APS Distributed Energy Resources (DER) Integration Engineering

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The APS DER Engineering Team

Distributed energy resources (DER) include generation, energy usage and energy storage technologies:

- ✓ Rooftop solar PV
- ✓ Battery energy storage systems (BESS)
- ✓ Demand response or load management devices
- ✓ Electric vehicles (EV)
- ✓ Other emerging technologies

APS has created a dedicated team of DER engineers to assess grid impacts and incorporate DER into both grid and resource planning

SOLAR

Electric Vehicles

Instant Information

Home Energy Management

Smart Thermostats

Battery Energy Storage

Grid-Interactive Water-Heaters

What We Do

DER engineers use advanced simulation and analysis tools:

- ✓ Study the impacts of DER integration
- ✓ Identify opportunities for DER deployment
- ✓ Evaluate reliability management and grid controls
- ✓ Ensure acceptable power quality and service voltage for all customers on the feeder

Coordinate internal activities that affect interconnecting DER to the grid, including:

- ✓ Renewable Integration
- ✓ Interconnection and Power Quality
- ✓ Distribution Planning and Engineering
- ✓ Customer Technology

Ongoing Activities

ACC Proposed Rules: Interconnection of Distributed Energy Resources (DG and Storage)

- Types of Generating Facilities
- Customer and Utility Rights and Responsibilities
- Application Submission Requirements
- Technical Screens
- Application Tracks
- Supplemental Review
- Energy Storage Systems
- Advanced Inverter Requirements

- ACC Workshops on Interconnection Rules
  - Standardizing state level requirements for stakeholders, utilities and customers
  - Stakeholder group is engaged to provide comment and review

Possible Impacts to Customers

- Voltage
  - High levels of solar PV on the same feeder can cause high voltage
  - Can trip customer inverter
  - Can prevent inverter from connecting
  - Affects all customers on the circuit

- Power Quality
  - Voltage fluctuations can be seen by sensitive customers

APS Solar Partner Program (SPP)

- 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 configuration changes from control center
- 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

Planning & Operations

- Feeder demand reduction from aggregated systems (5-8 %)
- West-facing coincident to system needs (66 vs 20 %)
- No negative VVO impacts
- Solar did not reduce transformer or customer peak load

Advanced Inverters

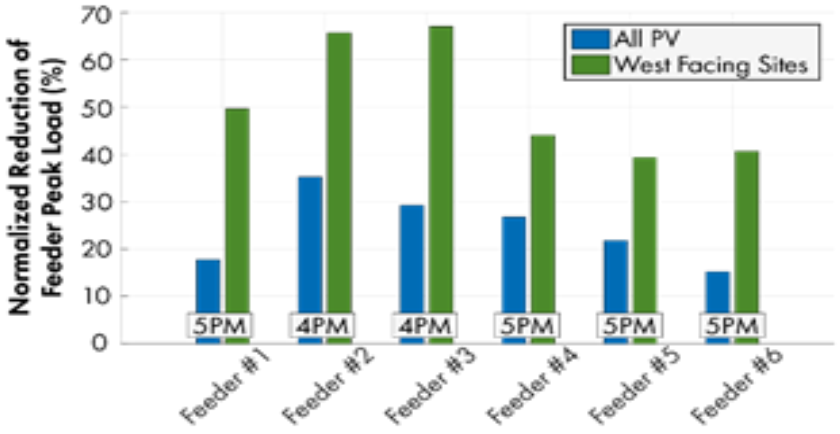
- Reliable response to commands
- Aggressive voltage settings caused no kW curtailment
- Secondary voltage impact dominates
- Ideal settings vary by feeder (Volt/VAR, PF, unity)

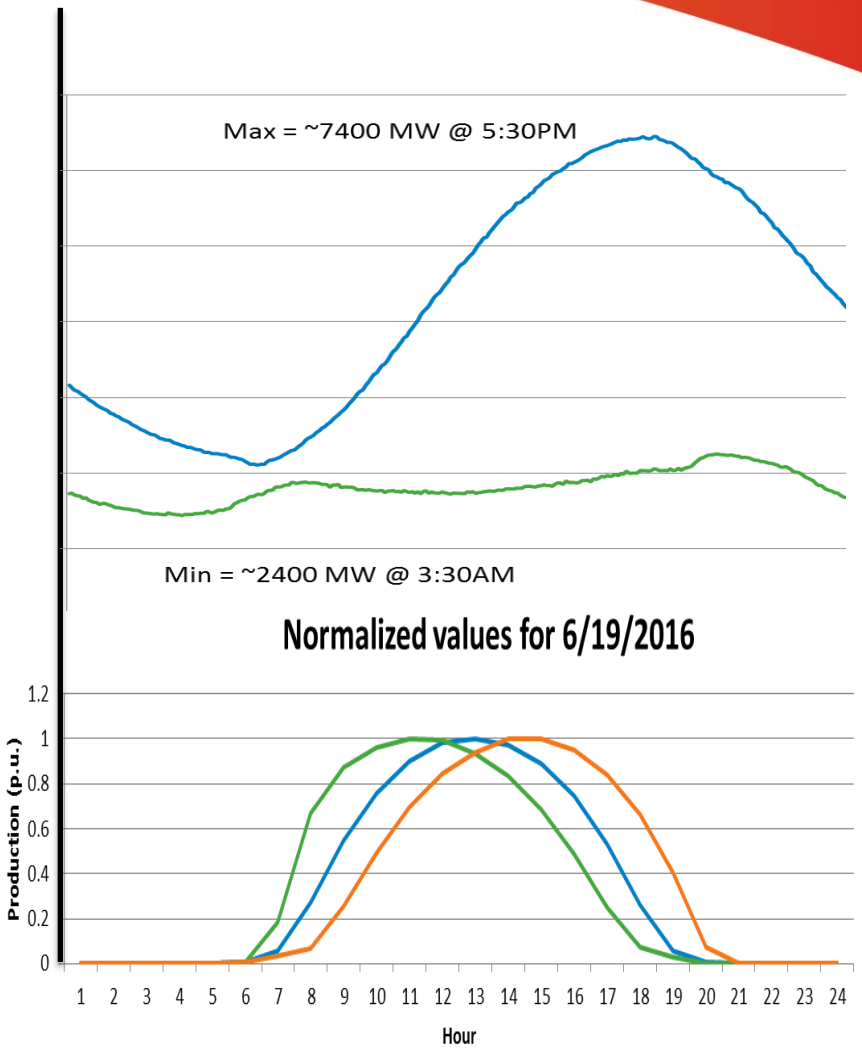
Interoperability & Communications

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

East vs. West Facing

West East South





Advanced Inverter and PV Hosting

- Advanced Inverters can help increase ability to add more PV
- BUT…
  - Depends on what's already installed
  - Results vary by feeder
  - If ALL inverters were smart, able to add more PV with fewer issues
- The impact and settings are feeder-dependent
  - In one case, they can significantly increase ability to add PV
  - In another case, much smaller improvement
- They're not a "magic bullet"

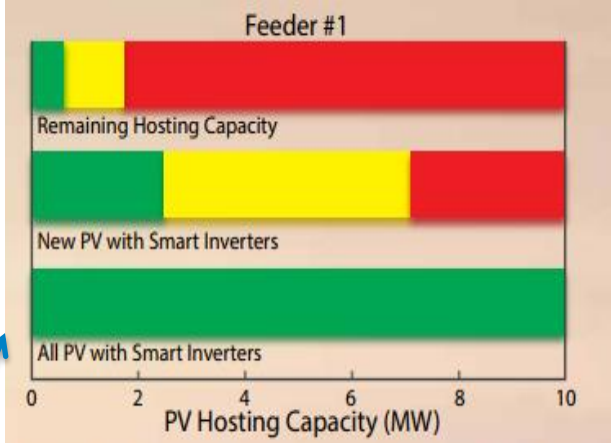


Figure 8 – Remaining hosting capacity on Feeder #1 shows an improvement using smart inverters

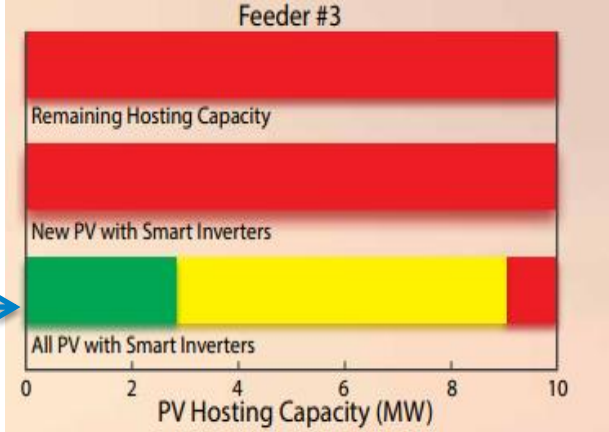


Figure 9 – Remaining hosting capacity on Feeder #3 showed little or no impact unless the feeder was retrofit with smart inverters

Final Remarks

- APS is already seeing impacts of high PV penetration
  - Need to ensure long-term sustainable integration of PV
  - At the same time, ensure no negative impact to customers

- APS improving ability to address feeder impacts
  - Eliminate any negative impact of PV
  - Understand new technology (Advanced Inverters, Battery Energy Storage)
  - Prepare the grid to accommodate more PV and other DER

- Proposed ACC rules
  - Changes to application review process are likely
  - Changes only on APS internal review steps
  - No changes expected to customers or installers application process in 2018
  - No changes expected to customer interaction in 2018

QUESTIONS