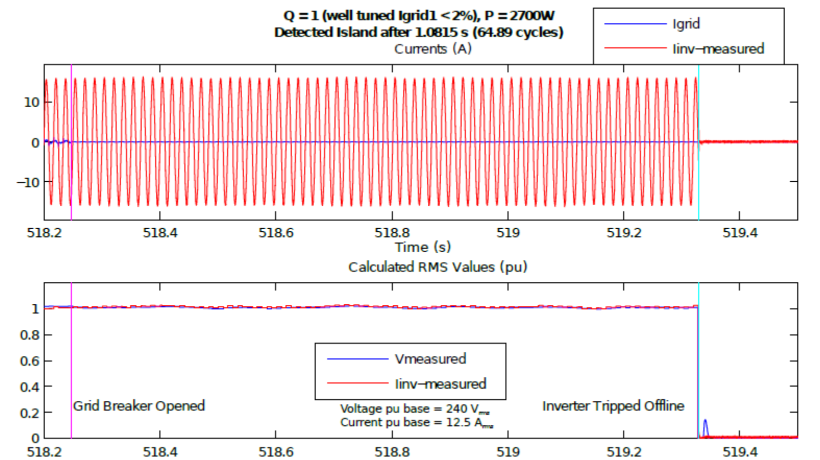
AI Testing via PHIL – Initial Results

Q = 3









- PHIL testing is able to emulate traditional AI lab testing – implications for future IEEE 1547.a standards development

- PHIL AI testing is capable of finely tuning load to generation – impact on AI performance evaluation is significant

Dev. of Adv. PV Interconnection Screens

- Collaborative project with EPRI, NREL, SNL and CA utilities to develop advanced screening methods for distributed PV grid interconnection
- Advanced screens will inform CA Rule 21 and will allow more PV to be interconnected quickly when those systems will not adversely effect the interconnected system and will reduce utility interconnection queue

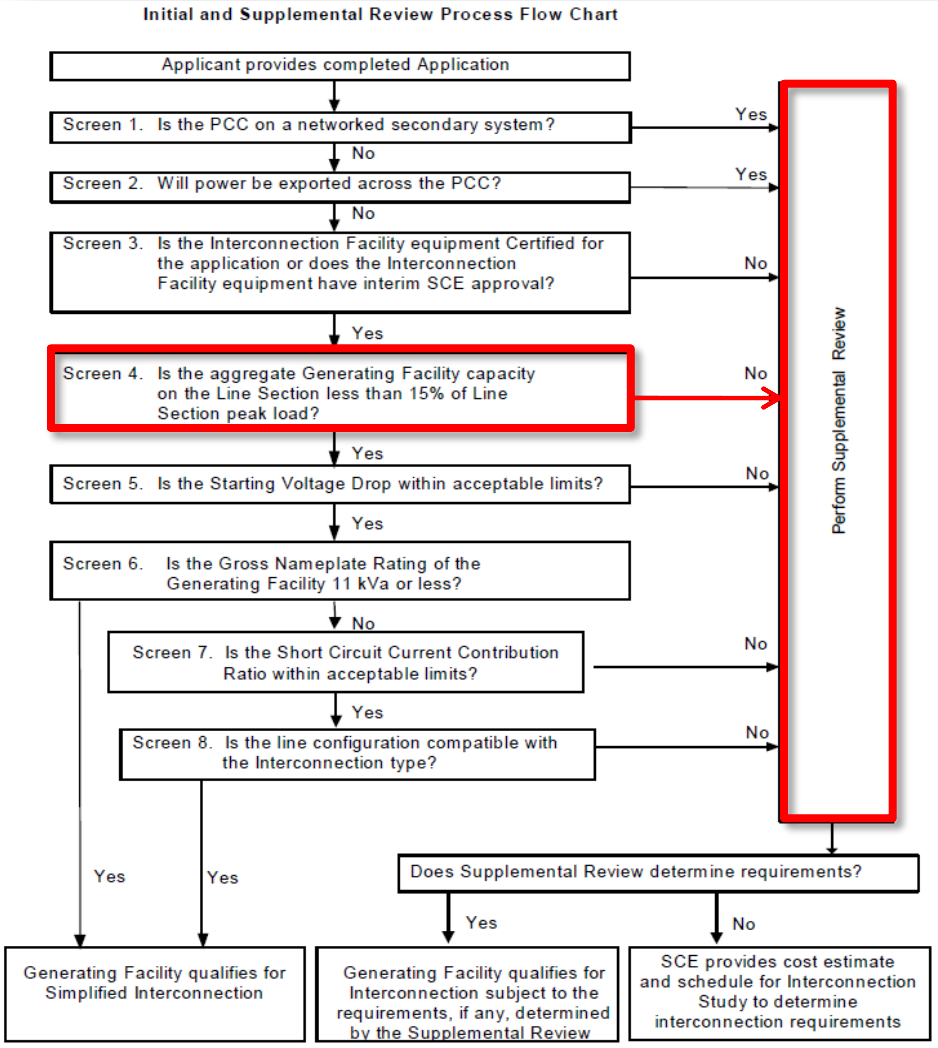
Review of Utility Interconnection Screens

California Rule 21 Initial Review Screens

1. Not a secondary network
2. Not exporting across PCC
3. Certified equipment
4. <15% of peak load in line section
5. Starting voltage drop within limits
6. <=11 kVA nameplate rating

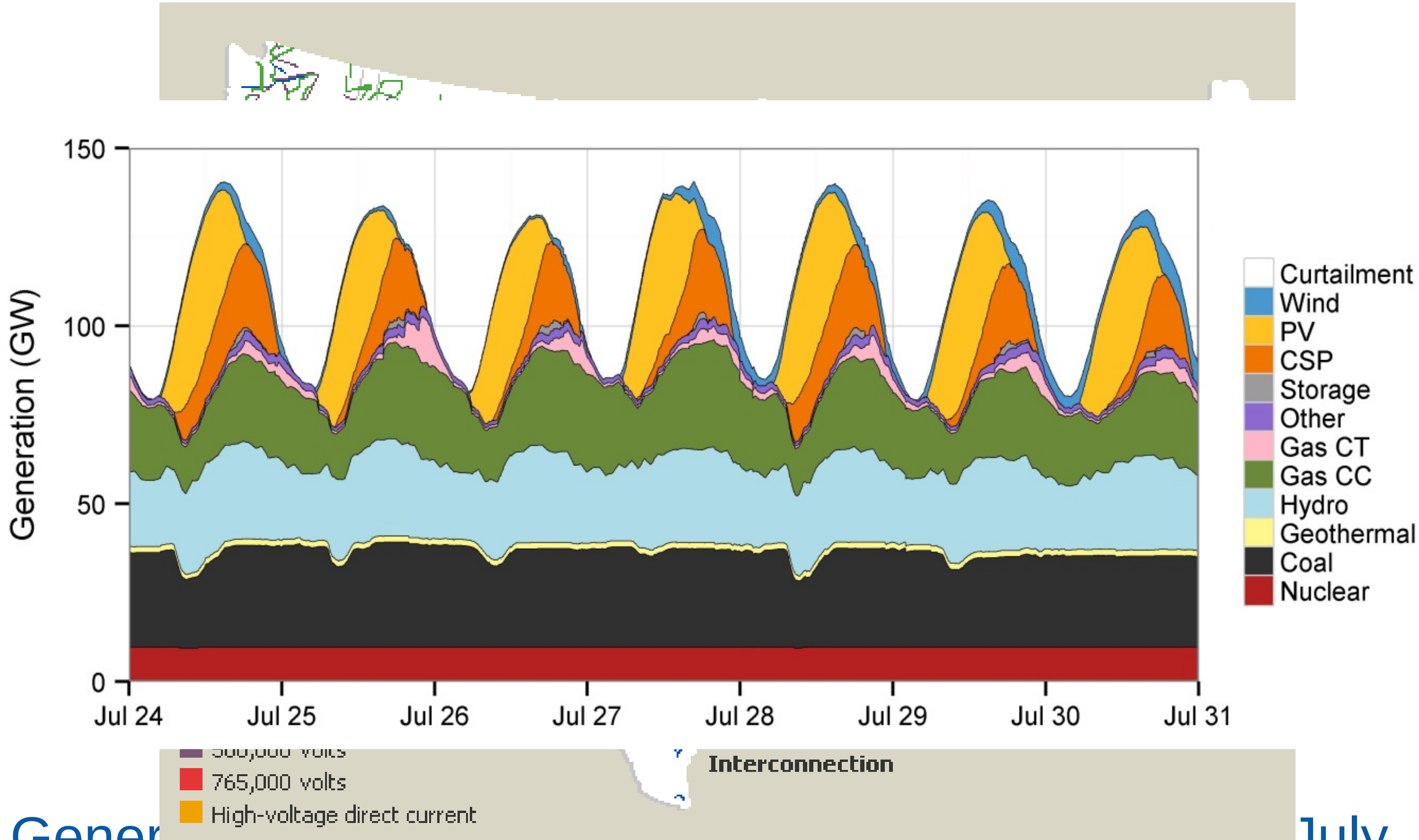
   If > 11 kVA rating …
7. Nameplate and short circuit contribution ratio within limits
8. Compatible transformer connection

If project passes all screens, interconnection agreement approved



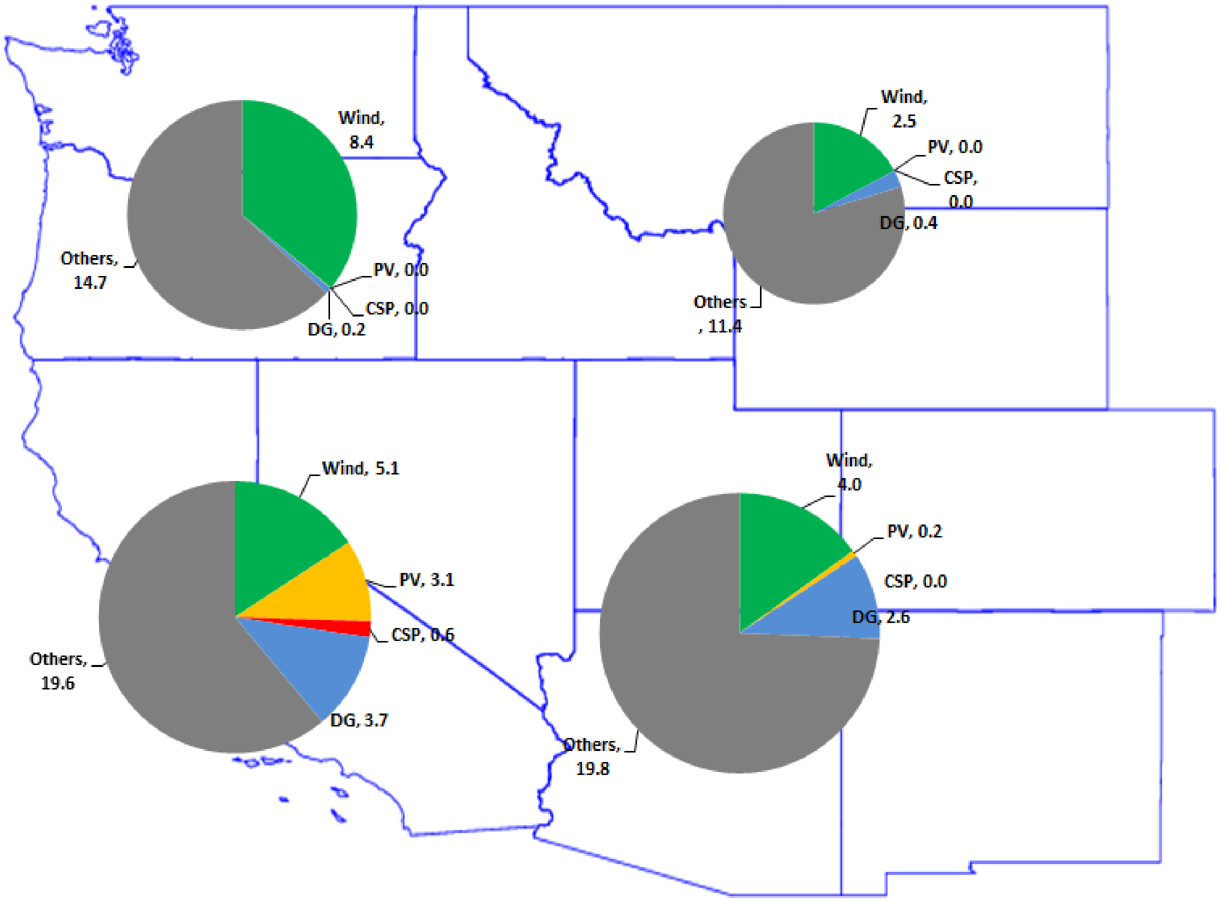
Source: SCE Rule 21 – Generating Facility Interconnections, August 2004

Western Wind and Solar Integration Study 2 (WWSIS2)



Generation 5-min. dispatch for high solar scenario – July
Energy Penetration: 25% Solar (PV & CSP), 8% Wind

Western Wind and Solar Integration Study 3 (WWSIS3) – in progress



- 2022 - outlook
- 10.3 GW of PV
- 21.6 GW of Wind
- Light Spring System Loading

WWSIS3 includes the bulk system response to large amounts of DG (mostly PV) – is the contingency case now the loss of all the DG?

IEEE 1547 Basics – after amendment “a”

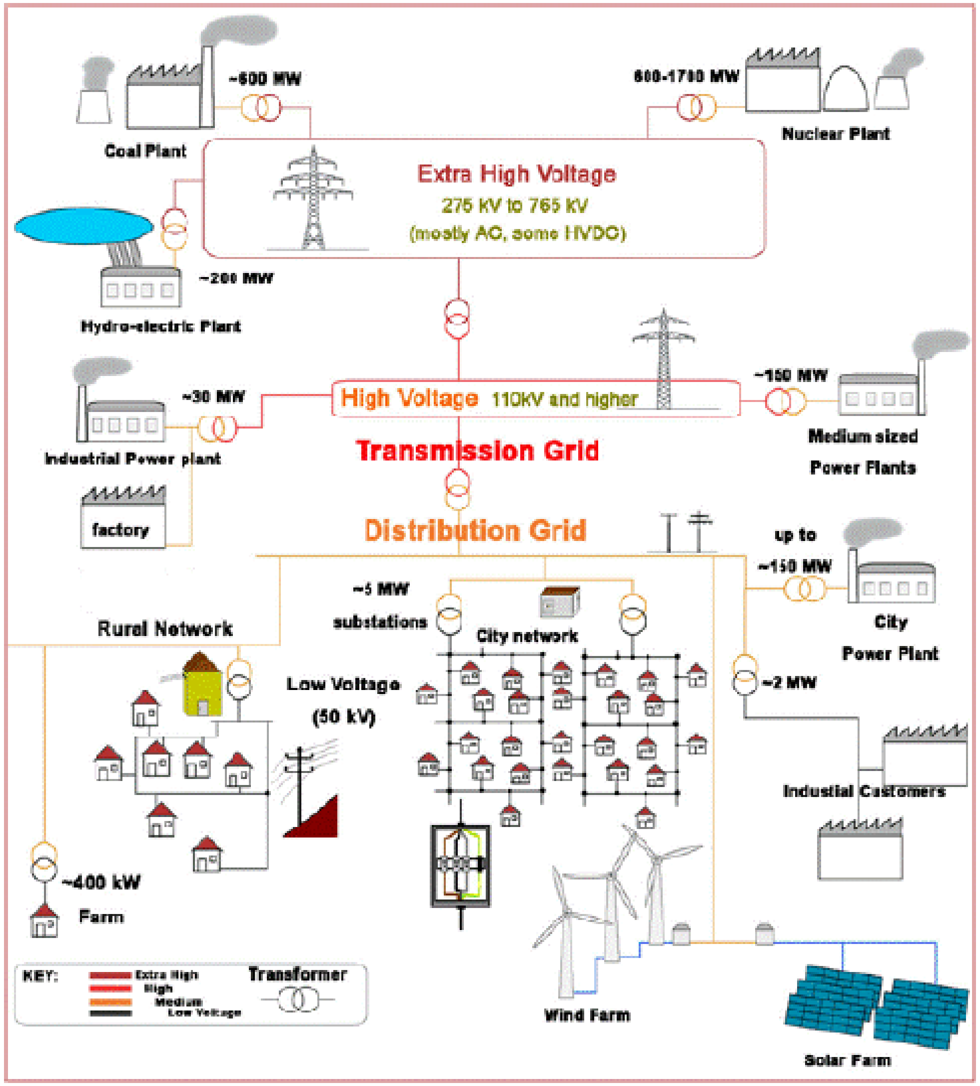
- IEEE 1547 has been a successful and useful DG interconnection standard for over 10 years
- Is technology agnostic – applies for any type of DG, not just PV inverters
- Describes the minimum requirements for DG interconnection at the point of common coupling (PCC)
- Voltage and frequency ride-through is allowed, not mandatory
- Active voltage regulation at the PCC is allowed, not mandatory

Default settings[a]		
Voltage range (% of base voltage[b])	Clearing time (s)	Clearing time: adjustable up to and including (s)
V < 45	0.16	0.16
45 < V < 60	1	11
60 < V < 88	2	21
110 < V < 120	1	13
V > 120	0.16	0.16

[a] Under mutual agreement between the EPS and DR operators, other static or dynamic voltage and clearing time trip settings shall be permitted

[b] Base voltages are the nominal system voltages stated in ANSI C84.1-20~~06~~11, Table 1.

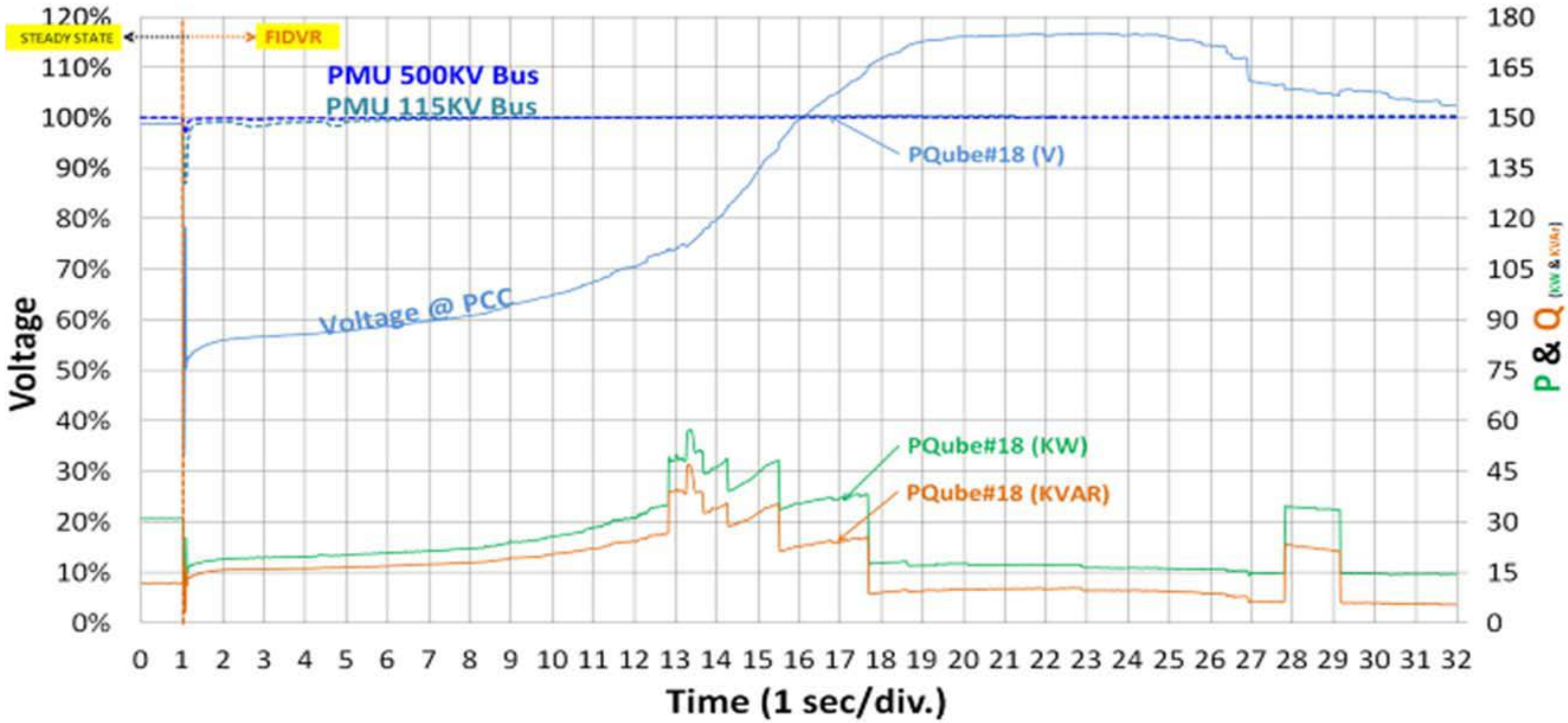
Technical Tradeoffs: Transmission vs. Distribution



- At low DG penetration, impacts on transmission level operations were considered minimal
- At the higher levels of DG seen, or soon to be realized, it is worthwhile to discuss what changes need to be considered
- Example: unintended transmission level impacts due to Germany's 50.2 Hz issue

Technical Tradeoffs: Transmission vs. Distribution – FIDVR Example

Figure from R. Bravo, SCE, FIDVR Working Group Meeting, CERTS



- Transmission – DG should not trip to support trans. grid
- Distribution – DG should trip if fault is on dist. circuit
- Manufacturer – Can’t design a “clairvoyant” DG

IEEE 1547 Revisions

IEEE 1547 – Base Standard Revision

- *What:* Workshop for the full revision of IEEE Std 1547: Standard for Interconnecting Distributed Resources (DR) with Electric Power Systems (EPS)
- *When:* December 3rd & 4th, 2013
- *Where:* Piscataway, NJ (IEEE HQ)

IEEE 1547.1a – Conformance Test Proc.

- *What:* Working Group Meeting for IEEE 1547.1a
- *When:* December 5th, 2013
- *Where:* Piscataway, NJ (IEEE HQ)

- ***Who:* All stakeholders**
- ***How:* http://grouper.ieee.org/groups/scc21/**

Thank you for your attention

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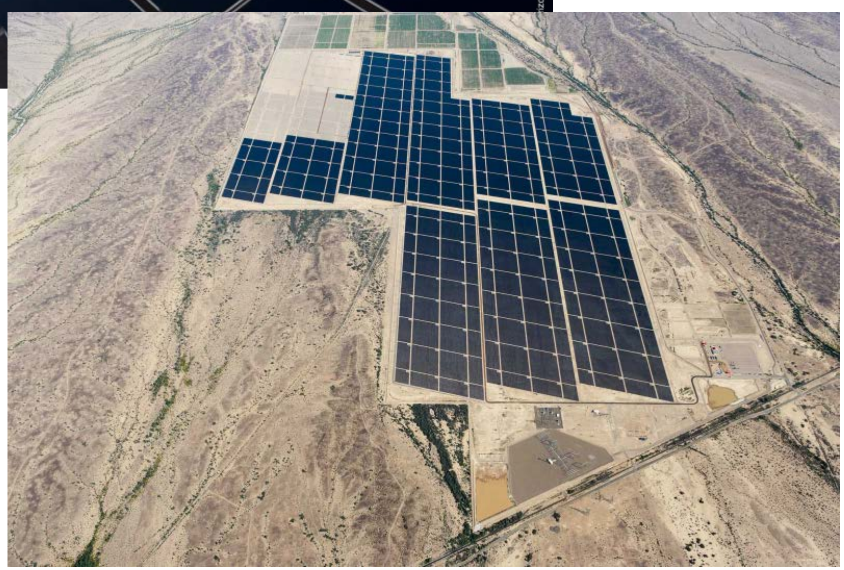
Current Status of PV in US

- 1231 MW of centralized solar installed in 2012
- California added 330MW, Arizona added 470MW
- Over 80% of the installed MW were sold as power purchase agreements
- Estimates are that about 3GW will be installed in 2013 (includes significant CSP)

Source: SEPA, updated Q4, 2012, Photo: Agua Caliente 290MW – Courtesy of First Solar, Inc.

Agua Caliente, Arizona – 262 MW



- 262 MW_{ac} operational as of mid of 2013
- Complete project build out is 290 MWac
- Located between Phoenix, AZ and Los Angeles, CA

Photos: Agua Caliente 290MW – Courtesy of First Solar, Inc.