Sunshine State Solar Grid Initiative (SUNGRIN)

SYSTEMS INTEGRATION

Solar PV Variability

- Collecting data from PV plant sites across Florida
- Resolution from 250 millisecond to 15 minute*
- Irradiance, PV power output (P&Q), voltages and currents*
- Installations ranging in size from 2kW to 15MW
- Also utilizing satellite data (on 10km x 10km resolution)
- Analysis of ramp rates, variability – spatial and temporal
- PV AC output data is input to models for hi-pen analysis

High-Penetration PV Modeling and Analysis

- Examining a wide range of PV-grid integration scenarios
- Six utility partners, with PV up to 100% penetration
- Have modeled circuits with PV at:
  - Jacksonville Electric Authority (JEA), 15 MW, 100% penetration
  - Gainesville Regional Utilities (GRU), ~2MW, 30% penetration
  - NASA Kennedy Space Center (KSC), 900kW
- To model circuits in Lakeland and Orlando in subsequent phases
- JEA feeder – 100% penetration
- ***Penetration level*** **of PV is *not*, by itself, an adequate indicator of the overall risk or impact of PV on a utility circuit.**

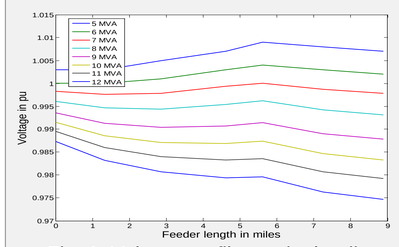
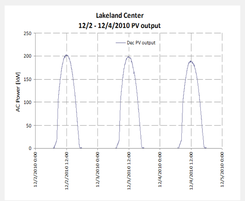
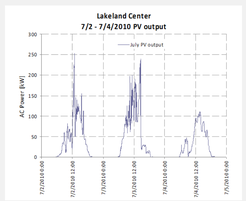


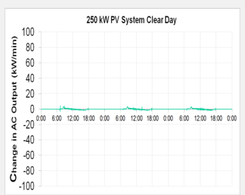
Fig. 1. Voltage profile vs ckt. loading

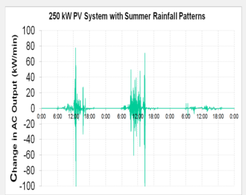




Lakeland Center,
Lakeland, FL (for example)

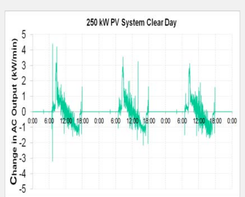
- 250 KW
- 1232 solar collectors
- 247 roof penetrations
- 40,000 sq. ft. rooftop
- Fixed mounted / south facing
- Produces ~ 475,000 KWh annually

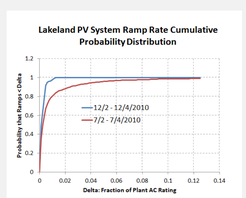


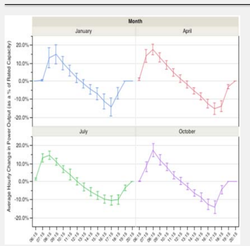


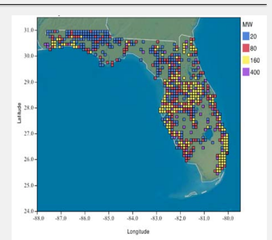
Lakeland Center, July 2010 Ramp Rates

Maximum Ramp Rates:		*1-minute*	
Overall	Max RR:	229.487	[kW/min]
2-Jul	Max RR:	108.939	[kW/min]
3-Jul	Max RR:	146.041	[kW/min]
99 Percentile Ramp Rates:		*1-minute*	
Overall	RR99	129.05262	[kW/min]
2-Jul	RR99	22.48161	[kW/min]
3-Jul	RR99	36.12926	[kW/min]







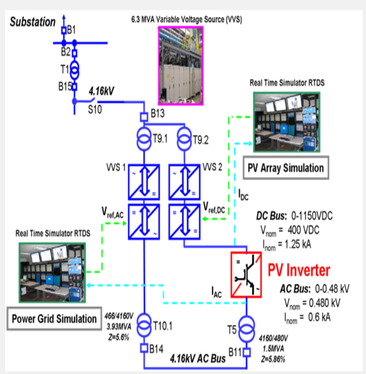


High-penetration PV Statewide Analysis with Satellite Data

- Based on satellite-derived irradiance data
- 10km x 10km grid
- Average hourly change
- Aggregate effects
- Useful tool for examining scheduling and dispatch of power, and,
- To quantify daily variability and ramp rates for different PV system layouts.

Issues examined

- Voltage rise due to reverse power flow
- Voltage fluctuations associated with solar irradiation variation
- Interaction of voltage regulation devices
- Protection coordination and fault response
- Low voltage result from false tripping of mass distributed PV systems.
- Potential islanding issues due to the interaction between multiple PV systems
- Appropriate metrics and modeling and analysis tools for identifying hi-pen issues
- De-risking solutions with HIL:



Plant / Project Name	Utility	Map ID Number	System Power Rating	Approx. Area [acres]	No. of Panels	Circuit Rated Load	Connection Type
Keys Eco-Discovery Center	FMPA	1	30 kW	0.11		8000 kW	Distribution
DeSoto	FPL/Nextera	2	25 MW	235	90,500		Transmission
Kennedy Space Center PV Site (PKS)	FPL/Nextera	3	900 kW AC	5.4	3,420	8 MVA	Distribution
Space Coast	FPL/Nextera	4	10 MW AC	60	37,000		Transmission
6th Street Solar Energy Park (Ckt. 435)	GRU	5	2 MW	7	8,600	11 MW	Distribution
Butler Plaza	GRU	5	2.6 MW 2011 3.8 MW 2016				Distribution
Jacksonville Solar (JSI)	JEA	6	15 MW DC 12.6 MW DC	91	200,000	18 MVA	Distribution
The Lakeland Center	Lakeland Electric	7	250 kW AC	0.92	1,232	10,553 kVA	Distribution
Lakeland Linder Airport Ph. 1, (Circuit T374)	Lakeland Electric	7	2.3 MW	41*	9,500	>27 MVA	Distribution
Lakeland Linder Airport Ph. 2 (Circuit D334)	Lakeland Electric	7	3.2 MW	41*	>8000	>25 MVA	Distribution
CNL/City of Orlando Parking Garage	OUC	8	500 kW	1.7		12.96 MW, 600 A	Distribution
Orange County Convention Center	OUC	8	1 MW	4.6	5,808	600 A - 12.96 MW	Distribution
Pershing Facilities	OUC	8	149 kW	0.22		600 A - 12.96 MW	Distribution
Stanton Energy Center Solar Project	OUC	9	5.91 MW	30	25,172	600 A -12.96 MW	Distribution

Voltage Profile and Regulation

- Voltage drops along the feeder is well in limits for various loading and 12.6 MW PV penetration (Figure 1).
- Profile depends on circuit design (Figure 2) and other factors
- Voltage regulation issues more challenging with distributed PV, due to interaction with other PV and traditional regulation devices such as on-load tap changers (OLTC)
- Risk of tap changer run away / saturation

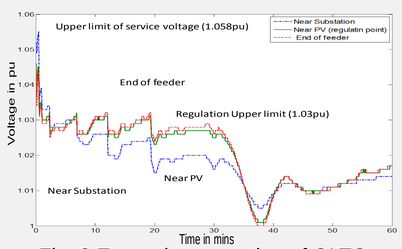


Fig. 3 Excessive operation of OLTC

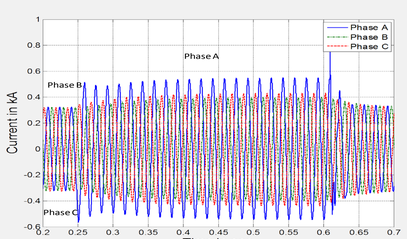


Fig. 4 Response to a fault

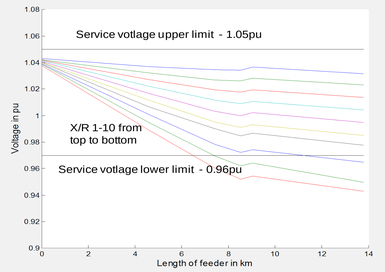


Fig. 2. Voltage profile vs. X/R ratio

Protective Relaying Impacts

- Real time digital electromagnetic transient program (EMTP) simulations were used to investigate potential impact on protection devices and to demonstrate hardware-in-the-loop methods with relays, using a detailed model of the JEA substation.
- PV fault current magnitudes are very low compared to synchronous DG fault contribution.
- If the relays are coordinated properly, reverse power flow should not have an effect on relay operation.
- Figure 4 shows fault current contribution of PV for line to ground fault on Phase A.

SunShot U.S. Department of Energy

Project Team: Florida State University, University at Buffalo The State University of New York, Florida Municipal Power Agency, FPL, GRU More than Energy, JEA, Lakeland Electric, OUC The Reliable One, FRCC, OSIsoft, SMA

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