Solar PV Variability

- Collecting data from PV plant sites across Florida
- Resolution from 250 milliseconds 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.

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:

Lakeland Center, Lakeland, FL (for example)
- 250 kW
- 1232 solar collectors
- 247 roof penetrations
- 40,000 sq. ft. rooftops
- Fixed mounted / south facing
- Produces ~ 475,000 KWh annually

Lakeland Center, July 2010 Ramp Rates
- 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 transient program (EMTP) simulations
- 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.

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

Voltage Profile vs X/R ratio

Fig. 4 Response to a fault

Fig. 3 Excessive operation of OLTC

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

Fig. 1. Voltage profile vs clkt. loading