IEA PVPS Task 14
High Penetration of PV into Electricity Grids

High Penetration Projects in the US

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United States
High Pen Projects

- DOE High Pen Awards
- Other High Pen examples in the US
- High Pen Workshop
DOE High Penetration PV Project Awards

- Arizona Public Service
- Commonwealth Edison (Illinois)
- Florida State University
- NREL-Southern California Edison
- Sacramento Municipal Utility District
- Univ. of California – San Diego
APS – Flagstaff Project

- Study the effects of large amounts of distributed PV on a utility feeder and its associated customers
- Create and validate models to describe the interactions between weather/PV/feeder equipment and operations
- Identify technical and operational modifications that could be deployed in future feeder designs.
ConEd – Smart Grid PV Pilot

- Evaluate customer perceptions of the value of PV in combination with net metering and hourly pricing
- Evaluate the way customers respond to price signals
- Observe and evaluate the way customers engage with technology
- Assess customer attitudes toward adopting new and emerging technologies
- Study how behind-the-meter PV systems will affect reliability of the distribution system
FSU - Sunshine State Solar Grid Initiative SUNGRIN

- Examining Solar Variation across Florida
- Conducting large scale PV integration simulations
- Engaging stakeholders
UCSD - Improved Modeling Tools Development for High Penetration Solar

- Power Analytics for Development and Validation of Steady State and Dynamic Models of PV Systems
- Solar Resources and Integration of Energy Storage and PV as an “Enabler Technology”
- Cloud Tracking and Insolation Forecast Model
- Command, Control and Communications for Power Flow Management
- Field Testing and Validation of the Suite of Models
- Raise Situational Awareness of Virtual Power Plants and Microgrids by Distribution Utilities and RTO/ISOs
Southern California Edison - NREL
PV Systems on Commercial Circuits

- SCE is installing 500MW of commercial rooftop PV systems over the next 5 years
- 250MW utility owned, 250MW IPP
- Interconnected at distribution circuit level

Specific Issues:
- Unsure of interconnection process for circuits with over 15% PV (Peak PV/Peak Load)
- Need to develop quick study process for penetrations >15%
- Issues include: voltage regulation, circuit ratings, circuit protection coordination, cloud variability
Sacramento Municipal Utility District – NREL
PV on Residential Circuit
Hawaii – High Penetration Examples

• Oahu
• Big Island
• Lanai
High Penetration RE Integration
Case Study: Island of Hawaii

Renewable Generation on the Big Island

Of the Hawaiian Electric Light Company's current 269-megawatt capacity, almost 30% (nearly 80 megawatts) already comes from renewable sources, including:

- Wind—31 megawatts
- Geothermal—30 megawatts
- Hydroelectricity—16 megawatts.

HELCO estimates that the island of Hawai‘i has the most rooftop photovoltaic (PV) installations per capita in the United States.

Already has individual distribution circuits with penetrations of 62%
High Penetration PV Integration Case Study: Lanai

- Currently there is a 1.2MW PV system installed on Lanai.
- Lanai peak load is 4.7MW and average load is 3.5MW.
- There is also a 900kW CHP plant that runs as base load.
- Plans are to install a large battery to smooth PV variability at large plant.
- Plans are to conduct island-wide interconnection study for new PV on Lanai (HCEI funded)
High Penetration PV Workshop

In May 2010 NREL held a workshop on high penetration PV standards and codes.

Addressed:

- High Penetration PV Concerns
- Gaps in Existing Standards and Codes
- High Penetration PV Technical Solutions
- High Penetration PV Solutions: Modeling and Studies

Workshop information available at:
http://www.nrel.gov/eis/high_penetration_pv_wkshp_2010.html
Penetration Definitions

At least three different measures are used to describe penetration levels: energy penetration, capacity penetration, and instantaneous penetration. They are defined and related as follows:

**Energy penetration** is the ratio of the amount of energy delivered from the generation to the total energy delivered. For example, if 200 megawatt-hours (MWh) of energy is supplied and 1,000 MWh is consumed during the same period, energy penetration is 20%.

**Capacity penetration** is the ratio of the nameplate rating of the plant capacity to the peak load. For example, if a 300-MW plant is operating in a zone with a 1,000-MW peak load, the capacity penetration is 30%. The capacity penetration is related to the energy penetration by the ratio of the system load factor to the plant capacity factor. If the system load factor is 60% and the plant capacity factor is 40%. In this case, and with an energy penetration of 20%, the capacity penetration would be $20\% \times \frac{0.6}{0.4}$, or 30%.

**Instantaneous penetration** is the ratio of the plant output to load at a specific point in time, or over a short period of time.
High Penetration Survey

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Feeder Name</td>
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<tr>
<td>Feeder Number</td>
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<tr>
<td>Substation Transformer Size (MVA)</td>
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<tr>
<td>Transmission Voltage (Primary) (kV)</td>
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<td></td>
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<tr>
<td>Feeder Voltage (Secondary) (kV)</td>
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<tr>
<td>Peak Load (MW)</td>
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<tr>
<td>Minimum Daytime Load (MW) if available</td>
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<tr>
<td>System Fault Current at Substation</td>
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<tr>
<td>Feeder conductor rating (A) – main size</td>
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<tr>
<td>Voltage regulation type</td>
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<tr>
<td>Voltage regulation location</td>
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<tr>
<td>Reclosers on feeder, setting if available</td>
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<tr>
<td>Any other DG on Feeder? Size?</td>
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<tr>
<td>Reverse power flow capability of transformer</td>
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<tr>
<td>Number of other circuits on substation</td>
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<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Installed PV Capacity (MWac)</td>
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<tr>
<td>Fault Current from PV (kA)</td>
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<tr>
<td>Zero sequence impedance of DG ground source</td>
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<td></td>
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<tr>
<td>Distance from Substation (miles)</td>
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<tr>
<td>Available Fault Current at PV location</td>
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<tr>
<td>Impedance of circuit at PV location</td>
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<tr>
<td>Utility ground source impedance</td>
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<tr>
<td>Transfer trip on PV?</td>
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High Penetration PV Case Studies

- Please contribute information for Case Studies
- Contact Ben Kroposki at
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