Solar on the APS Grid

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NREL Utility-Owned Distributed Generation Models
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Presentation Overview

- Arizona Public Service Overview
- Utility Scale Solar
- Residential and Commercial DG
- Solar Partner Program and Lessons Learned
APS Service Territory

- 11 of Arizona’s 15 counties
- 34,646 square mile service area
- 1.2 M meters, 2.7 M people
- Over 35,000 transmission and distribution line miles
- 430 substations; 300,000 transformers; over 550,000 poles and structures
- Operating voltages 500, 345, 230, 115, 69, 21, 12.47 kV
- System Peak Load 7,350MW
APS Resource Diversity

<table>
<thead>
<tr>
<th>Resource</th>
<th>Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>3,179</td>
</tr>
<tr>
<td>Coal</td>
<td>1,672</td>
</tr>
<tr>
<td>Renewables</td>
<td>1,475</td>
</tr>
<tr>
<td>Nuclear</td>
<td>1,146</td>
</tr>
<tr>
<td>Power Contracts</td>
<td>1,554</td>
</tr>
<tr>
<td>Energy Efficiency</td>
<td>737</td>
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<tr>
<td>Micro-grids</td>
<td>37</td>
</tr>
<tr>
<td>Demand Response</td>
<td>25</td>
</tr>
</tbody>
</table>

Total: 9,825 MW
**APS Renewable and DER Profile**

- **Renewable profile**
  - 769 MW utility scale solar and wind
  - 1030 MW customer owned solar
    - Average 1400 applications/mo.
- **Energy storage**
  - Solana (solar thermal)
    - 250 MW
  - Battery energy storage
    - 8 MW/12 MWh
- **Anticipated DER Forecast**
  - 4100 MW* by 2032
  - Most from customer DER

* Based on 2017 IRP data
Where do we rank
(Energy Information Administration – accessed 12/2018)

- Arizona is 3\textsuperscript{rd} nationally for solar PV production
- APS 2\textsuperscript{nd} highest large utility for residential installations per customer
- APS 5\textsuperscript{th} highest solar PV installed capacity of all utilities nationally

https://www.eia.gov/electricity/data/state/
Utility Scale Solar at APS

- Luke Air Force Base – 10 MW
- Desert Star – 11 MW
- Hyder – 16 MW
- Cotton Center – 17 MW
- Paloma – 17 MW
- Chino Valley – 19 MW
- Gila Bend – 32 MW
- Foothills – 35 MW
- Red Rock – 50 MW
- Solana – 250 MW

Distributed Solar PV

- **Residential**
  - Over 90,000 rooftops
  - Over 700 MW

- **Commercial**
  - Approximately 1,500 systems
  - Over 320 MW

- **APS Owned Distributed Solar**
  - APS Schools and Governments Program
    - Over 300 sites
  - APS Solar Partner Program (SPP)
    - 1500 residential rooftops
  - APS Solar Innovation Study (SIS)
    - 125 homes

APS Projects

- APS Solar Innovation Study (SIS)
- Punkin Center Battery Storage
  - 2 MW/8 MWh
  - Peak shaving
  - Non wires alternative
- Microgrids
  - Aligned Energy Data Center
  - Yuma Marine Corp Air Station (MCAS)
  - 35 MW, clean diesel generators
- APS Solar Partner Program
Solar Partner Program with EPRI

• Phase 1 - initiated 11/2014
  – 10 MW, 1600 residential customers
  – External Advisory Council
    • Industry, academia, government and research lab

• Rooftop solar PV
  – Residential systems (4-8 kW)
  – West-facing, with advanced inverters
  – 20 year contract - $30/month bill credit (no usage reduction)
  – APS controls inverters (grid side of meter)

• Centralized communications and control
  – Utility communications, control, and centralized configuration changes

• Phase 2 – initiated 01/2017
  – Feeder energy storage (2 MW / 2 MWh) on 2 feeders
  – Interoperability with VVO and advanced inverters

• Phase 1 EPRI Report (May 2017)
  – Product ID: 3002011316

• Phase 2 EPRI Report 11/2018
  – Product ID: 3002014455
APS / EPRI Lessons Learned

Planning & Operations
- Feeder demand reduction from aggregated systems (5-8%)
- West-facing coincident to system needs (66 vs 20%)
- No negative VVO impacts
- No transformer or customer demand reduction

Advanced Inverters
- Respond to commands
- Ideal settings vary by feeder (Volt/VAR, PF, unity)
- Aggressive voltage settings caused no kW curtailment
- Secondary voltage impact dominates

Interoperability & Communications
- Need for standards and protocols (nascent industry)
- Inverters do not talk at night (solar PV)
- Interaction with VVO seen but managed
- Tradeoffs abound – thoughtful consideration required
Lessons Learned
Voltage Variability

- Voltage impact
  - Voltage variability with PV output intermittency
  - Aggregate impacts will be seen at transmission unless mitigated
  - High/Low voltage can damage customer and utility equipment
- Illustrative Example
  - Three contiguous days with intermittency - low (clear day), moderate and high (cloudy)
  - High voltage variability with PV output variability
  - Existing device (capacitor) operation
Distribution System Example

• High PV penetration feeder (4.5 MW PV, 10 MW demand peak)
  ✓ 800 residential PV systems

• Impacts
  ✓ Voltage rise in areas of high PV concentration
  ✓ System operations challenges
  ✓ Line losses

• Studies show a range of impacts
  ✓ Penetration level not a determinant of PV impacts
  ✓ Topology (length and wire size) and design are significant factors
Intra-Day Production Spread

- Roof orientation matters
- West-facing systems
  - High coincidence with system needs
  - Dependent on construction
- South and East facing
  - Very early production peaks
  - Non-existent output at load peaks
- Practical deployment
  - Mixed orientations will always exist
  - Different system value