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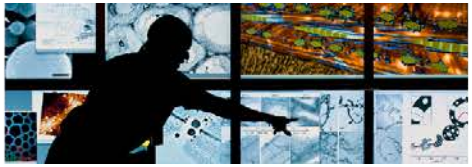
Distributed Generation Interconnection Collaborative (DGIC)



"Lessons Learned with Early PV Plant Integration"

Elsa Gonzalez, Rachel Sall, Frankie Greco and David Narang with Arizona Public Service Company

June 12, 2014

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Speakers

Elsa Gonzales
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Arizona Public Service Company

Lessons Learned with Early PV Plant Integration

Elsa Gonzalez
Rachel Sall
Frankie Greco
Dave Narang

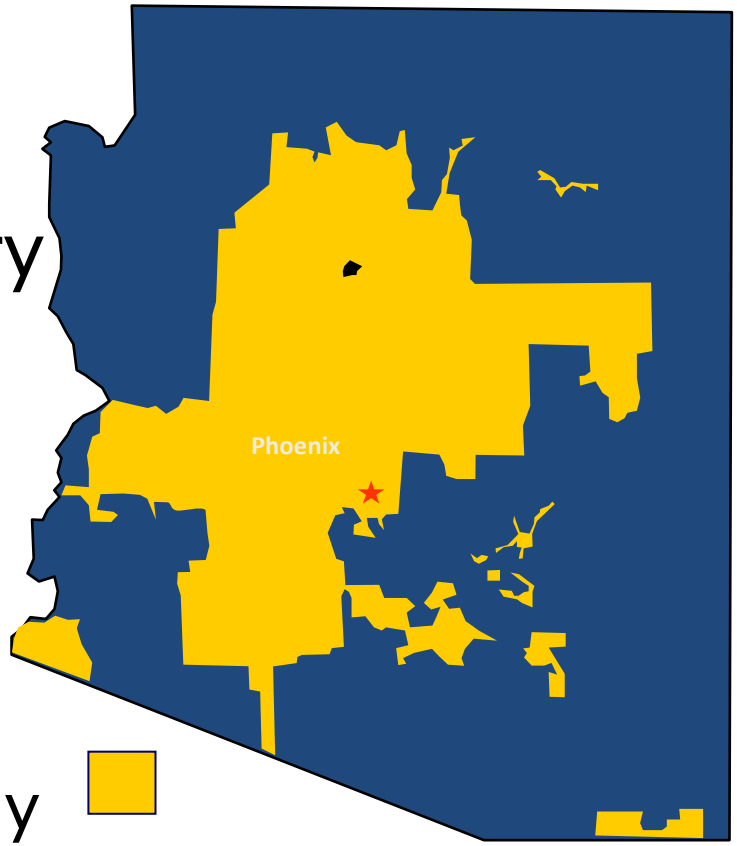
Elsa Gonzalez

Engineer, APS Distribution Planning & Operations

Introduction

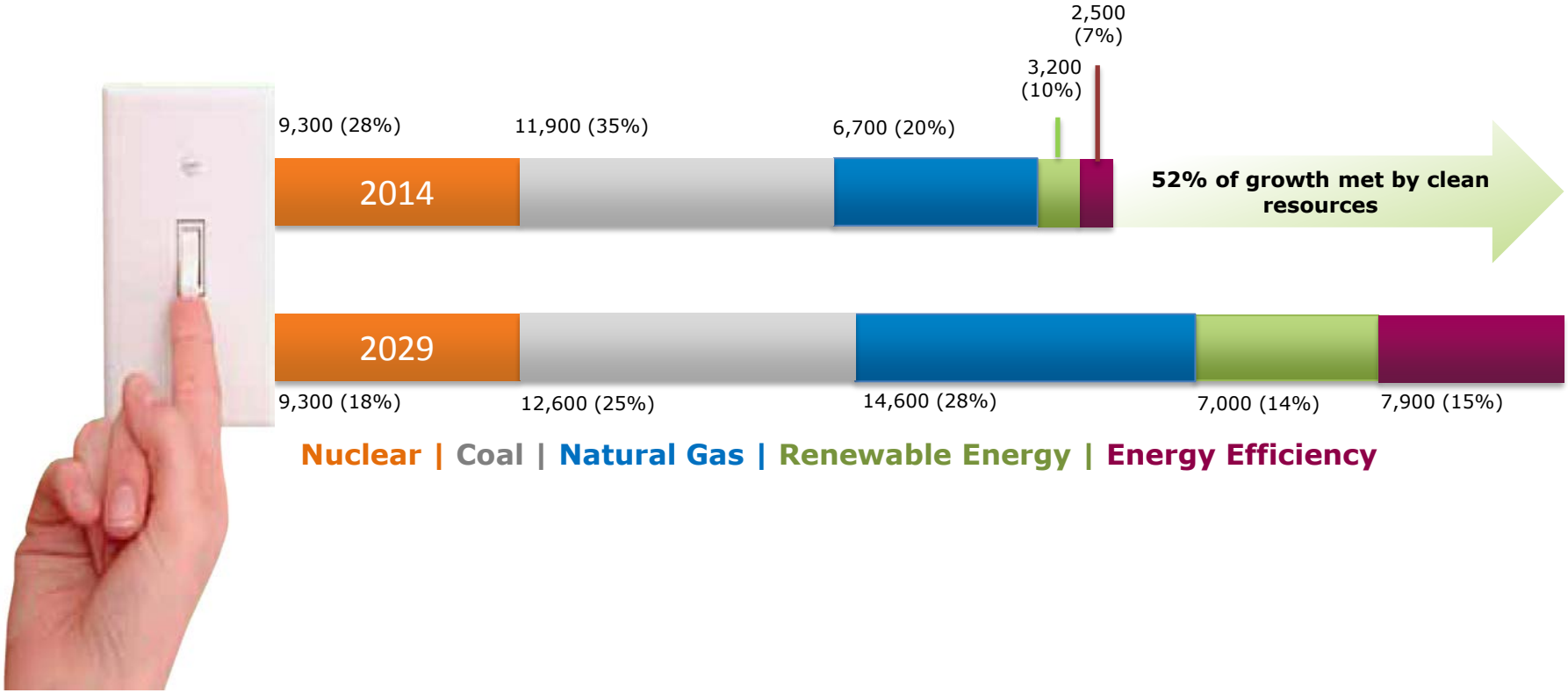
APS: Arizona's Largest Utility

- Service Territory
  - 1.1 million customer accounts
  - 34,646 square miles
- Scope of Energy Delivery
  - 28,000 distribution miles
  - 5,300 transmission miles
  - 410 substations
- Resources
  - 8,600 MW total capacity
  - Peak demand- 7,100 MW
  - Energy demand will nearly double in next 20 years



APS Retail Service Territory

APS's Diverse Energy Mix (GWh)



APS Total Solar Portfolio and RPS

- RPS requires 5% and 15% of retail sales by 2015 and 2025, respectively
- Less than 70% utility scale
- More than 30% distributed
  - 50% from Residential
  - 50% from Non-Residential
- 2013 PV portfolio is twice the 2015 commitment at 925 MW

# Distribution Feeders	% of Feeders	Amount of Generation
928	73%	With Solar
84	6.6%	With >1 MW_{DC} of Solar
81	6.4%	With >10% Penetration (Capacity to Feeder Peak)

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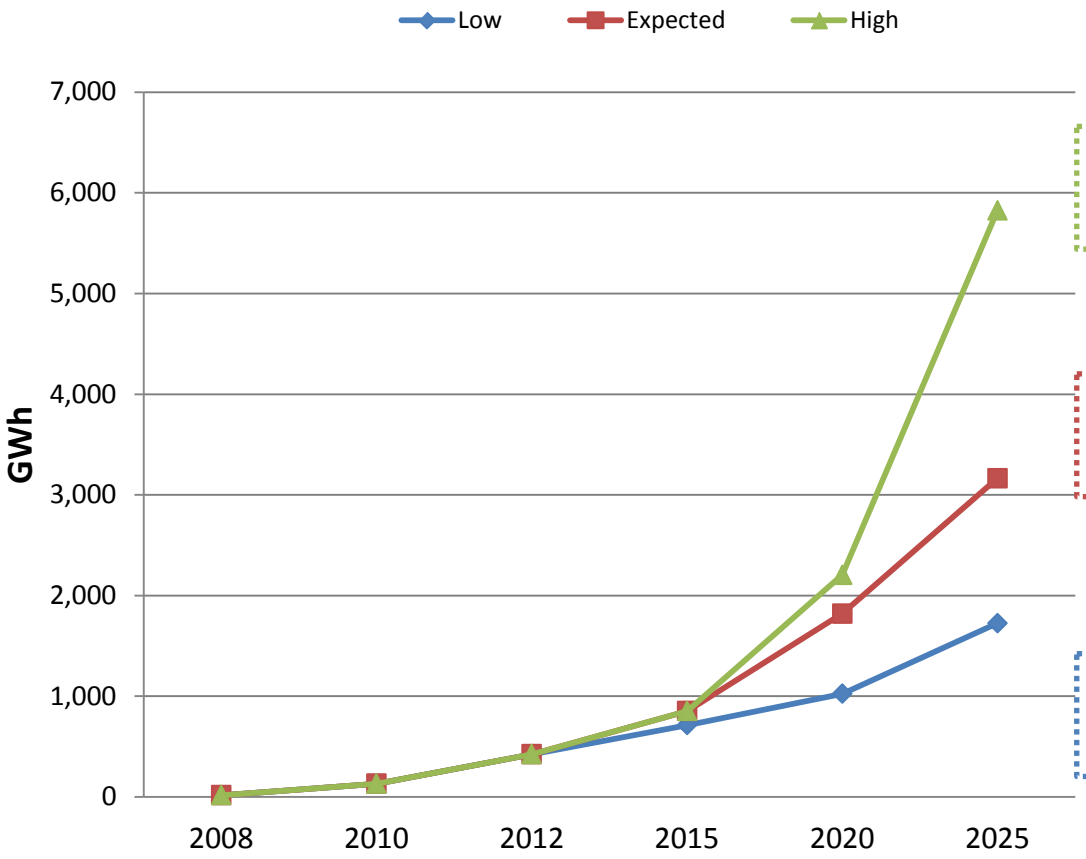
APS Distributed PV Projections



High Case 2025:

~3500 MWdc
~245,000 Customers

Current Trajectory 2025:

~1,900 MWdc
~190,000 customers

Low Case 2025:

~1,050 MWdc
~70,000 customers

Source: 2013 SAIC Study

Rachel Sall

Engineer III, APS Distribution Asset Management

Distribution Planning and Operations

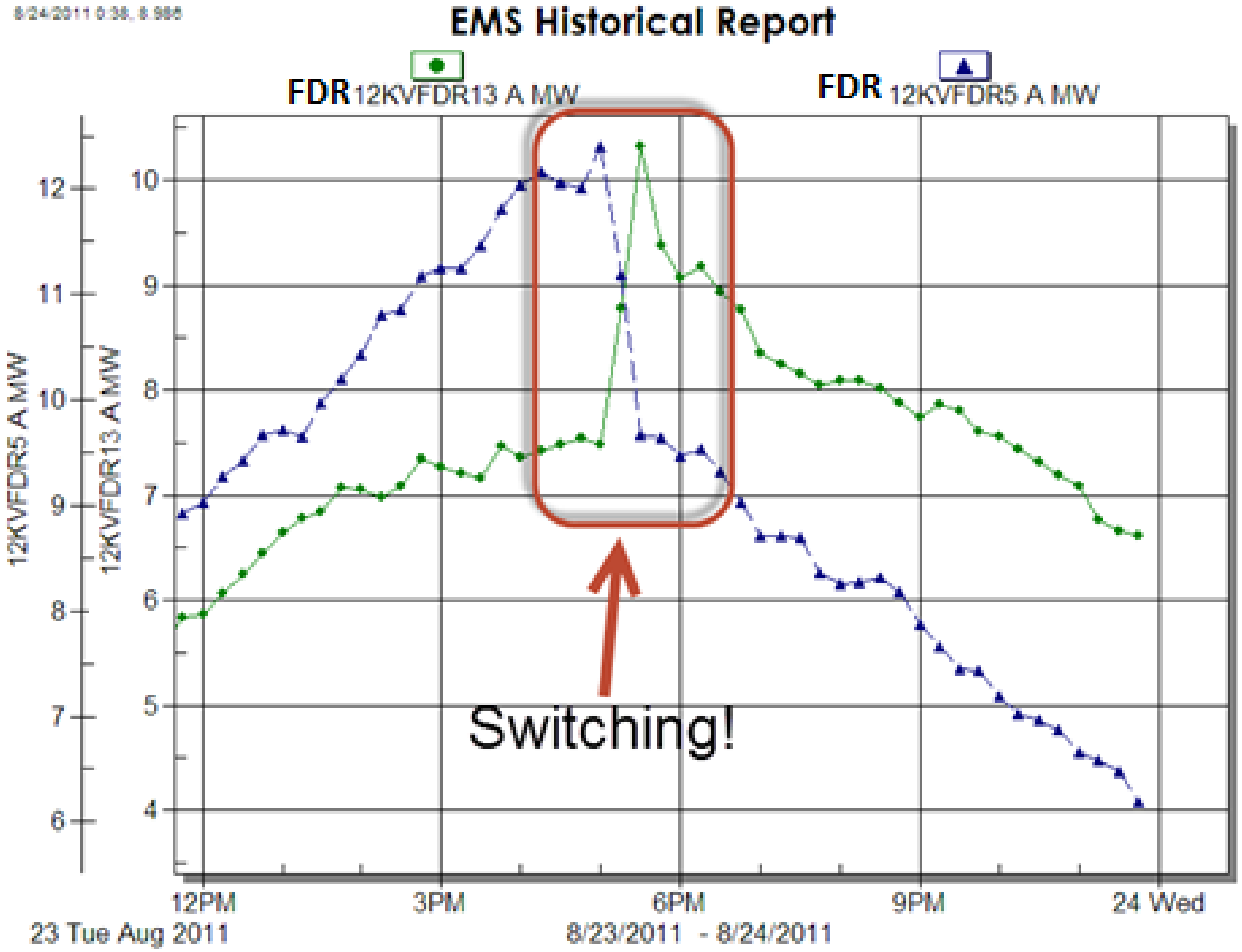
Agenda Topics

- Feeder Peak Analysis
- Distribution Forecasting
- Accounting for Distributed Generation – Current
- Accounting for Distributed Generation – Future

Feeder Peak Analysis

- Gather Data : November 1 – October 31
  - Consists of all transformers and feeders for entire system
- Compare past years' load to current year's loads
- Higher load than expected typically attributed to two main reasons:
  - Large customer or development came into an area
  - Load switching occurred between one or more feeders

Feeder Peak Analysis



Distribution Forecasting

- Consider multiple sources
  - New Work Orders
  - New customer load – residential, commercial, industrial
  - State region and/or climate
    - kW/home
    - Rate of lots to be sold
  - Past growth pattern
  - Business/Residential load leaving the area

Distribution Forecasting

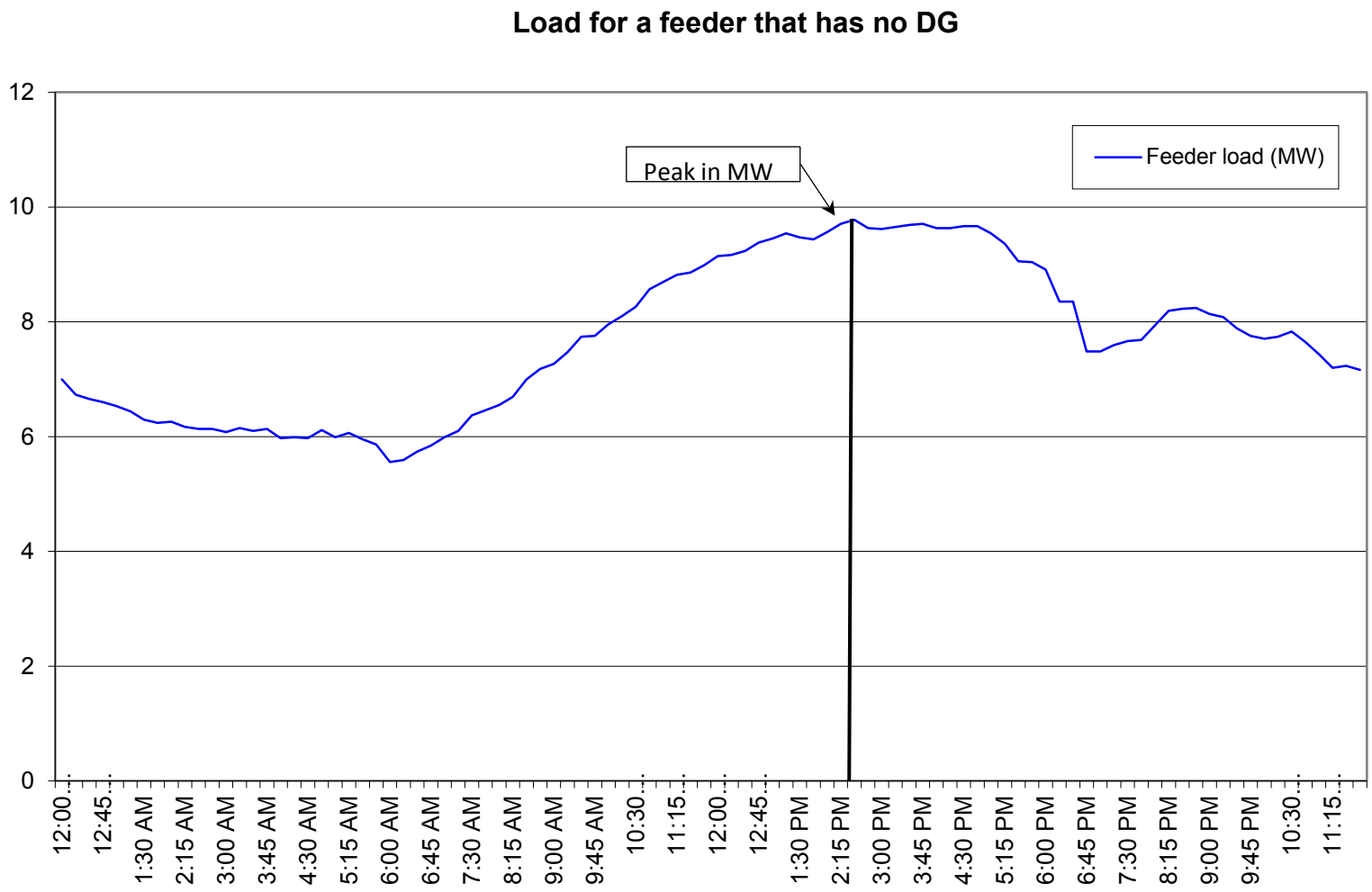
- Next Steps – What if there is not enough capacity on an existing feeder?
  - Capacity projects
    - Build new distribution line
    - Build new substation
  - Alternative/Risk Analysis

Distribution Generation - Current

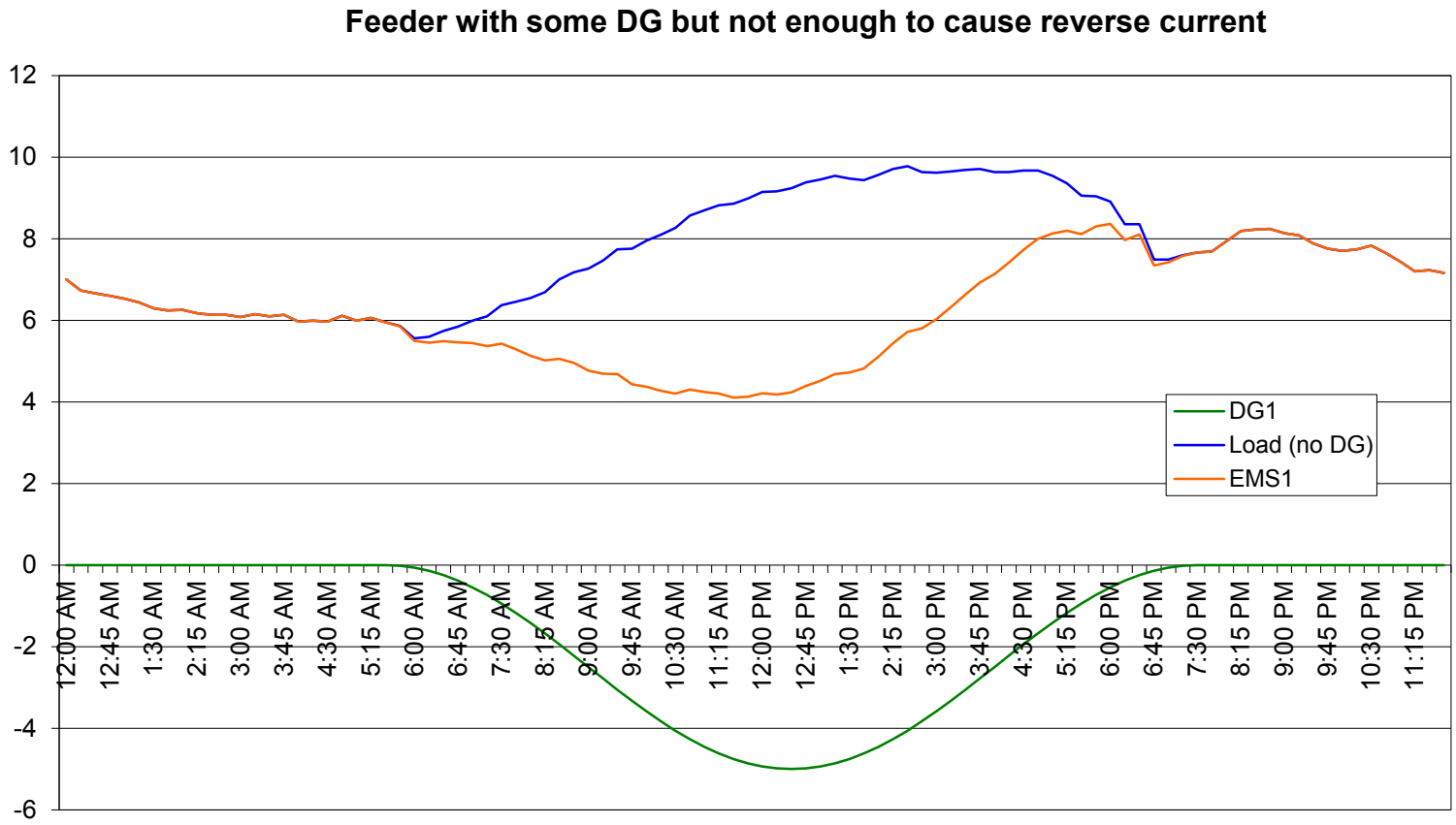
- Prior to 2013, peaks accounted for by one peak value
- This year, peaks accounted for by multiple peak values
  - Maximum Forward
  - Maximum Reverse
  - Maximum Calculated Forward with no DG
  - Maximum DG
- Allows for analysis of transformers considering maximum forward and reverse peaks

Distribution Generation – Current

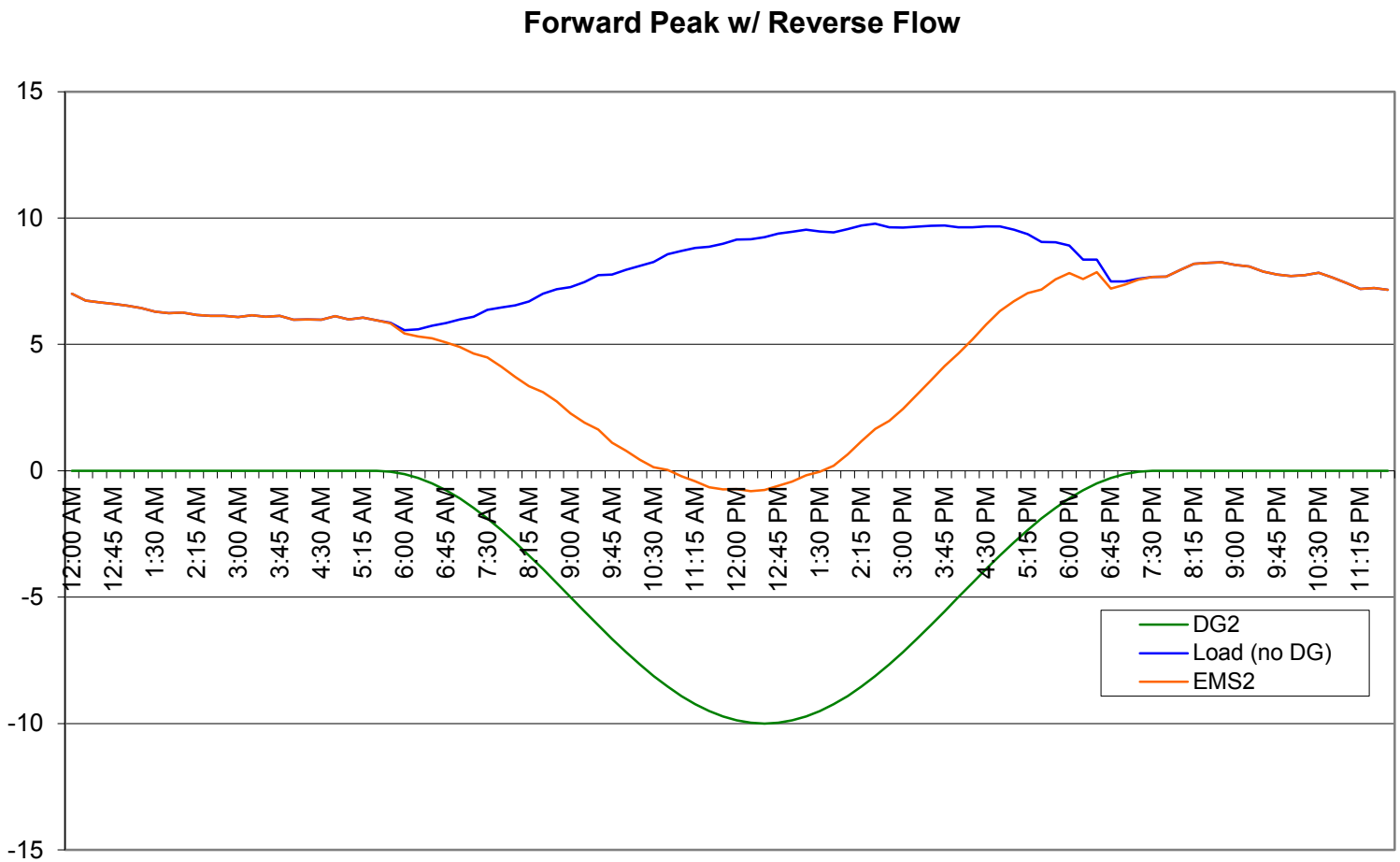
Feeder with no DG



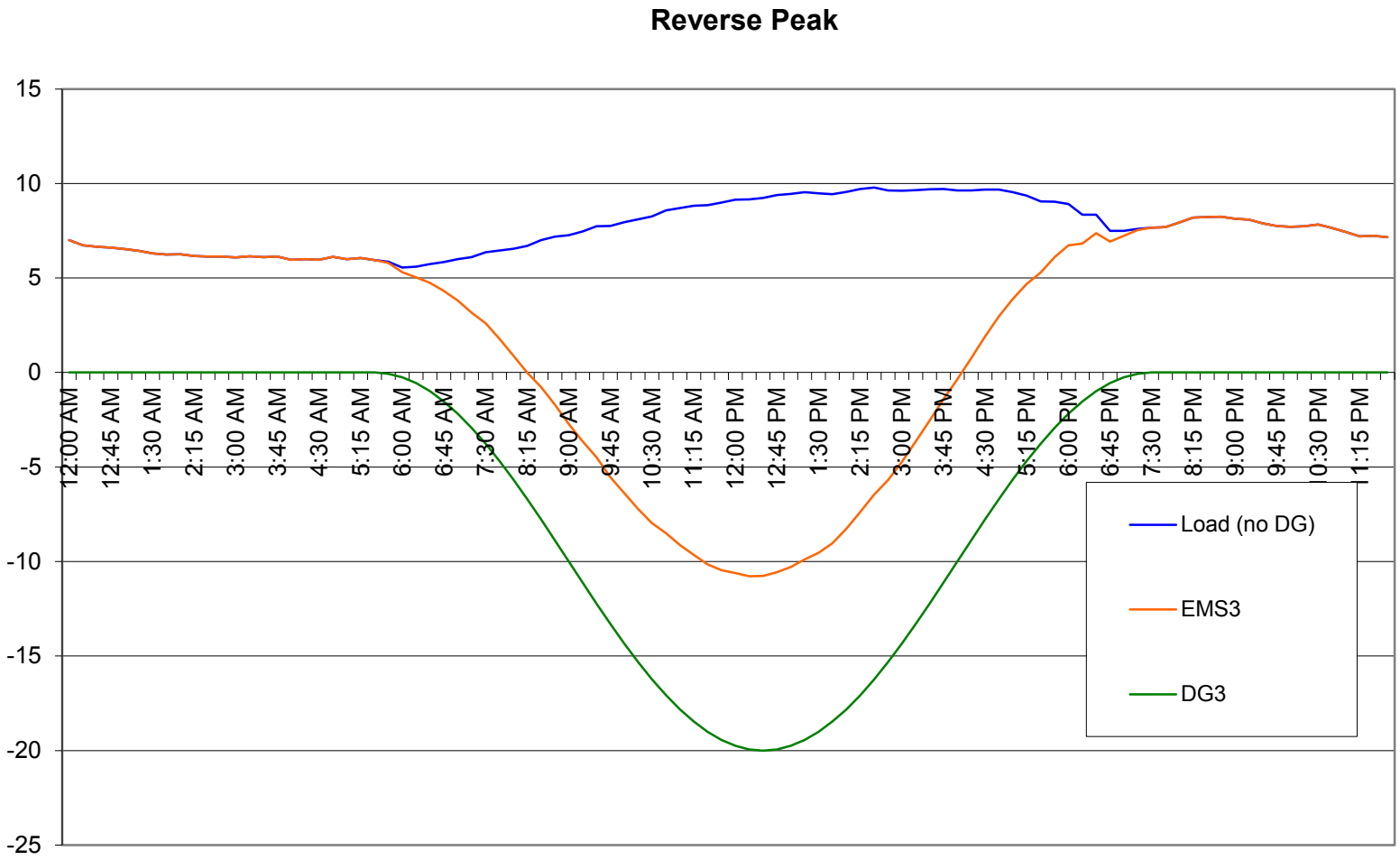
Distribution Generation – Current
Feeder with DG, no reverse flow



Distribution Generation – Current
Feeder with DG, reverse flow



Distribution Generation – Current
Feeder with DG, reverse peak



Distribution Generation - Future

- Utilize renewable feeder tool
  - Allows us to capture amount of DG on a feeder that is not strictly dedicated DG
  - Will need to determine how much DG was on at exact peak

- Other tools
  - Utilize feeder DG forecasting and visualization tools to determine amount and impact of DG on distribution feeder

Frankie Greco

Sr. Electrical Engineer, APS Interconnection

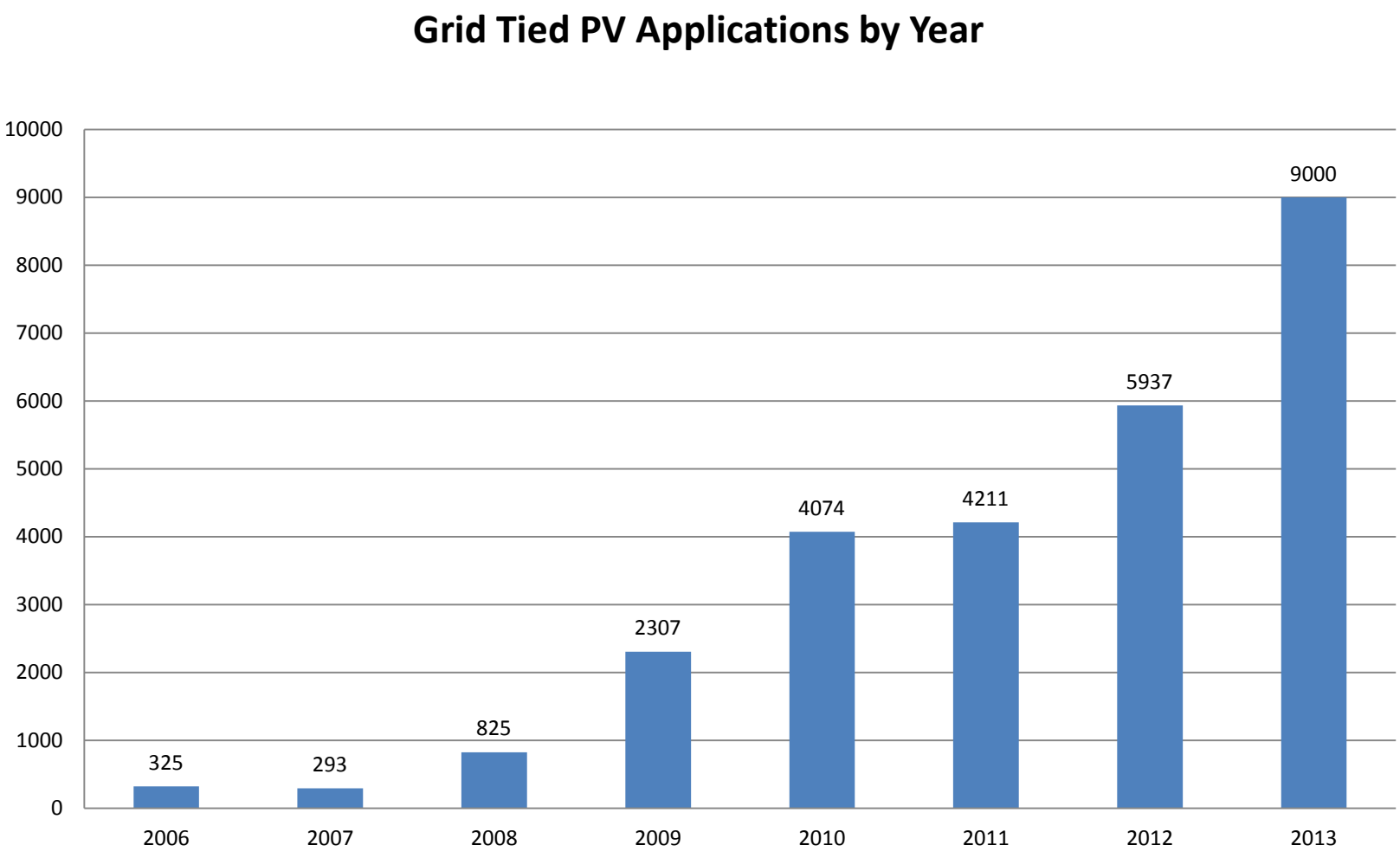
Interconnection Requirements and Lessons Learned with Power Plant Integration

Agenda Topics

APS INTERCONNECTION REQUIREMENTS

- APS Rooftop Solar Installation Numbers
- Summary of Interconnection Operation
- Standard APS Interconnection Requirements:
- Lessons Learned – The last 5 years
- Future Challenges

Distributed Generation-Photovoltaics (Residential)



Summary of Interconnection Operation

Interconnection of Generating Facilities can be any of the following:

- **Continuous Parallel – 95% of all projects fall in this category**
- Smooth Parallel Transition (normally 5-15 seconds)
- Momentary Parallel Transition (typically < 10 cycles)

Standard APS Interconnection Requirements:

Utility Disconnect Switch:

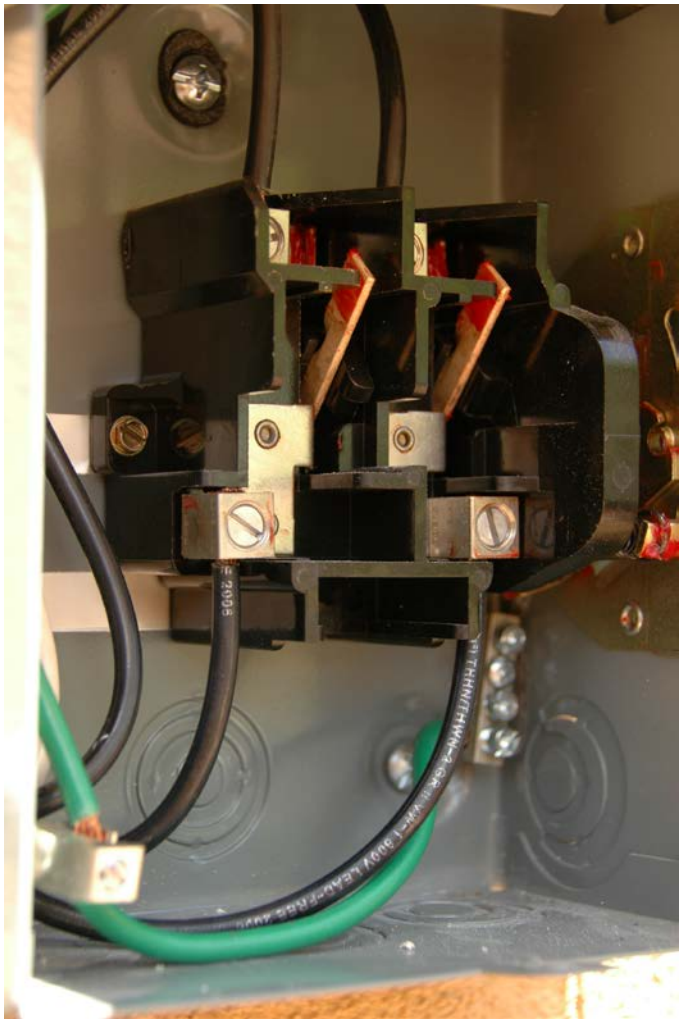
Customer must install a visual open disconnect switch in accordance with section 8.2 of the APS Interconnection Requirements

- Must be locked with an APS Padlock with a 3/8” shank.
- Shall installed and located between 36” and 60” above grade and include a 36” square clear working space.
- If the Disconnect switch is not located within close proximity to the SES, APS requires a placard at the SES with explicit directions as to the location of the disconnect switch.

Standard APS Interconnection Requirements:

Utility Disconnect Switch (cont.):

- The "Utility Disconnect Switch" blades, jaws and air gap between them shall be clearly visible when the switch is in the open position.
- Arc shields are acceptable only if they do not impede our ability to verify a visual open.
- May have fuses if required to meet available fault current.

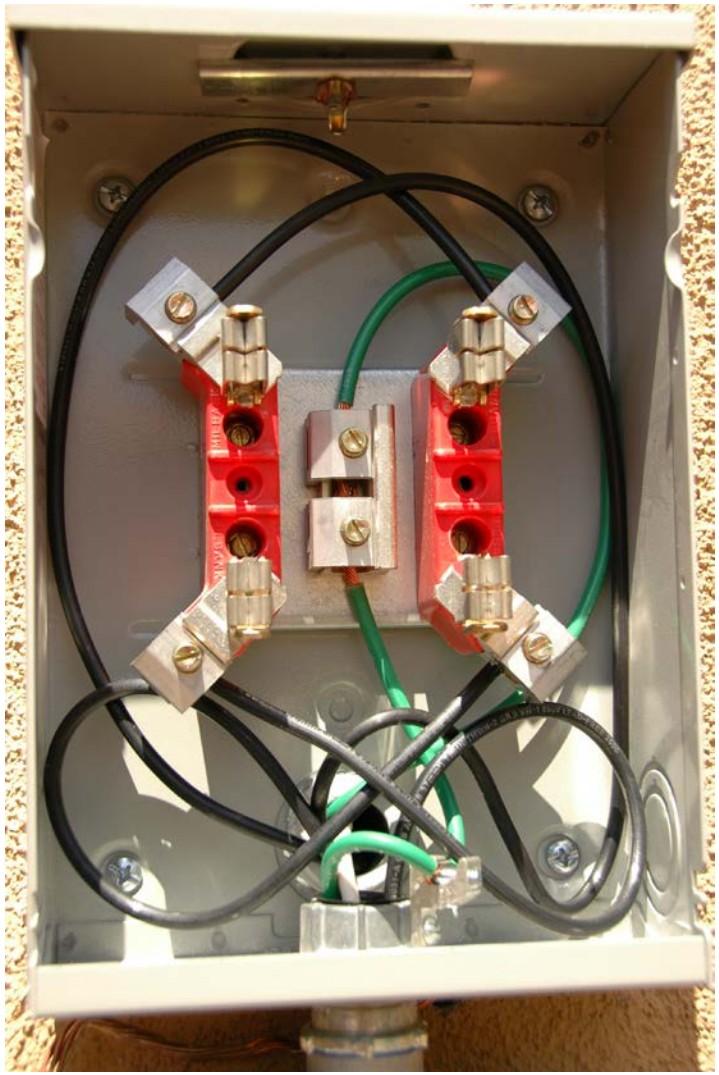


Standard APS Interconnection Requirements:

Production Metering – Section 9

Customer must provide and install, at Customer's expense, meter sockets and metering cabinets in accordance with APS service standards, in locations acceptable to APS

- 36" X 36" working space
- Meter height must be between 48" and 75" from finished grade
- Any CT rated production metering sections shall have suitable visual open disconnecting means, subject to APS Approval.



Standard APS Interconnection Requirements:

The Utility Disconnect Switch and Production Metering Enclosure shall be installed in a Readily Accessible location:

- **Readily Accessable as defined by APS:** Capable of being reached quickly and conveniently on a **24-Hour** basis without requiring climbing over or removing obstacles, obtaining special permission, keys or security clearances.
  - If access is restricted for security reasons, subject to APS approval, a lock-box may be provided to gain access to the Utility Disconnect Switch and/or Production Metering as long as the lock box is installed within 36" of the door/gate and located between 36" and 60" from finished grade.
  - The Utility Disconnect Switch and/or Production Metering Shall not be installed behind a gate, fence, wall or other barrier unless expressly agreed to by APS.

Standard APS Interconnection Requirements:

Study Process – 1MW and Larger Plants

- Any interconnection 1MW and greater (69kV and less) installed behind the load side of an APS retail customer's meter and is primarily intended to serve the customers load will require a Facilities Study.
- Customer's wishing to install a generating facility with the sole purpose to sell generation to APS and not subject to FERC interconnection process or rules will be subject to APS Service Schedule 6.
  - Three study options for customers: **Feasibility** (quick estimate, voltage deviation, red flag land issues, not more than 5 hours spent), **System Impact** (estimate, site visit, land issues, power flow and stability analysis, system upgrades), and **Facilities** (full blown estimate).
  - All Interconnections wishing to move forward (3rd Party or APS Owned) shall go through a Facilities Study.
  - An Interconnection Study Agreement shall be signed and fees paid before APS will provide an estimate to the customer.

Standard APS Interconnection Requirements:

Study Process – 1MW and Larger Plants (cont.)

- Study process may take between **90 to 120 days** depending on complexity.
- **For a Feasibility Study**, customer will get a detailed description of Sub-transmission and Distribution Power Flow Results, Substation Capacity and System Protective Devices, Description of Work Required (APS or Customer provided) and a full blown Cost Estimate including contingency.
- All Interconnected customers that are either **Behind the Meter** or subject to **APS Schedule 6 Requirements** will go through an Estimate True Up at Project Completion.

Standard APS Interconnection Requirements:

Remote Disconnect for 1MW and Larger – Section 8.8

- Any Generating Facility with an AC Nominal Nameplate Rating of 1MW or larger will be subject to APS remote disconnect and monitoring requirements
  - Customer will install an APS provided RTU enclosure.
  - Customer will provide a breaker control circuit in which APS operations has control authority over.
  - Customer will secure a communication path back to the APS communication system (i.e. VG36 leased line and/or fiber).
- Systems less than 1MW may be subject to the APS remote disconnect and monitoring requirements depending on the generation type (i.e. synchronous generation).
- **APS Operations requires remote disconnect and monitoring of larger generation sites in order to aid with forecasting/planning, load restoration efforts, and power quality concerns.**

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Standard APS Interconnection Requirements:

Remote Disconnect for 1MW and Larger – Section 8.8 (cont)

FYI – APS has installed over 32 sites within the last 5 years 1MW and larger with Remote Disconnect and Monitoring capabilities.

APS Requires an RTU (Remote Terminal Unit) and comm. equipment to handle remote disconnect and Remote Monitoring (SCADA).

Standard APS Interconnection Requirements:

Dedicated Feeder Requirements – 12kV

- Typical Triggers used to determine the need for a Dedicated Utility Feeder
  - AC Nominal Nameplate Rating greater than ½ of a typical APS distribution feeder rating **(Phoenix Metro ~ 13MW, and State ~ 10MW & less).**
  - A Rotating Machine (i.e. Synchronous Generation) normally 1MW and greater.
  - DG penetration limits of the distribution feeder will be exceeded based on the results of APS Engineering Study.
- All Generating Facilities interconnected via a Dedicated Feeder will include Direct Transfer Trip (DTT) capabilities.

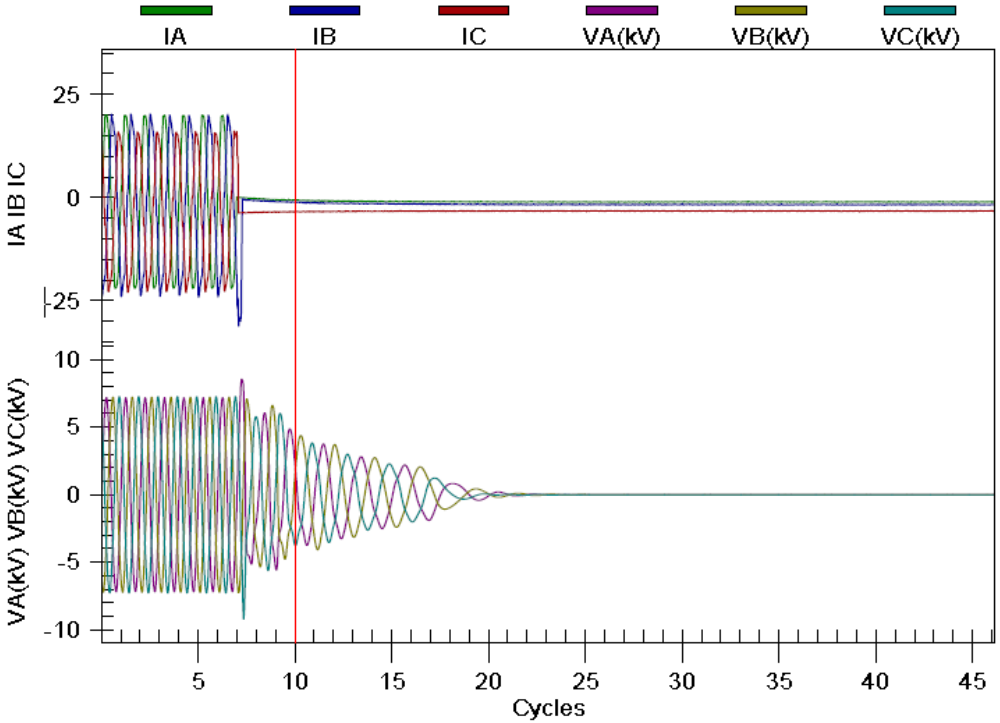
Standard APS Interconnection Requirements:

Advanced Grid Support Requirements (applicable to Utility Scale systems ≥ 10MW)

- Voltage Regulation at the Point of Interconnection (POI).
- PFC within ± 0.95 pf at POI.
- Reactive Control or VAR control mode within MVAR range.
  - VARs at Night mode if available may be activated if Grid requires it.
- **Dynamic Response to any step input within 8 seconds or less.**
- Voltage and Frequency Ride Through capability (utilizing the PRC-024-1 NERC standard).
  - Provide grid support during system sags/brown outs.
  - No trip zone between 0.90 and 1.10 pu voltages.
  - Frequency ride through utilizes the Western curves of suggested standard.
- APS Operations to determine most effective mode for plant operation and may make seasonal adjustments.

Lessons Learned – The Last 5 Years

- Sites requiring communication and control shelters are best served via a separate single phase circuit via a separate feeder.
- Systems with Power Plant Controller communication latency has been an issue with previous projects. Also, controller technology is lacking.
- Drop out testing/shut down testing per APS requirements may be difficult to achieve (no main breaker), therefore APS has been requiring a certified test report showing voltage and frequency at t = 0 and the number of cycles the plant shuts down.



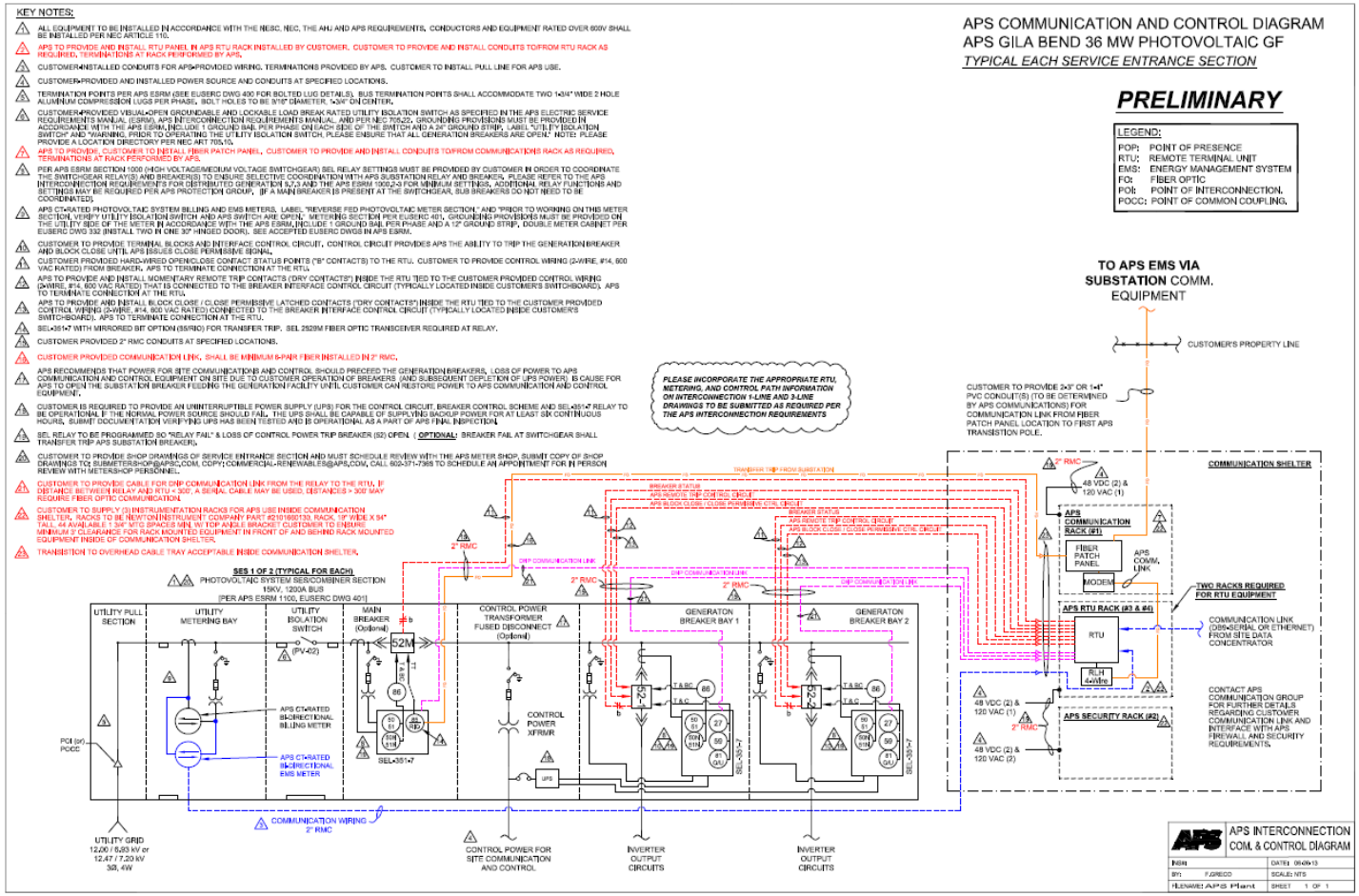
Lessons Learned – The Last 5 Years (Continued)

- Clarifying the type of switchgear (open air vs. metal clad) up front.

- Clarifying the number of metering points required and following up with customer shop drawing submittal prior to equipment installation.

Lessons Learned – The Last 5 Years (Continued)

- Communication and Control template was developed to eliminate possible mix ups with control circuitry (remote disconnect, DTT/F.O., remote monitoring/Comm., DNP, Engineering Access) and other equipment necessary for utility scale and behind the meter generation sites.



Lessons Learned – The Last 5 Years (Continued)

- Tracking technology shall be installed to capture the afternoon sun (APS Peak).
- Ground treatment for weed control is recommended.
  - APS Provides weed treatment on an annual basis for all APS Owned plants.
- Inverters with modular design to aid with O&M/downtime of equipment.
- Inverters to represent 5% - 10% of plant to minimize downed inverter output during maintenance.
- Most plant failures occur at the switch-gear level, suggest spending a bit more money and time in ensuring a more robust switch-gear is installed.

APS Future Challenges

- Some Challenges:
  - Smart Grid interoperability
    - Smart inverters
      - » Interconnection and Communication Standards
      - » Ownership issues
  - Solar Forecasting / Resource Planning
  - Load management under High Penetration scenarios
    - Feeder reconfigurations
  - Distribution Planning for High Penetration scenarios
  - Tools and Capabilities:
    - DOE High Penetration study
    - In-house tools
      - » Feeder loading tool
    - Training
    - Education / awareness
      - » Training internal and external personnel
  - Building the infrastructure to control numerous different Distributed Resources (DR).
    - Whom will have control and what O&M requirements will APS need to implement.

David Narang
Sr. Engineer, Technology Assessment

Tools And Capabilities for Integration of Distributed Generation

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Agenda

- Goals
- Baseline
- Gaps– Learnings from DOE HPSD Study
- Next Steps

Big Picture Goals for Integration of Distributed Generation

Determine/Develop Level of Capability Needed:

- Grid Operations
  - during normal ops and emergencies,
  - distribution & transmission,
  - load management, safety, reliability, interconnection standards
- System Planning
  - distribution & transmission
- Fleet Dispatch/Power Marketing & Trading
  - aggregated forecast, resource planning
- Utility Equipment Interoperability
  - existing - voltage profile – voltage regulators, cap banks
  - new – smart inverters, IVVC, energy storage
- IT/Infrastructure Requirements
  - Field hardware/communications
  - IT/back-end tools & processes, presentations/dashboards

Agenda

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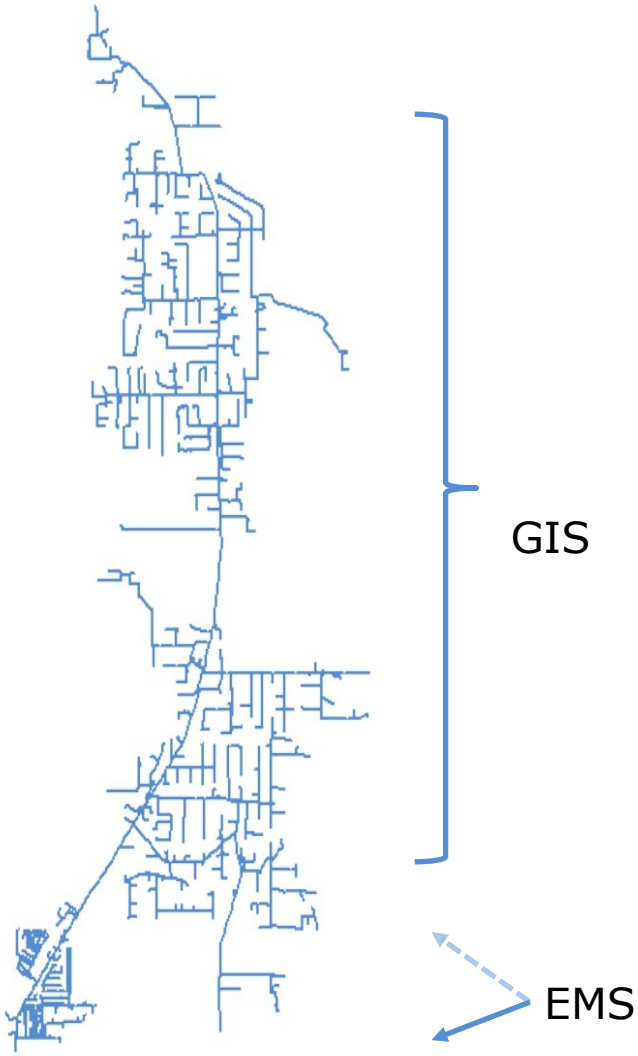
Integration of Distributed Generation

Current Baseline



Situational Awareness

feeder topology (GIS)

feeder historic peak load (manual process - annual)

substation transformer loading (EMS)

equipment status/state/settings (mix – EMS, manual)

- reclosers, cap banks, fuses

Power System Studies & Tools

steady-state

- load (power) flow (FeederAll - Asset Mgmt)
- short-circuit/protection coord (manual? PMAC)

dynamic

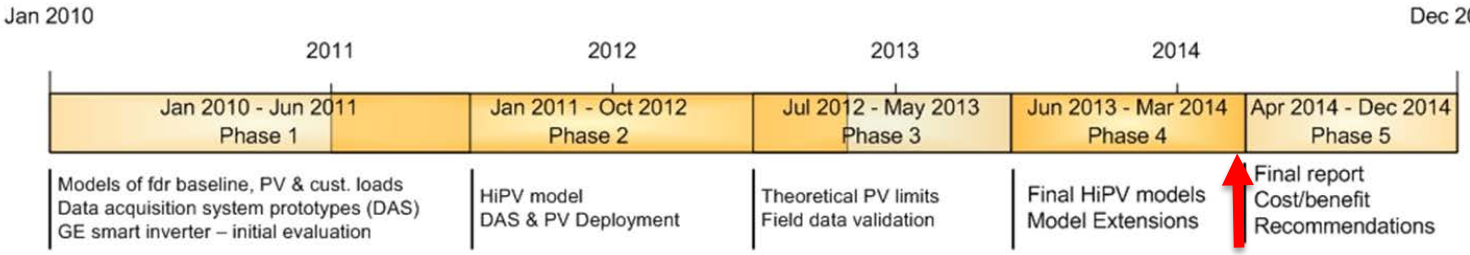
- voltage stability (PSLF – Transmission Planning)

Agenda

- Goals
- Baseline
- Gaps– Learnings from DOE HPSD Study
- Next Steps

DOE Hipen Study Project Objectives

- Determine how high penetration PV affects a working utility distribution feeder
- Validated feeder, PV Inverter and load models
- Data acquisition methodology and field deployment
- High penetration PV paired with grid-support inverter and energy storage



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Key Findings from DOE HPSD Flagstaff Project

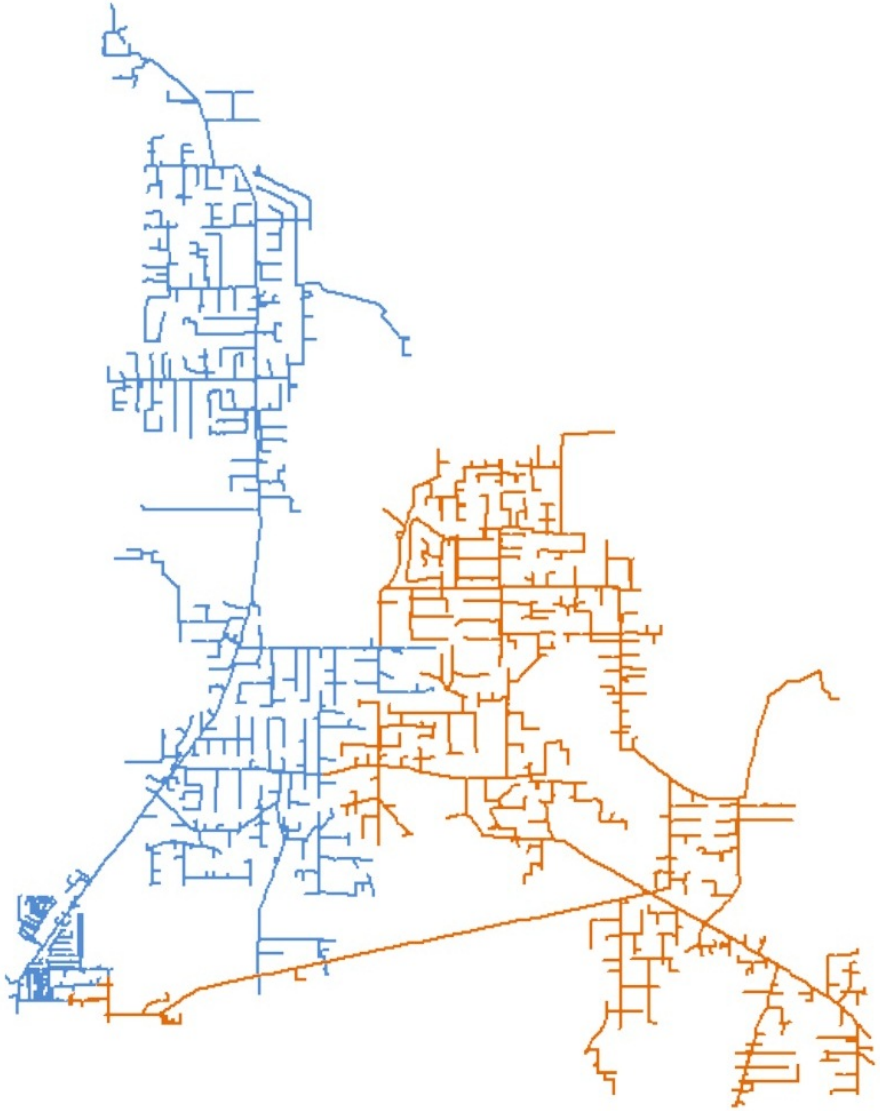
- The greatest voltage change does not coincide with the largest PV site
- Do not overlook the impact of distributed PV
- Watch out if placing large PV sites in areas of high susceptibility
- Variability due to load may far exceed variability from PV
- Percent penetration is not the most effective metric for determining impact of PV systems
- Effect of PV systems are dependent on feeder topology and no two feeders are alike
- Modeling at different timescales is necessary for answering different questions and requires different tools and training

Agenda

- Goals
- Baseline
- Gaps– Learnings from DOE HPSD Study
- Next Steps

Integration of Distributed Generation

Next Steps – Development / Integration of Tools & Capabilities



Situational Awareness

feeder topology (GIS)
- equipment specifications/ratings
- DG size, location, orientation, specifications
- DG point of interconnection "stiffness ratio"
- adjacent feeder characteristics

feeder historic peak load (manual process - annual)
- feeder minimum daytime load

substation transformer loading (EMS)
- measurements interior to feeder

equipment status/state/settings (mix – EMS, manual)
- reclosers, cap banks, fuses
- settings for dynamic voltage control devices

solar irradiance
- historic, real-time, forecast

Power System Studies & Tools

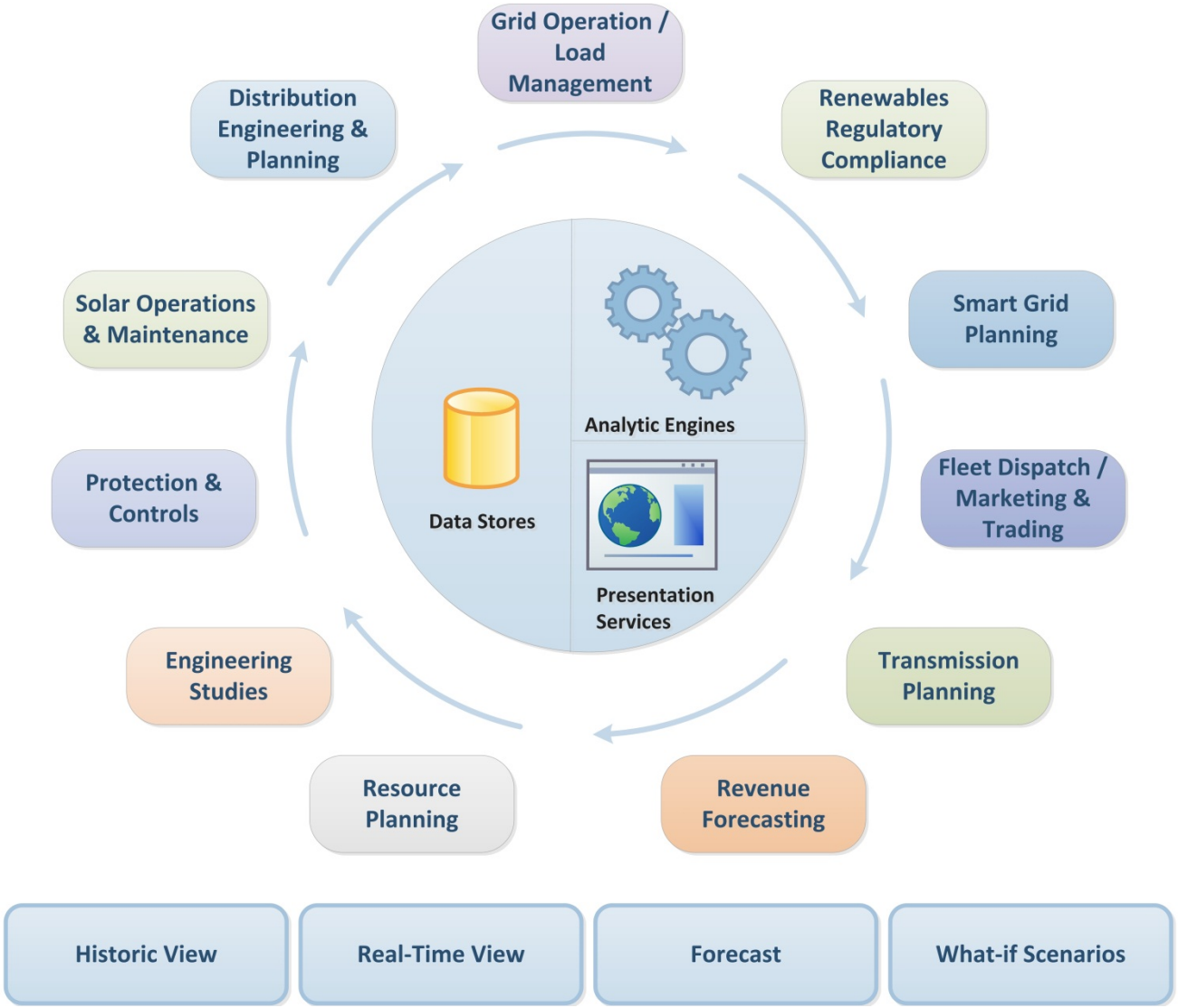
steady-state
- load (power) flow (FeederAll - Asset Mgmt)
- short-circuit/protection coord (manual? PMAC)
- feeder PV hosting capacity

dynamic
- voltage stability (PSLF – Transmission Planning)
- interactions between smart grid devices

advanced scenarios
- optimal location & size of energy storage
- control settings for smart inverters
- feeder reconfiguration
- microgrid applications
- aggregation of DG, forecast

transients
- harmonics

Application to APS Business Processes



References and Sources for Further Information

APS Requirements:

1. APS "Interconnection Requirements for Distributed Generation" http://www.aps.com/dg http://www.aps.com/main/green/choice/choice_79.html
2. APS "Electric Service Requirements Manual" (ESRM) http://www.aps.com/esrm
3. APS Service Schedules http://aps/RRC/Pages/ServiceSchedules.aspx

Additional Resources:

1. NFPA 70, NEC 2011 National Electrical Code
2. NERC Standards (PRC-024-1) http://www.nerc.com/pa/Stand/Pages/AllReliabilityStandards.aspx?jurisdiction=United States
3. DOE Sunshot - High Penetration Solar Deployment Projects: https://solarhighpen.energy.gov/projects/doe

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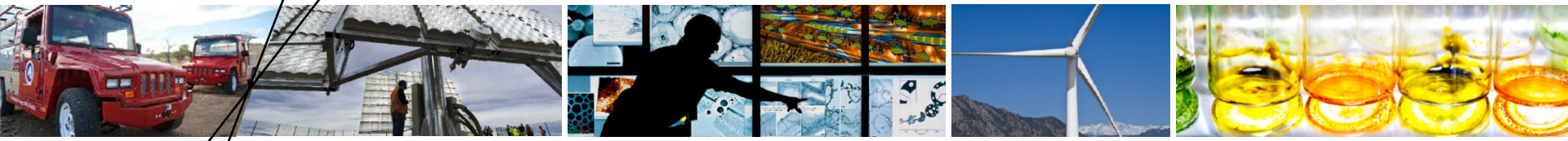

Thank you!

http://www.nrel.gov/tech_deployment/dgic.html