GRID IMPACTS OF DISTRIBUTED SOLAR

Workshop for Utah Municipal Utilities

Presented by:
Jim Lazar and John Shenot
Regulatory Assistance Project

April 13, 2017
GROUP DISCUSSION/ICEBREAKER

• Two-minute description of your utility: # of customers, peak demand, annual sales, installed solar, energy efficiency program levels
• What goals, targets, or hopes do you have for solar power?
• What are your biggest concerns or challenges for the coming 5-10 years?
• What questions do you hope to answer today?
ROOFTOP SOLAR WORKSHOPS FOR UTAH MUNICIPAL UTILITIES

Grid Impacts of Distributed Solar

Solar Valuation & Cost/Benefit Analyses

Rate Design & Solar

TODAY

MAY 11

JUNE 15
OVERVIEW

• Back to the Future
• Grid and Power Supply Impacts
  – Low-Level Saturation
  – Mid-Level Saturation
  – High Level Saturation
• Utility Planning and Investment Impacts
• Teaching the Duck to Fly
SOLAR IS HOT IN UTAH

CAPACITY INSTALLED IN 2016 (mw)

- California: 5,096
- Utah: 1,241
- Georgia: 1,023
- Nevada: 984
- North Carolina: 923
- Texas: 672
- Arizona: 657
- Massachusetts: 406
- Florida: 404
- Colorado: 382

SOLAR CAPACITY PER CAPITA (watts per person)

- Nevada: 745
- Utah: 488
- Hawaii: 472
- California: 466
- Arizona: 430
- New Mexico: 305
- North Carolina: 297
- Vermont: 270
- New Jersey: 223
- Massachusetts: 218

Source: SEIA

RAP® Energy solutions for a changing world
GRID AND POWER SUPPLY IMPACTS CAN BE SIGNIFICANT

Postcard from the Future: Hawaiʻi
EXPENSIVE ELECTRICITY
AVERAGE PRICE, CENTS/KWH

http://www.eia.gov/electricity/data.cfm#sales
HAWAII RENEWABLE ENERGY LEGISLATION 2015

- Currently ~15% renewable statewide
- 30% by 2020
- 40% by 2030
- 70% by 2040
- 100% by 2045
  - Solar
  - Wind
  - Geothermal
  - Storage
CIRCUIT LIMITS RAISED DRAMATICALLY

• IEEE: 15% of Peak
• 2011: 85% of Minimum Daytime Load
• 2013: 100% of MDL
• 2013: 125% of MDL
• 2015: 250% of MDL
SOME CIRCUITS >250% OF MINIMUM LOAD

%DG of Circuit Daytime
Gross Min Load
Less than 50%
50 up to 100%
100 up to 250%
250% and greater

*published as of 4/12/2017
### Table 3. HECO Companies’ Net Energy Metering Program Capacity and Enrollment

<table>
<thead>
<tr>
<th>Capacity (MW)</th>
<th>HECO</th>
<th>HELCO</th>
<th>MECO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed or Approved</td>
<td>327.9</td>
<td>73.3</td>
<td>88.8</td>
</tr>
<tr>
<td>In the Queue</td>
<td>17.3</td>
<td>5.1</td>
<td>11.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>345.2</strong></td>
<td><strong>78.4</strong></td>
<td><strong>100.7</strong></td>
</tr>
<tr>
<td>Total NEM Customers</td>
<td>51,680</td>
<td>11,549</td>
<td>12,893</td>
</tr>
<tr>
<td>System Peak Load (MW)</td>
<td>1,165</td>
<td>188</td>
<td>191</td>
</tr>
<tr>
<td>NEM % of All Customers</td>
<td>17%</td>
<td>14%</td>
<td></td>
</tr>
<tr>
<td>NEM % of System Peak</td>
<td>30%</td>
<td>42%</td>
<td>53%</td>
</tr>
</tbody>
</table>
PEAK LOAD AND RAMPING IMPACTS

2006 Peak: 1,200 MW at 1 PM

2014 Peak: 1,050 MW at 7 PM

2006: 500 MW ramp 6 AM to 1 PM

2014: 250 MW ramp 6 AM to 1 PM

Source: Hawaiian Electric Co
CIRCUITS AND SUBSTATIONS “RUNNING BACKWARDS”

Tracking Change – 46kV Level

Average Transformer Load (MW) - December

Backfeed occurring 10am-2pm

8/8/2013 Backfeed Condition

Hawaiian Electric
Maui Electric
Hawai‘i Electric Light

RAP® Energy solutions for a changing world
Pumped storage hydro: The system proposed for Kauai’s west side will use an upper storage pond connected by a five-mile-long buried steel pipeline to a lower pond. During the day, inexpensive solar power would be used to push the water uphill to the storage pond. At night, when demand for electricity is at its peak, the water would be released, flowing downhill through the pipe to turn a turbine and generate electricity.
HAWAIIAN ELECTRIC TOU RATES (OPTIONAL)
POWER SUPPLY IMPACTS
POWER SUPPLY IMPACTS

• Total electricity consumption: no change
• Total generation: decrease (line losses)
• Total utility power supply: bigger decrease
  – Avoided line losses
  – Customer self-supply
  – Customer excess generation
  – Could reduce utility generation or power purchases
• Peak demand/load shape/resource adequacy
• Balancing/ramping
• Note: Negligible impacts at low penetration; geographic dispersion of PV not as important for bulk power supply as for distribution system impacts
HAWAIIAN ELECTRIC: 2006 <1% PV
HAWAIIAN ELECTRIC 2014  ~14% PV
• At high levels of deployment, distributed solar affects power quality, reliability, and safety on the local distribution system.

• Strategies and solutions are available for avoiding/mitigating negative impacts.

• Hawaii and California are leading.
CAPACITY VALUE OF PV DECREASES AS PENETRATION INCREASES

Source: LBNL (2012)
LOW SATURATION

- 20% to 60% capacity credit for each kW of PV installed
- Few voltage or other variations observed
- Within flexibility and capacity of existing distribution system
- No real need for direct expenditure
HAWAIIAN ELECTRIC 2010
<2% PV
MEDIUM SATURATION: 5% - 10% OF KWH

- 0% to 40% capacity credit for each additional kW of PV installed
- Still gaining capacity benefits
- No backfeed at substations
- May see need for voltage regulators, or smart inverters
HIGH SATURATION

- Peak load shifted to post-solar hours
- Very small or zero capacity credit
- Backfeed at circuit and substation level observed
- Requires active control of voltages; set-and-forget voltage regulators insufficient.
WHENEVER YOU INVERT DC TO AC, YOU HAVE THE OPPORTUNITY TO CREATE ANY VOLTAGE OR WAVEFORM THAT IS DESIRABLE FOR THE GRID
CAPABILITIES OF SMART INVERTERS

• Smart Inverters can provide 24 functions:
  – Voltage support
  – Frequency regulation
  – Power Factor support
  – Connect / disconnect
  – Price-driven or temperature-driven controls
USE OF BATTERIES FOR GRID RESILIENCE

- **System Frequency (Hz)**
  - D9 Trips - 5.6 MW Loss of Generation
  - Frequency drops to 59.4 Hz

- Koloa BESS - 1.5 MW
  - Initial BESS frequency response of 1.4 MW

- Port Allen BESS - 3.0 MW
  - Initial BESS frequency response of 2.8 MW

BESS units pushing Power for 95 seconds
USE OF BATTERIES TO SMOOTH SOLAR

Port Allen 6MW PV Array

Port Allen 3MW BESS

BESS Exporting Power when PV Array moving from a high state to a low state. Notice large duty cycle.
ELECTRIC VEHICLES AND SMART CHARGING
UTILITY PLANNING AND INVESTMENT IMPACTS

JOHN SHENOT
RECOMMENDED REFERENCE DOCUMENTS

**INTEGRATION OF HOSTING CAPACITY ANALYSIS INTO DISTRIBUTION PLANNING TOOLS**

https://www.epri.com/#/pages/product/000000003002005793/

**Planning for a Distributed Disruption: Innovative Practices for Incorporating Distributed Solar into Utility Planning**

Andrew Mills, Galen Barbose, Joachim Seel
Lawrence Berkeley National Laboratory

Changgui Dong, Trieu Mai, Ben Sigrid
National Renewable Energy Laboratory

Jarett Zuboy
Independent Consultant

August 2016

https://emp.lbl.gov/publications/planning-distributed-disruption
DISTRIBUTION SYSTEM PLANNING
HOSTING CAPACITY — EPRI DEFINITION

“The amount of PV that can be accommodated without impacting power quality or reliability under existing control and infrastructure configurations”

Results are location-specific and change over time
INTERCONNECTION REQUESTS: MOVING BEYOND RULES OF THUMB

• **Before PV**: very few interconnection requests, generally for larger units (e.g., CHP), possible to analyze individually

• **Low PV penetration**: many utilities fast-track interconnection requests by applying conservative “rule of thumb” screens
  – e.g., Will total PV capacity on a circuit be less than 15% of circuit peak load?

• **Higher PV penetration**: some utilities now using distribution system planning models (e.g., OpenDSS) to analyze actual feeder characteristics
  – Simple approach: cluster feeders based upon topology, and model a single (representative) feeder from each feeder “type.”
  – Emerging best practice: rigorous analysis on each individual feeder.
HOSTING CAPACITY ANALYSIS METHODOLOGY

1. Baseline Power flow/short-circuit
2. Select DER location
3. Increase DER
4. Apply Power System Criteria
5. Hosting Capacity Limit?

Source: EPRI
HOSTING CAPACITY VARY FOR EACH FEEDER (OR FEEDER CLUSTER)
TYPICAL OUTPUT: HOSTING CAPACITY MAP
HOSTING CAPACITY AT DIFFERENT SCALES

Source: EPRI
EXAMPLES OF UTILITIES PROVIDING ONLINE HOSTING CAPACITY MAPS

• California IOUs (PG&E, SDG&E, SCE)
• PEPCO (DC and Maryland)
  – see previous slide
• Con Edison (New York)
• Green Mountain Power (Vermont)
• Others have created maps that aren’t online
BENEFITS OF HOSTING CAPACITY ANALYSIS

✓ Provides information to customers and solar project developers
✓ Streamlines interconnection approvals
✓ Less conservative than rules of thumb – allows for more PV deployment at lower cost
✓ Helps identify/prioritize needed T&D investments
RESOURCE PLANNING & INVESTMENT
OPTIONS FOR FORECASTING DISTRIBUTED PV DEPLOYMENT

• Assume an amount for planning purposes
  – Legislated requirement
  – Program goal
  – Organizational goal
  – Pick a number!

• Extrapolate from historical data

• Use a technology adoption model
TECHNOLOGY ADOPTION MODEL

Source: LBNL (2016)
NEW APPROACHES TO FORECASTING DEMAND

Focus on “net demand”: the demand that needs to be met with conventional, dispatchable generators. Net demand equals gross demand minus the variable generation from distributed PV and other non-dispatchable generators.
NET DEMAND => THE FAMOUS “DUCK CURVE”

Source: CalISO
OPTIONS FOR PROCURING RESOURCES IN LIGHT OF PV DEPLOYMENT UNCERTAINTY

• Use a single PV deployment forecast
  – NOT RECOMMENDED

• Test sensitivity of preferred resource portfolio against a range of PV deployment scenarios to see if it is “risky”

• Identify a preferred resource portfolio for different PV deployment scenarios, and look for common elements - the least risky choices
ILLUSTRATION OF SCENARIO PLANNING

Plan with Low DPV

Plan with High DPV

Source: LBNL (2016)
HIGH PENETRATIONS OF RENEWABLES WILL ALSO CHANGE LEGACY PLANT UTILIZATION...
...AND EVENTUALLY TRANSFORM THE OPTIMAL PORTFOLIO OF DISPATCHABLE RESOURCES
CAPACITY VALUE OF PV DECREASES AS PENETRATION INCREASES

Source: LBNL (2012)
T&D PLANNING TO ACCOMMODATE HIGHER PENETRATIONS OF DISTRIBUTED PV

• Use hosting capacity analysis to steer private (and utility?) investment toward best locations

• Adopt strategies to enable even more PV:
  – Smart inverters
  – Operational changes (e.g., LTC setpoints)
  – Grid investments (e.g., add voltage regulators, reconductor, or replace transformers)
  – “Teach the Duck to Fly”
TEACHING THE DUCK TO FLY
TEACHING THE DUCK TO FLY

JIM LAZAR
THINGS ARE CHANGING
THE CALIFORNIA ISO “DUCK CURVE”

Source: CalISO

28 thousand megawatts

California's electrical grid throughout the day

The net load on March 31 of each year

2012

2013

2014 proj.

2015

2020

12 a.m. 3 9 12 p.m. 3 6 9

10 12 14 16 18 20 22 24 26

RAP®
Energy solutions for a changing world

solarmarket PATHWAYS
OPTIONS TO TEACH “THE DUCK” TO FLY

• Distribution System Upgrades
• Flexible Generation
• Control Loads
  – Water Heaters
  – Air Conditioners
  – Water Pumping
• Pricing
  – Time of Use
  – Critical Period
TEN STRATEGIES TO ALIGN LOADS TO RESOURCES (AND RESOURCES TO LOADS)

1. Targeted energy efficiency
2. Peak-oriented renewables
3. Manage water pumping
4. Grid-integrated water heating
5. Storage air-conditioning
6. Rate design
7. Electricity storage in key locations
8. Demand response
9. Inter-regional exchanges
10. Retire inflexible older generating units

Not every strategy will be applicable to every utility.
STRATEGY 3: WATER PUMPING

$0.08/kWh when power is “cheap”
$0.25/kWh when power is “expensive”
STRATEGY 4: WATER HEATERS

• Utah has ~ 150,000 electric water heaters. 600 MW
• Controls adequate to provide 50% of needed flexibility for current PV.
• Heat water when the sun is shining or the wind is blowing
• $50/water heater if installed when built = $7.5 million
STRATEGY 5: AIR CONDITIONING STORAGE

Simple technology; great peak relief.
Teaching the Duck to Fly
SUMMARY

• Generation impacts
  – Generally favorable to ~10% saturation
  – Significant flexibility required at 15% or more

• Distribution impacts
  – Generally easy to manage to ~10% saturation
  – More challenging when minimum daytime loads drop below nighttime loads
  – Smart inverters or other adaptation needed

• Planning and Investment
  – Need to anticipate and plan for change over time
ROOFTOP SOLAR WORKSHOPS FOR UTAH MUNICIPAL UTILITIES

Grid Impacts of Distributed Solar

Solar Valuation & Cost/Benefit Analyses

Rate Design & Solar

MAY 11

JUNE 15
The information, data, or work presented herein was funded in part by the Office of Energy Efficiency and Renewable Energy (EERE), U.S. Department of Energy, under Award Number DE-EE0006907.
AWARDEES OF

solarmarket PATHWAYS

Center for Sustainable Energy
California

Virginia Private Colleges

 Pace Energy and Climate Center
 Pace Law School

extensible ENERGY

Dominion

The City University of New York

mrea

midwest renewable energy association

ecolibrium3

LOCAL ENERGY MATTERS

SF Environment

Our home. Our city. Our planet.
A Department of the City and County of San Francisco

SEPA
solar electric power association

Vermont Energy Investment Corporation

THE SOLAR FOUNDATION
Research and Education to Advance Solar Energy