High Penetration Solar Forum

March 2011

High Penetration of Photovoltaic Generation Study – Flagstaff Community Power

DOE Grant #: DE-EE0002060

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Arizona Public Service Company

Presentation Overview

- Project Context
  - APS & Renewable Energy
  - Distributed energy in particular
- Project Focus
- Sponsors and Partners
- Key Deliverables
- Overall Study/Milestones
- Work to Date
  - Modeling
  - Data Acquisitions
  - Smart Inverter

Arizona Public Service

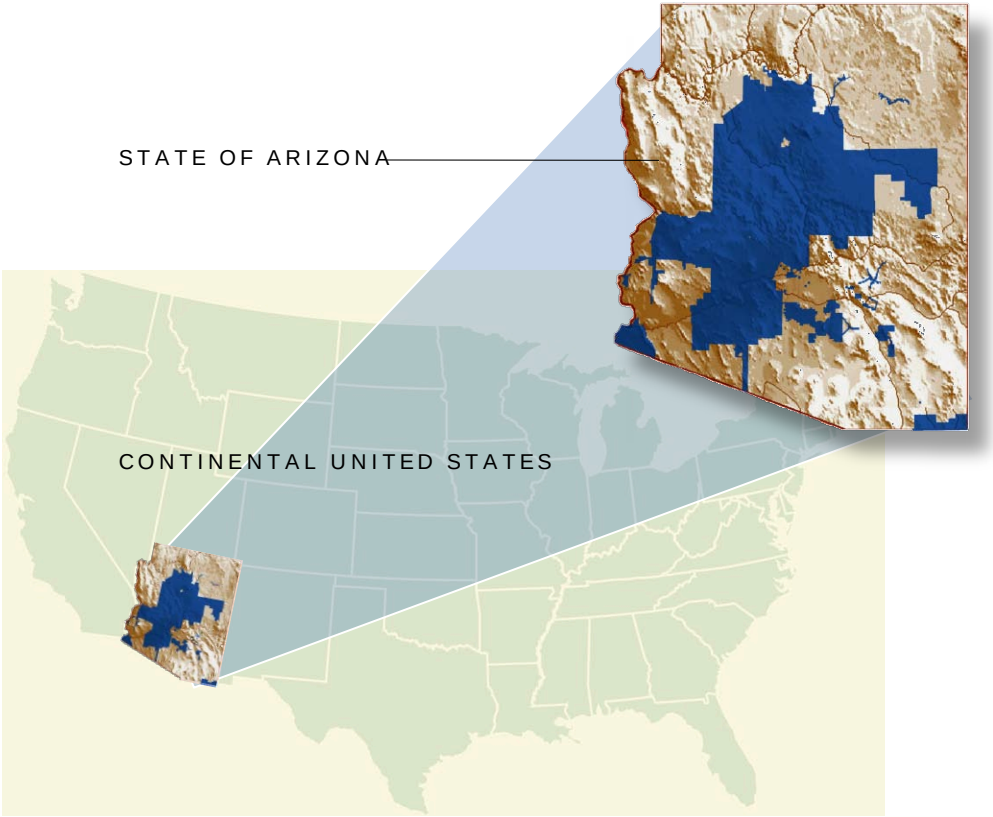
APS is Arizona's largest and longest-serving electric utility.

Service Territory
- 1.1 million customer accounts
- 34,646 square miles

Customer Growth
- 1% average annual growth expected through 2012
- 3-4% historical average — well above industry average

Resources
- 6,293 MW owned/leased capacity
- 2,454 MW contracted conventional resources
- 605 MW contracted renewables

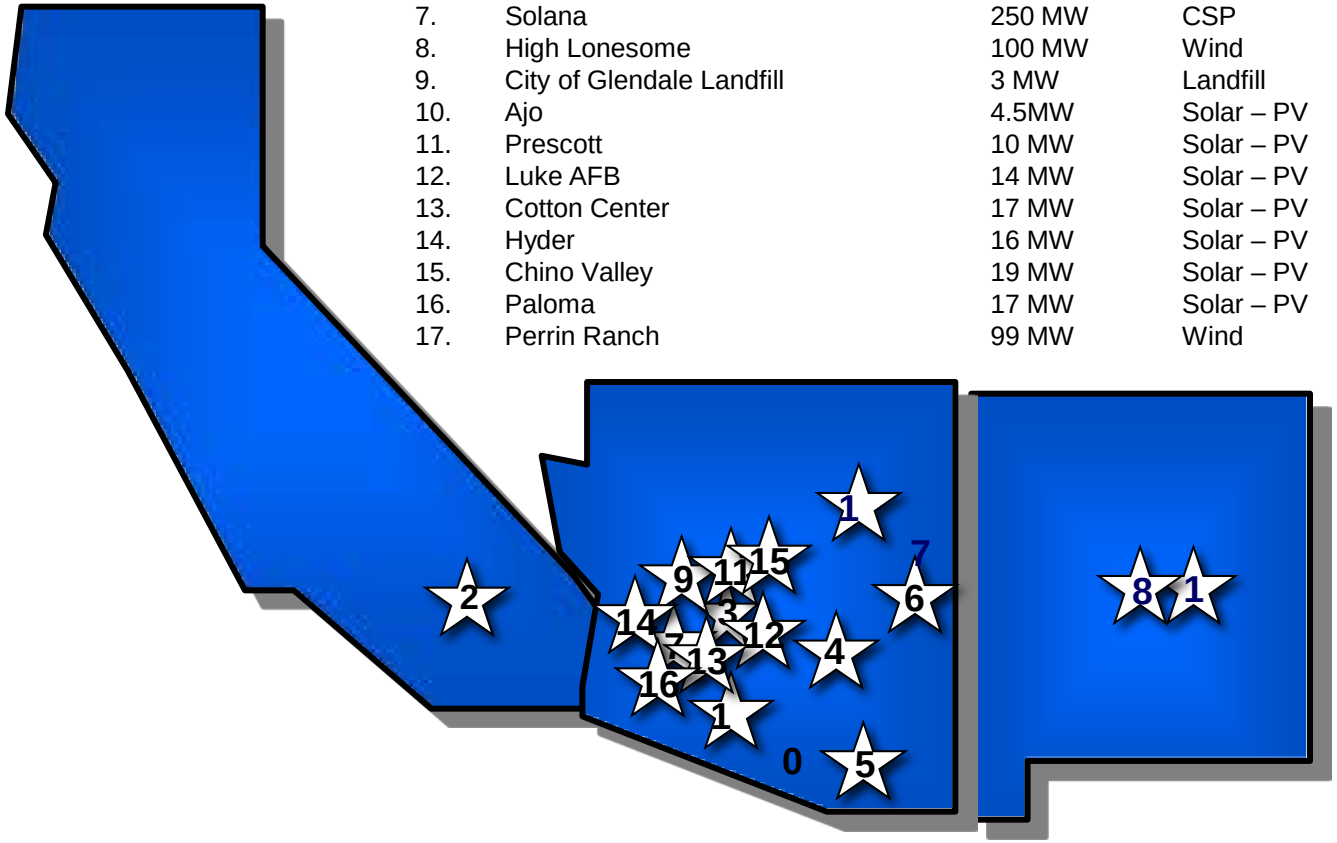
2010 Peak Demand – 6,936 MW



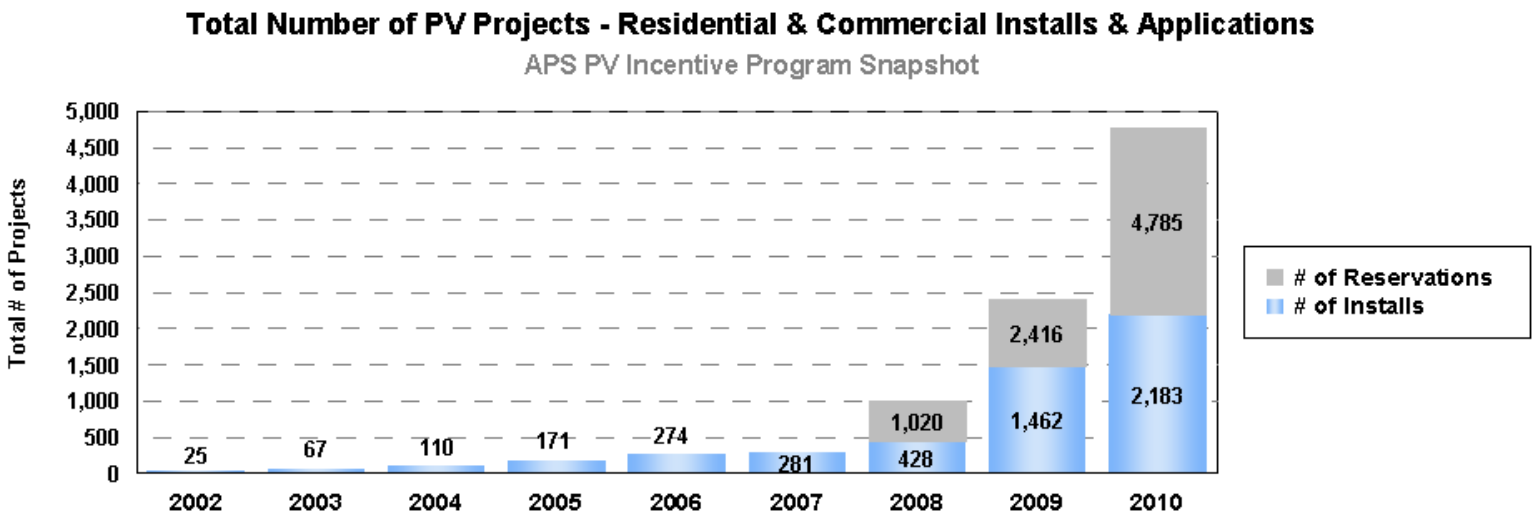
APS Renewable Generation - Current Portfolio

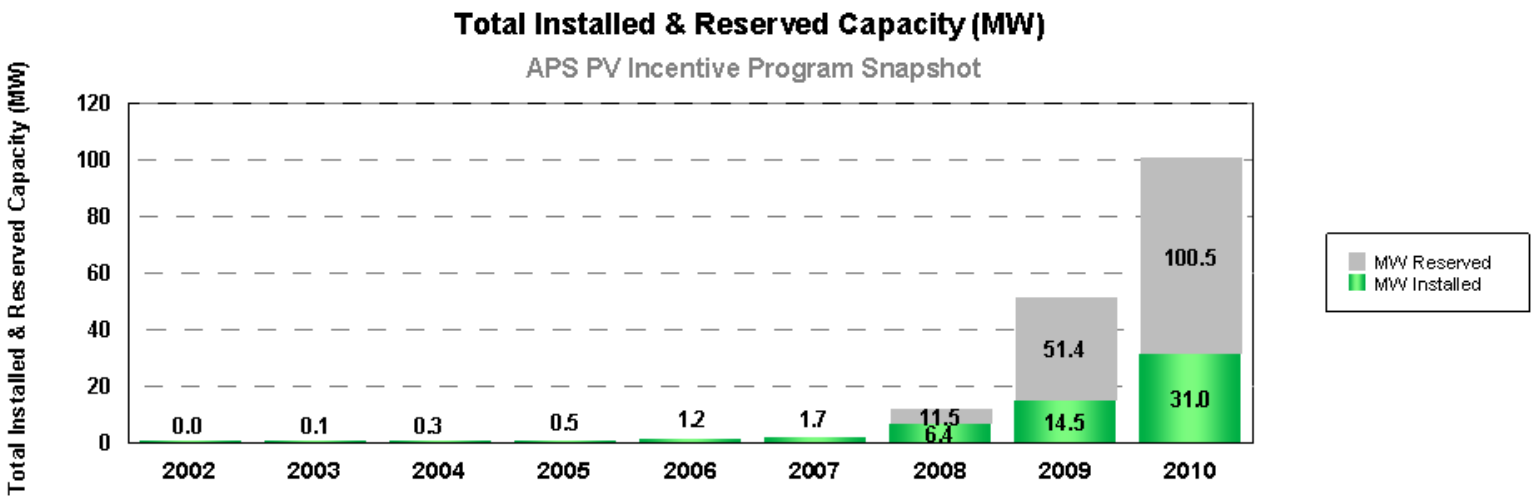
Current Capacity Contracted - > ~600 megawatts (MW)

Projects		Net Capacity	Type	Status
1.	Aragonne Mesa	90 MW	Wind	In operation
2.	Salton Sea	10 MW	Geothermal	In operation
3.	Prescott Airport	3.6 MW	Solar - PV	In operation
4.	STAR Center (and other AZ sites)	1.0 MW	Solar - PV	In operation
5.	Saguaro	1 MW	CSP	In operation
6.	Snowflake White Mt.	15 MW	Biomass	In operation
7.	Solana	250 MW	CSP	Under development
8.	High Lonesome	100 MW	Wind	In operation
9.	City of Glendale Landfill	3 MW	Landfill	In operation
10.	Ajo	4.5MW	Solar – PV	Under development
11.	Prescott	10 MW	Solar – PV	Under development
12.	Luke AFB	14 MW	Solar – PV	Under development
13.	Cotton Center	17 MW	Solar – PV	Under development
14.	Hyder	16 MW	Solar – PV	Under development
15.	Chino Valley	19 MW	Solar – PV	Under development
16.	Paloma	17 MW	Solar – PV	Under development
17.	Perrin Ranch	99 MW	Wind	Under development



Distributed Energy Context





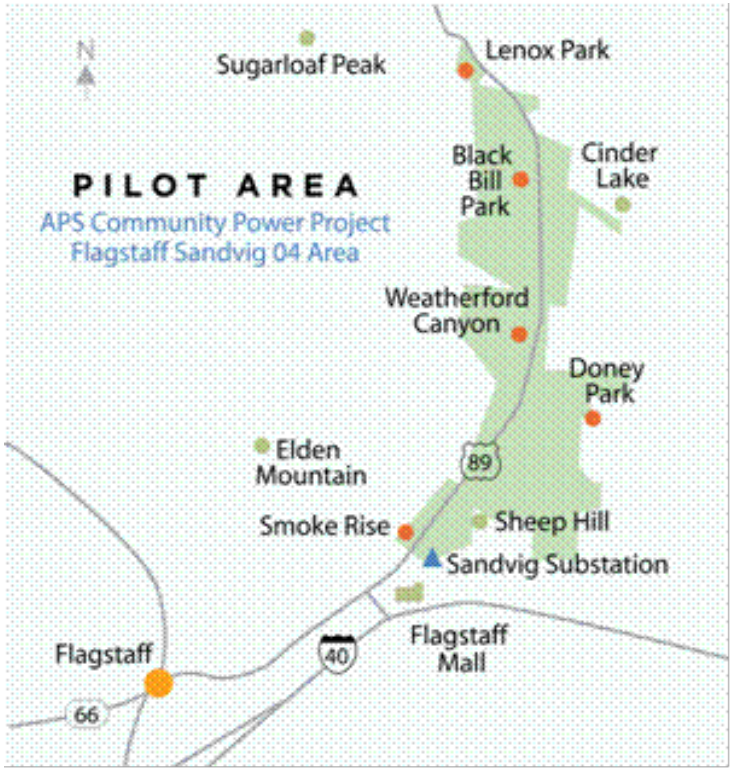
Community Power Project Background

Primary Objective:

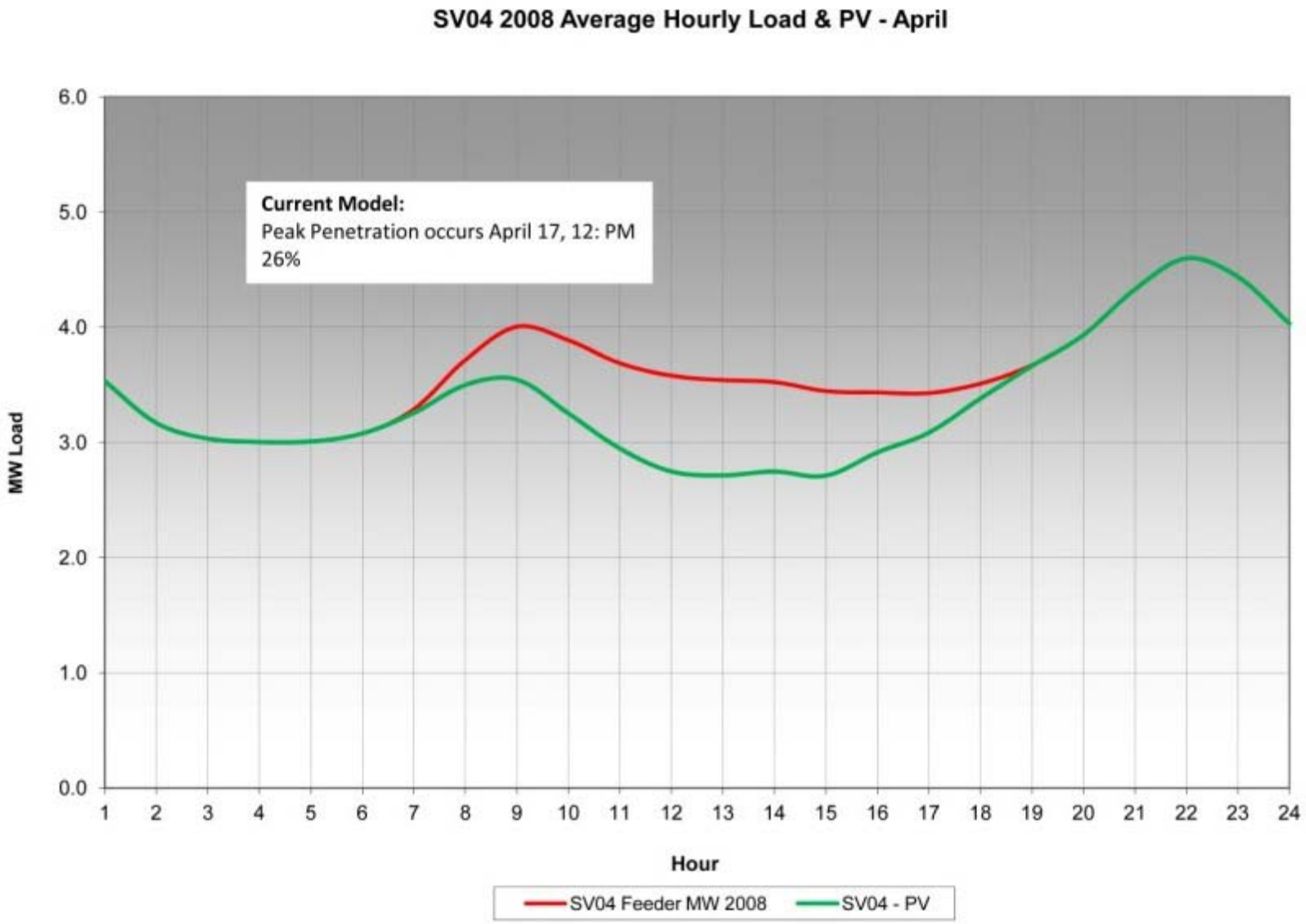
Determine how high penetration of PV affects a working utility distribution feeder

Study Focus Areas:

- Feeder Models
- Data Acquisition Platform
- Grid Support Measures (complementary to PV)



Expected % PV Penetration (preliminary)



Project Sponsors and Partners

US Department of Energy
Arizona Public Service Company
Arizona State University
GE Global Research
National Renewable Energy Laboratory
ViaSol Energy Solutions
Arizona Corporation Commission
Flagstaff Customers
PV deployment partners/installers

Key Deliverables

- Validated feeder models
  - Existing baseline, high penetration, future feeders?
- Development of high penetration PV data acquisitions methodology and hardware/software configurations to:
  - measure effects of/on PV, weather, feeder & customer load
  - address concerns of interconnections/safety, grid operations, O&M, study, other stakeholders
- Study/report on high penetration PV paired with grid-support inverter
- Study/report on high penetration PV paired with energy storage
- Share results!

Study Phases and Critical Milestones

Phase 1 (Dec 31, 2009 – Dec 31, 2010 – extended to June 30, 2011)

1. Base model of feeder, PV, and customer loads
2. Data acquisition system prototypes
3. Utility-scale inverter – initial evaluation at APS-STAR

Phase 2 (Jan 1, 2011 – Dec 31, 2011)

1. High PV penetration feeder model
2. Data aggregation methodology
3. PV inverter safety schemes
4. Utility-scale inverter field deployment

Phase 3 (Jan 1, 2012 – Sept 30, 2012)

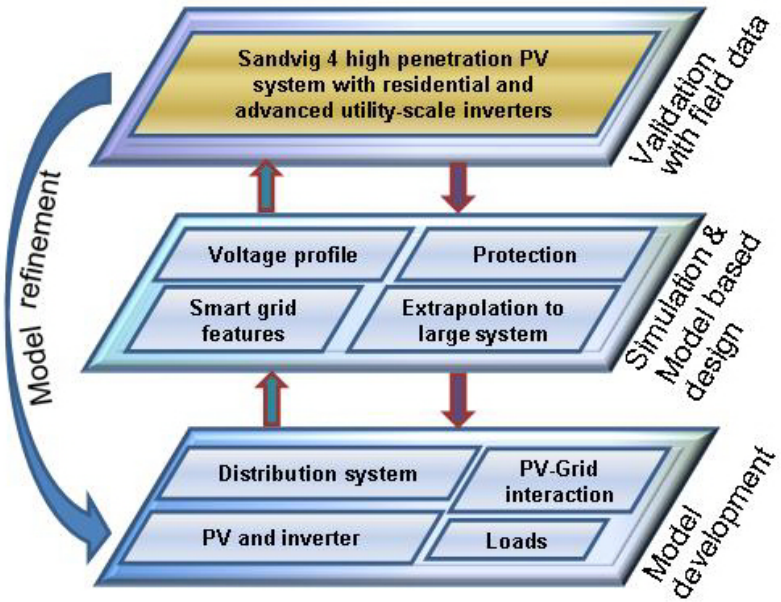
1. Theoretical limits of PV penetration
2. Field data validation

Phase 4 (Oct 1, 2012 – Jun 30, 2013)

1. Final high PV penetration models
2. Model extension (battery, microgrid)

Phase 5 (July 1, 2013 – Mar 31, 2014)

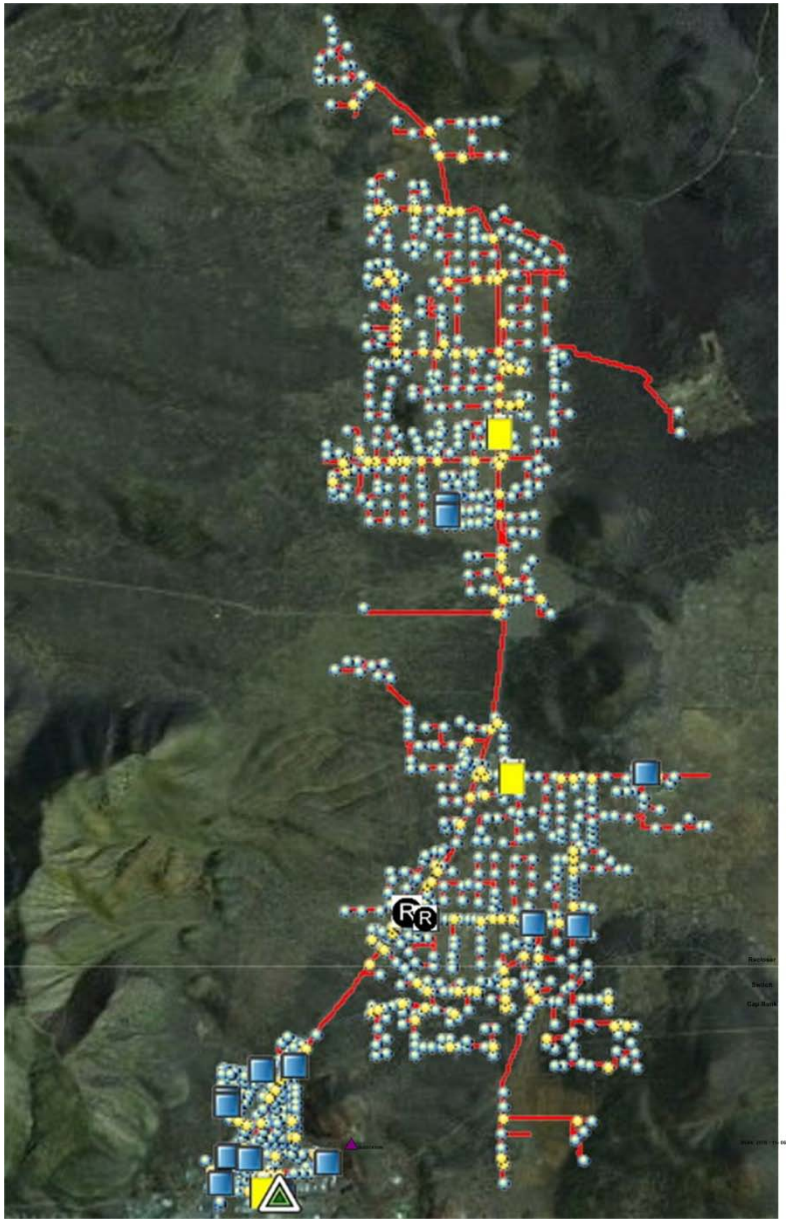
1. Final recommendation for future study/deployment
2. Final data sharing



Modeling Task Details

Background - Feeder Information

- Located in Flagstaff, AZ
- Radial feeder 8.5 miles long
- Maximum capacity: ~13 MW
- Peak load: ~10 mw
- 2 Reclosers
- 3 Switched capacitor banks
- other details in slides to follow



APS COMMUNITY POWER PROJECT

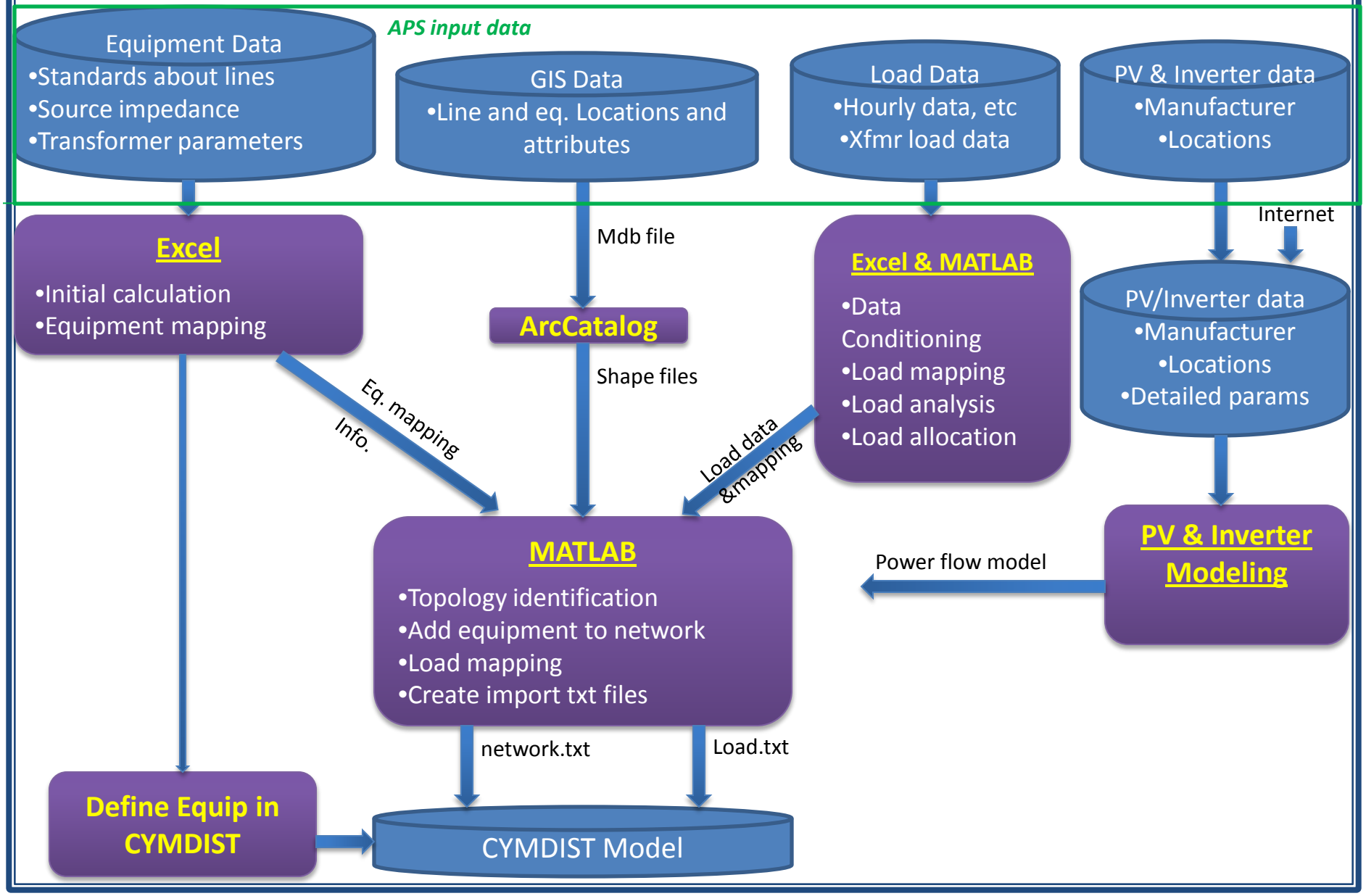
Flagstaff

Work To Date - Modeling

- Feeder Baseline
  - Completed initial baseline using CYMDIST,
  - Validation has started
- Customer Loads
  - Completed 1st run at developing 8760 load shapes
  - Validation has started
- PV
  - Early stages of analysis

Feeder Baseline Model

Modeling Process – Feeder Baseline

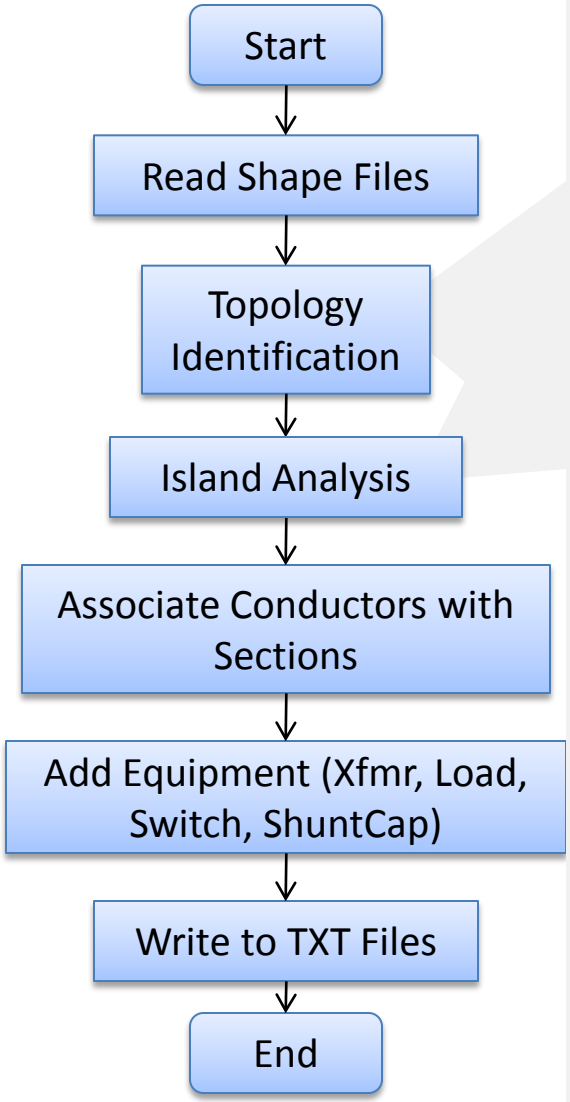


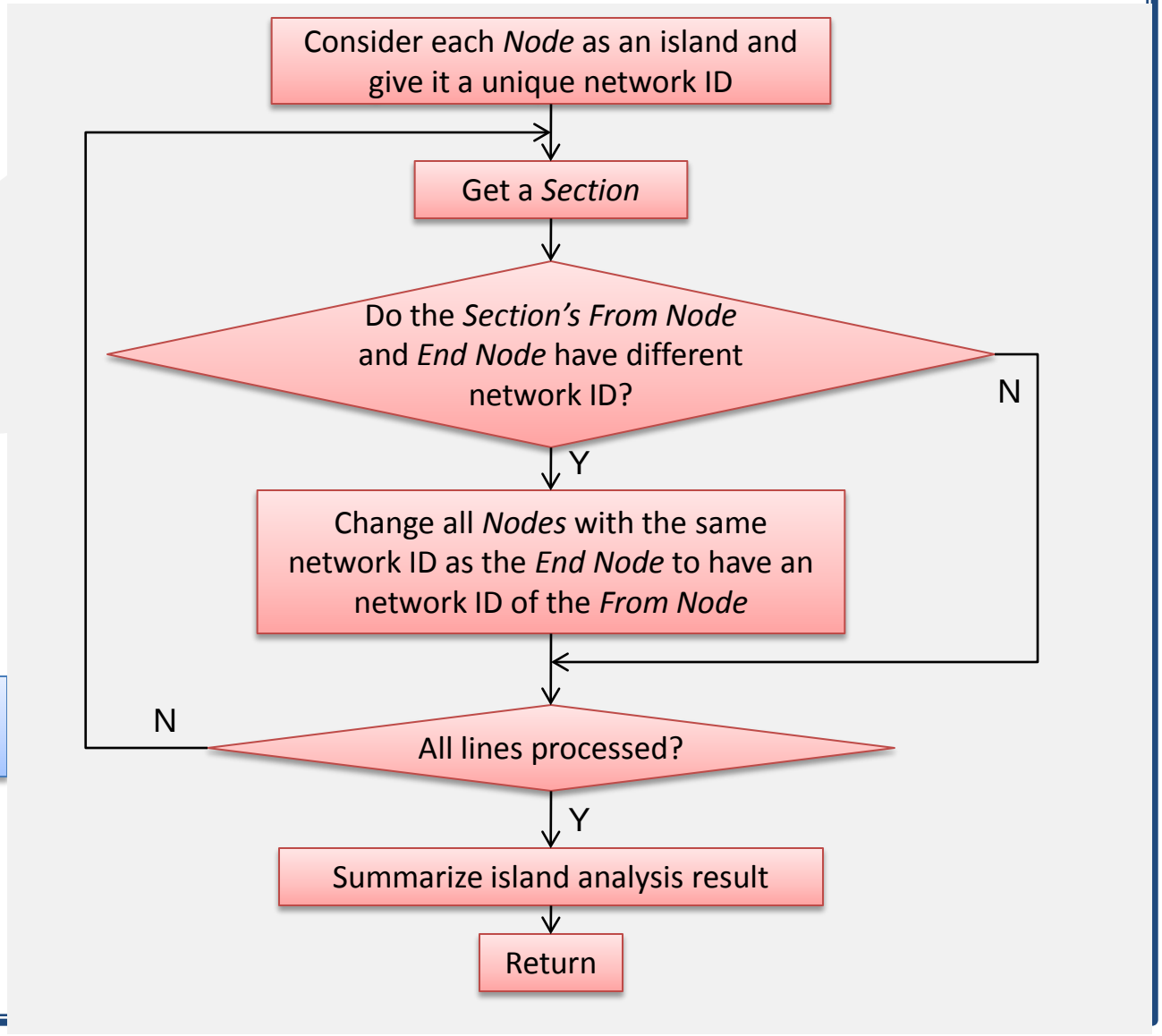
Feeder Details (Equipment Library Elements)

Equipment Name	Total Number	Legend
Feeder segment	1809	Red line
Transformer	921	Blue dot
Fuse	186	Orange dot
Capacitor bank	3	Blue pushpin
Switch	18	Green pushpin
OCR	2	(not shown in fig)
Switching cabinet	66	(not shown in fig)
Voltage regulator	0	None on this feeder

Feeder Network Model Development

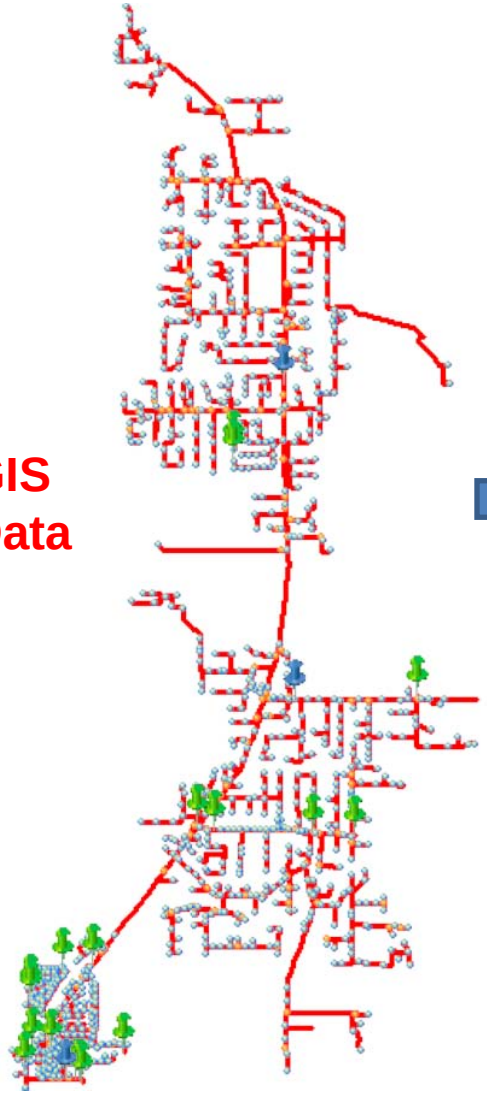
(Auto. converting GIS data to CYMDIST model)





Feeder Modeling Outcome

GIS Data



MATLAB Program

CYMDIST Model

Load Modeling

Modeling Overview – Loads

- **GIS data (topology)**
- **Equipment (conductors, fuses, switches, caps…)**
- **Transformers**

Matlab, Excel, CEPS, CYMDIST, ArcGIS Explorer

Master Tables

Matlab, Excel, CYMDIST or COM

CYMDIST Ref Case

Net-load Tables

COM

Load Analysis

- EMS load
- End-use load
- Inverter location and capacity
- Solar forecast

- Analyze feeder load
- Extract statistical props
- Allocate

- Analyze forecast data
- Extract statistical props
- Allocate

1 **Data Preparation**

2 **Model Development**

3 **Temporal analysis**

4 **Documentation & Report**

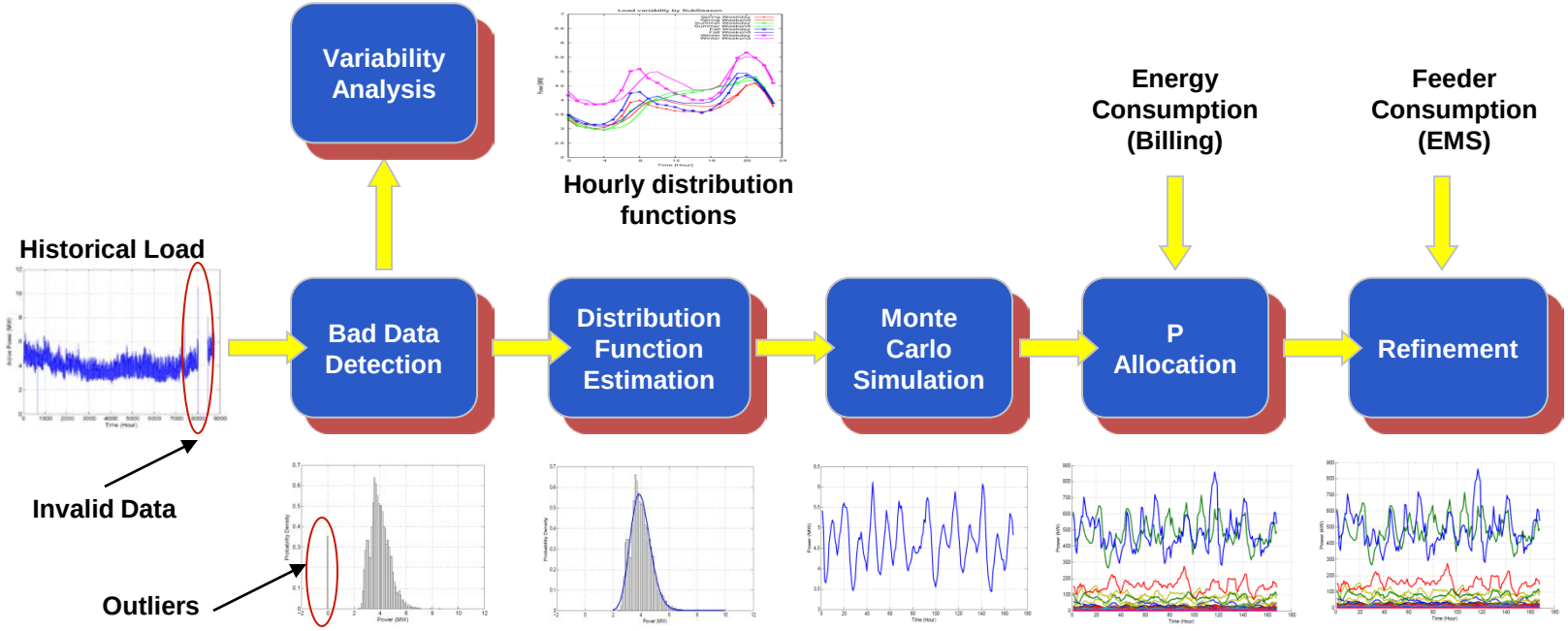
- Calculate line parameters
- Validate feeder topology
- Locate equipments
- Locate dist. transformers
- Estimate spot loads

- Build nodes and sections
- Associate conductor with section
- Add equipments
- Add spot loads

- Analysis under hourly load profile
- Impacts of solar generation on:
  - o Voltage profile
  - o Reactive demand
  - o Capacitor switching
  - o Losses

Teams synchronized at these points

Load Analysis – process map



Historical load profiles analyzed to extract trends:

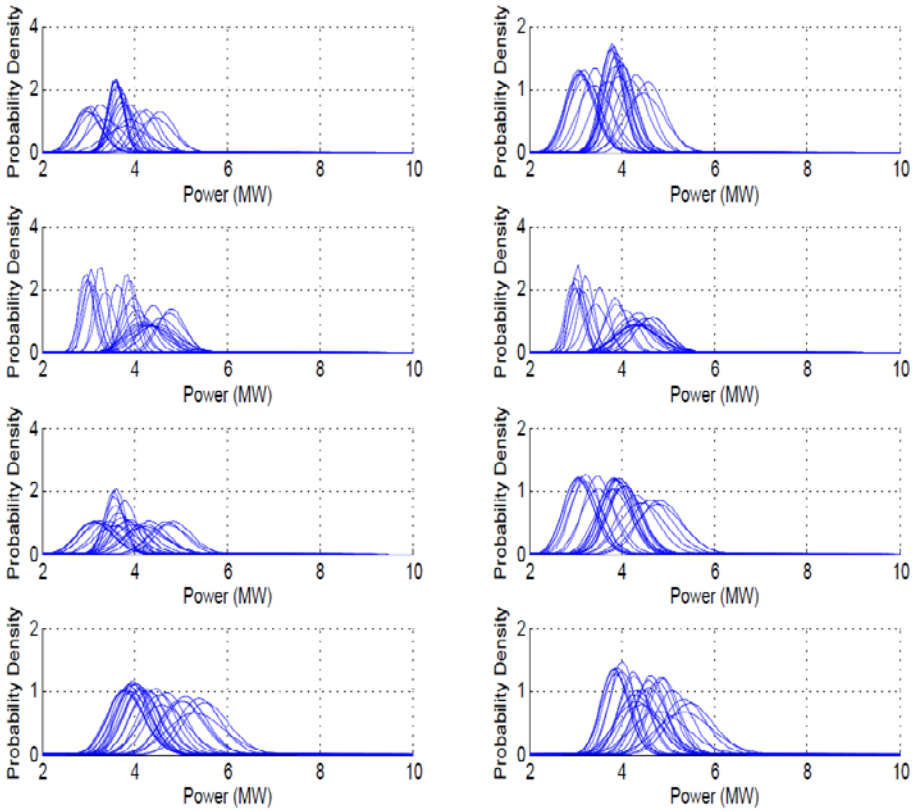
- Data separated by season and day of week
- Individual statistical distribution function assigned to every hour

Load assigned by customer class based on actual billing data

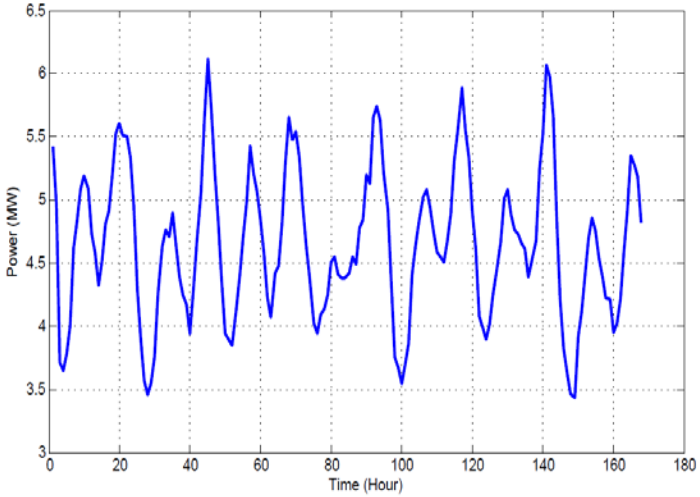
Total load scaled to fit similarly processed feeder head-data

Load Allocation - sampling

Estimate distribution function for each category of each hour



Monte Carlo Simulation

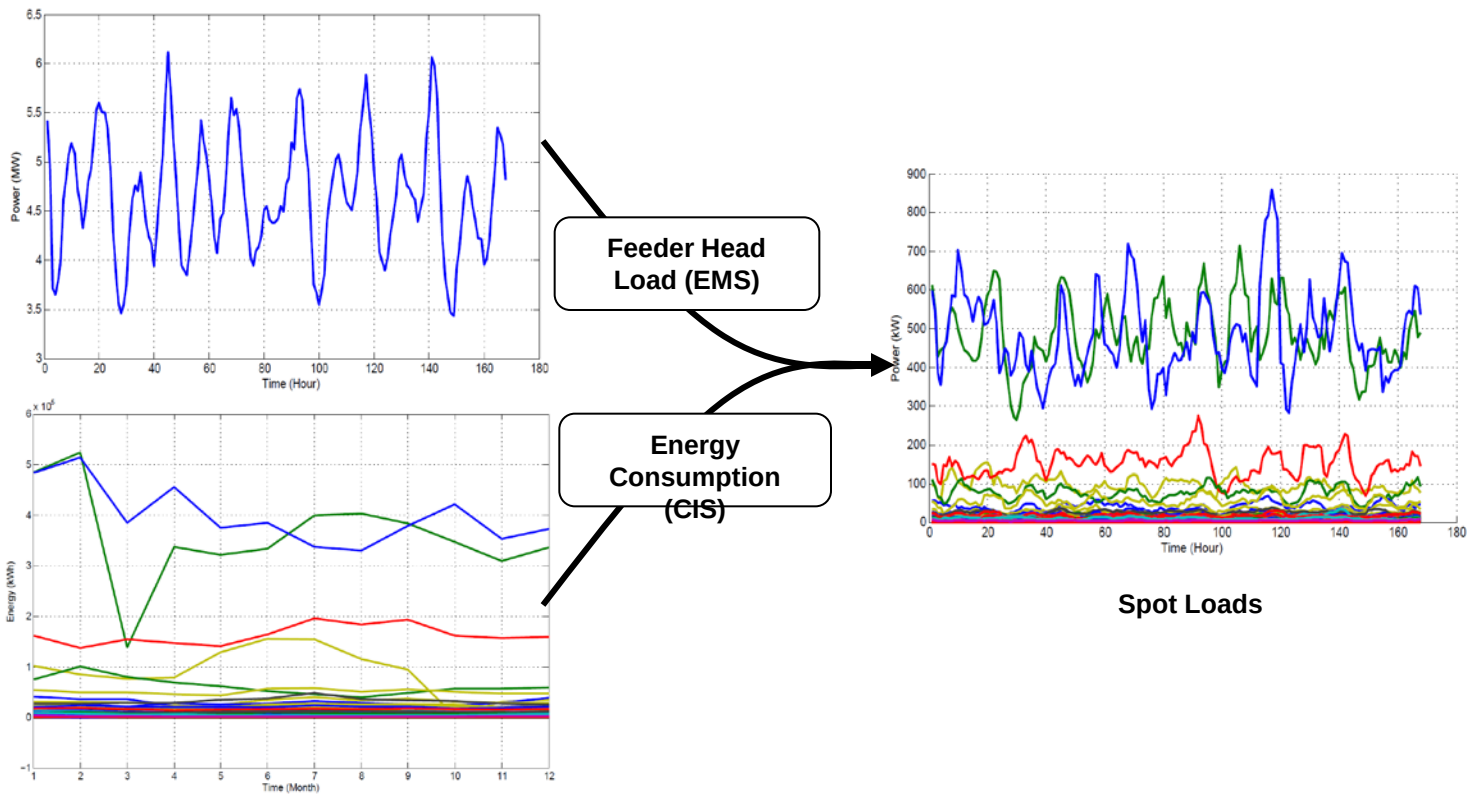


Estimated Distribution Functions

Sampled Load – one week

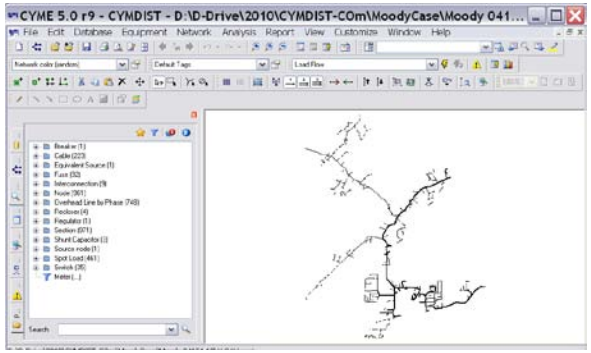
Load Allocation - scaling

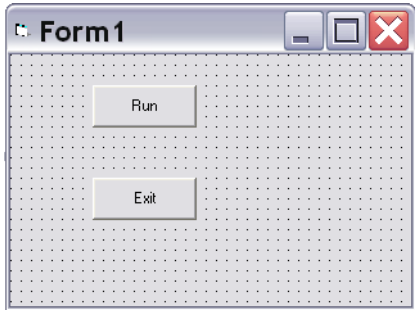
1. Sample spot loads from corresponding distributions (load research)
2. Normalize scaling factors by energy consumption (billing)
3. Rescale to match expected total (EMS)



COM for Temporal Analysis

- **Scenarios where COM is required:**
- To simulate load flow based on year-round substation load measurements
  - 8760 power flow cases to run
- To change all the feeder loads at once
  - Hundreds of spot loads





Manually adjust parameters in GUI

Adjust parameters via code

Modeling/Simulation – Lessons Learned

- Validation needed
- Other elements to be considered

Data Acquisitions

Work To Date – Data Acquisitions

- Data acquisitions framework
- Data acquisitions prototypes

Data Acquisitions Context & Methodology

Field Data Acquisitions Methodology

1. Weather
2. Feeder
3. PV sites
    1. Residential (2, 3, 4 kW (3 versions each)
    2. Commercial (~ 400 kW)
    3. Utility-Scale (~ 500 kW, smart inverter)
4. Data storage

Considerations

1. Study
2. PV system O&M
3. Grid operations
4. Ownership/Requirements
    1. APS
        1. Data/comm. path security
        2. Stability (infrastructure, platform)
        3. Deployment (maintainability)
    2. Study
        1. Data/comm. open access
        2. On-the fly re-configurable platform

Final Methodology

Low, medium and high bandwidth systems

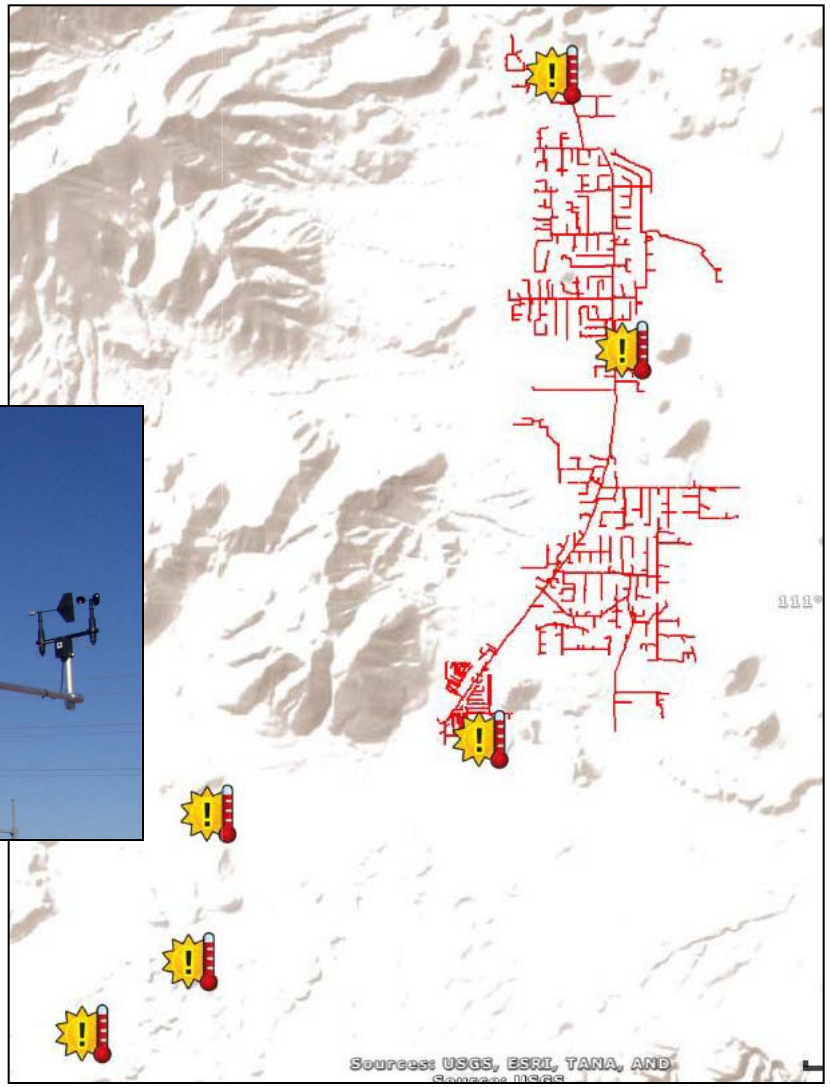
Data Acquisitions - Weather Stations

Weather Stations

- 5 to 6 locations
- 1-second data capture
- Campbell Scientific CR1000-based
- GPS time sync

Sensor Complement

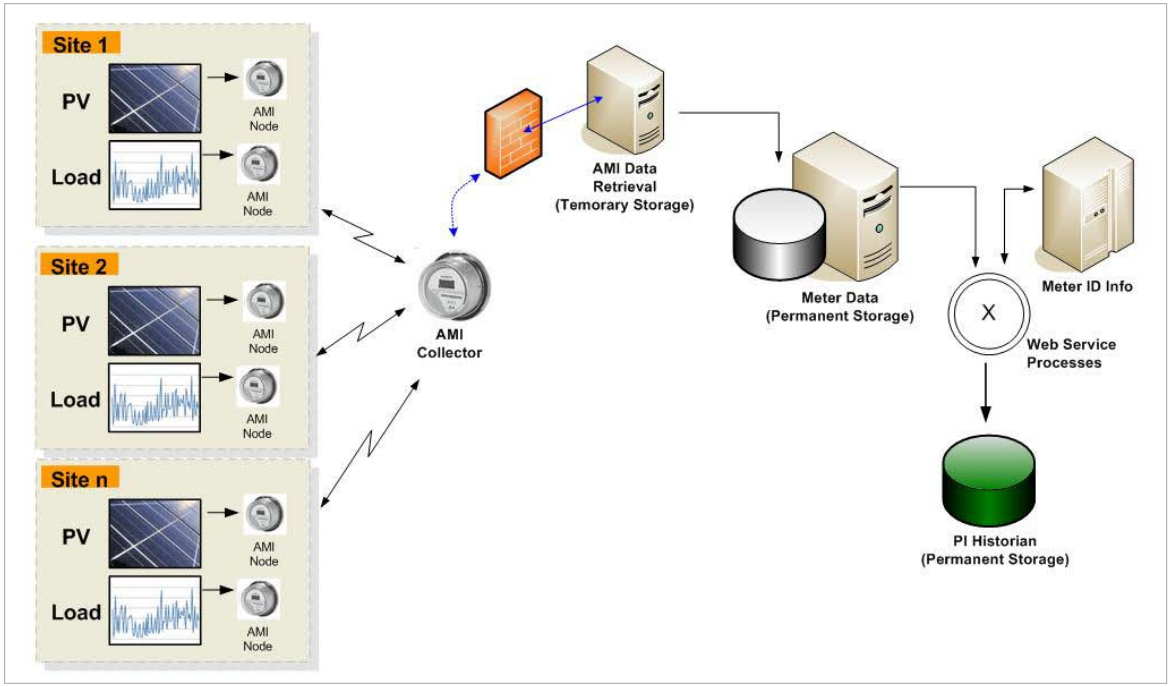
- solar radiation (GHI, fixed latitude)
- wind speed/direction
- site temperature
- relative humidity
- atmospheric pressure
- rain

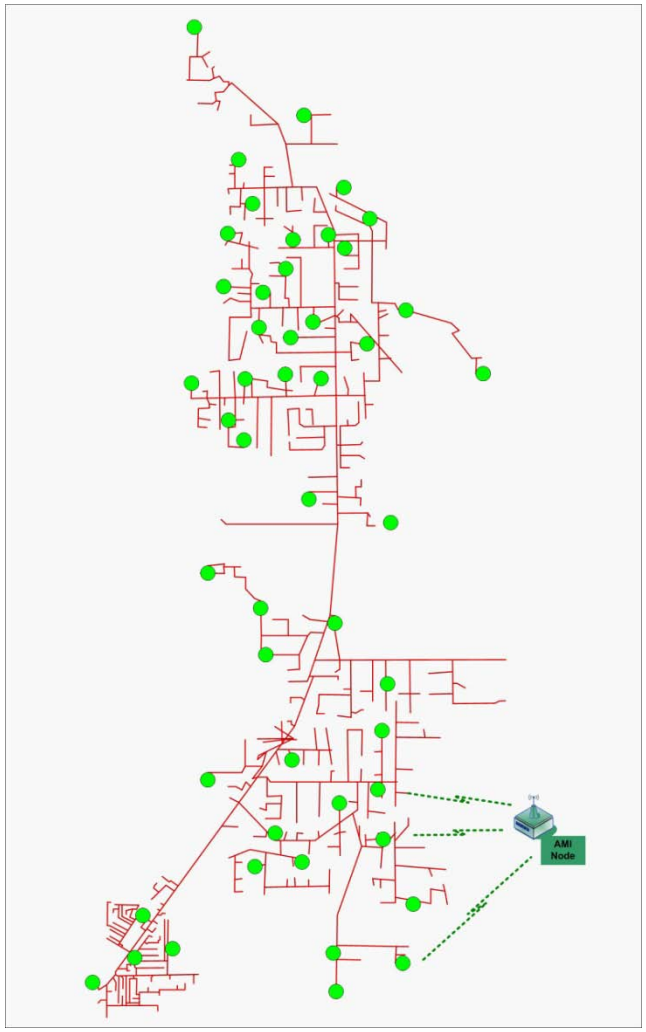


Data Acquisitions – AMI

Low Bandwidth

- Elster AMI meters on load and PV generation
- Record customer demand (hourly intervals)
- Record PV generation (15 min intervals)
- Retrieve data nightly (day-behind)
- Supports O&M and energy studies

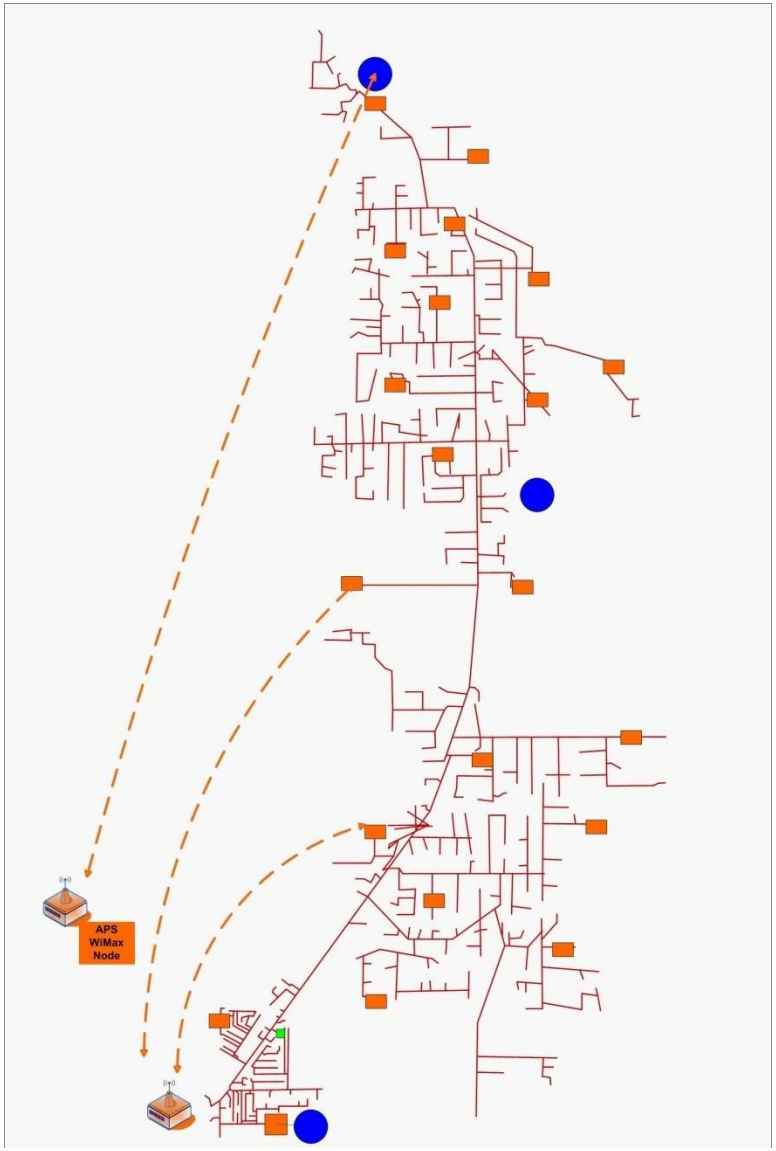




Data Acquisitions – PV (SEL PQ Meters)

- SEL 734P meters
- 1- sec data
- Retrieve data using APS SCADA (semi real-time)
- Meters recording
  - voltage, current
  - PQ info as needed

(blue dots shown are weather stations)

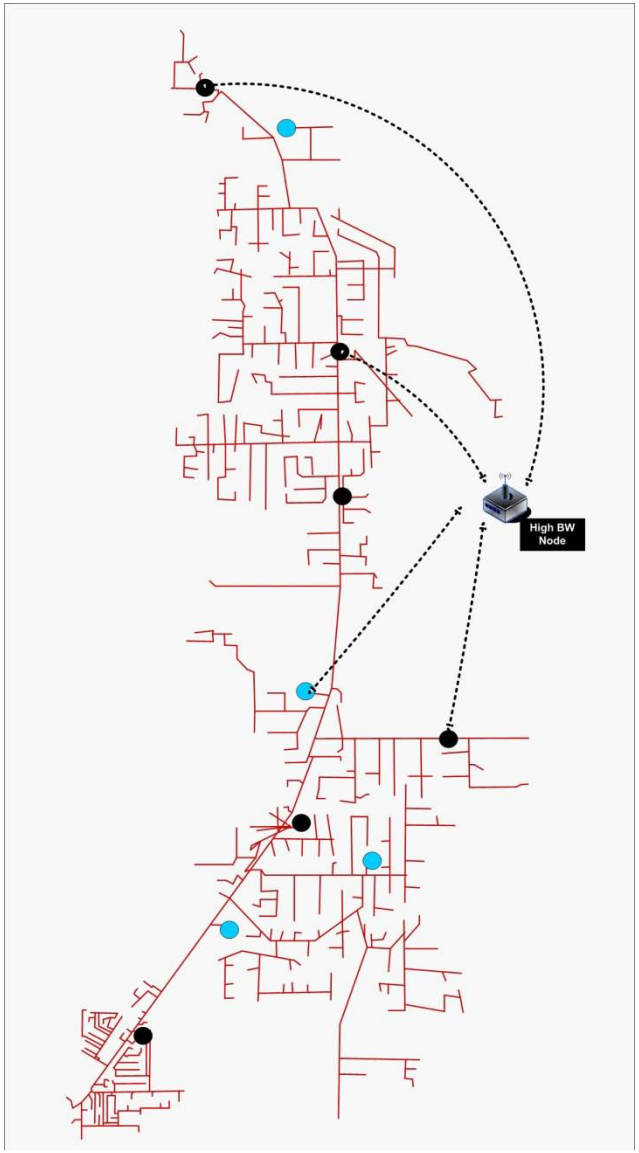


Data Acquisitions – High Bandwidth (Feeder & Customer)

NI Compact RIO

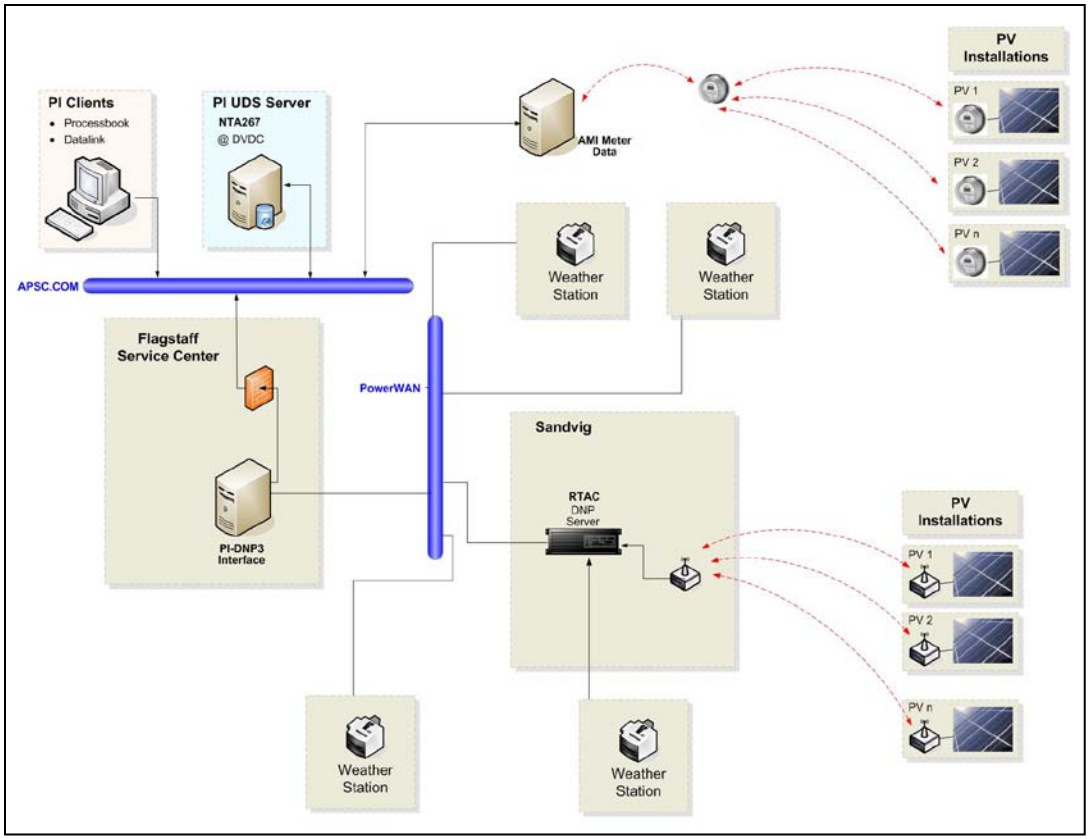
High Bandwidth DAS Features:

- High Event Sample Rate
- GPS Synchronized Data
- Event Based Data Capture
- Wireless Network Trigger and Data Download
- 6 locations along feeder
- 4 locations at PV sites



Data Store

APS platform: PI Historian
Study platform:
- flat files
- other data historian (~Propheci)



Data Acquisitions – Next Steps

- Fabricate field units
- Deploy
- Collect data

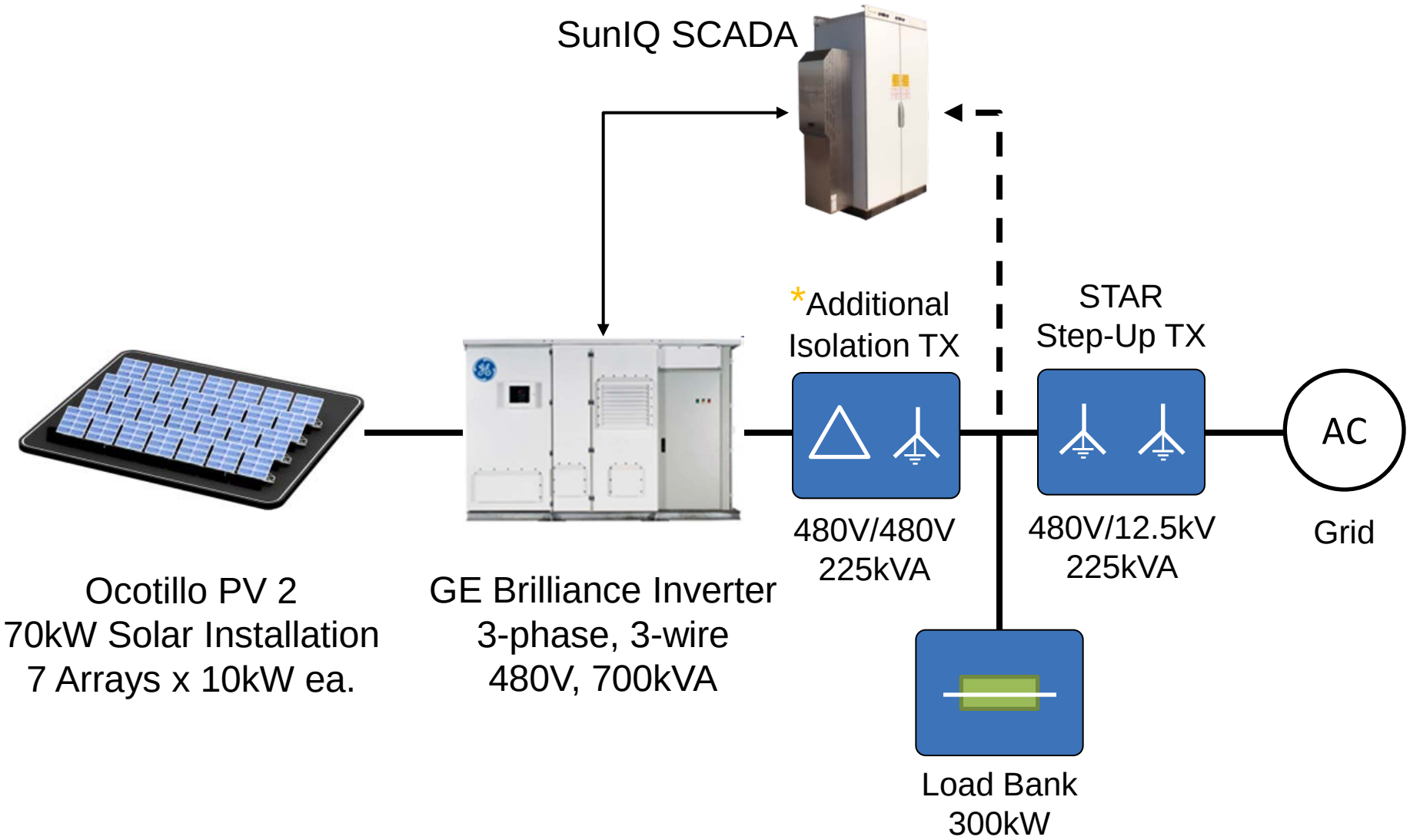
Smart Inverter

GE Brilliance Inverter & SunIQ SCADA Systems

- Single point of communication for large solar installations
- Controls up to 50 inverters to a point of common coupling
- Integrates into utility Operations and SCADA functions

- 3-phase, 480V, 700kVA Inverter
- Grid support features
  - Voltage Regulation
  - Power Factor Support
  - High/Low/Zero Voltage Ride-Through
- Can help mitigate intermittency effects

Current STAR Installation



Energy Storage

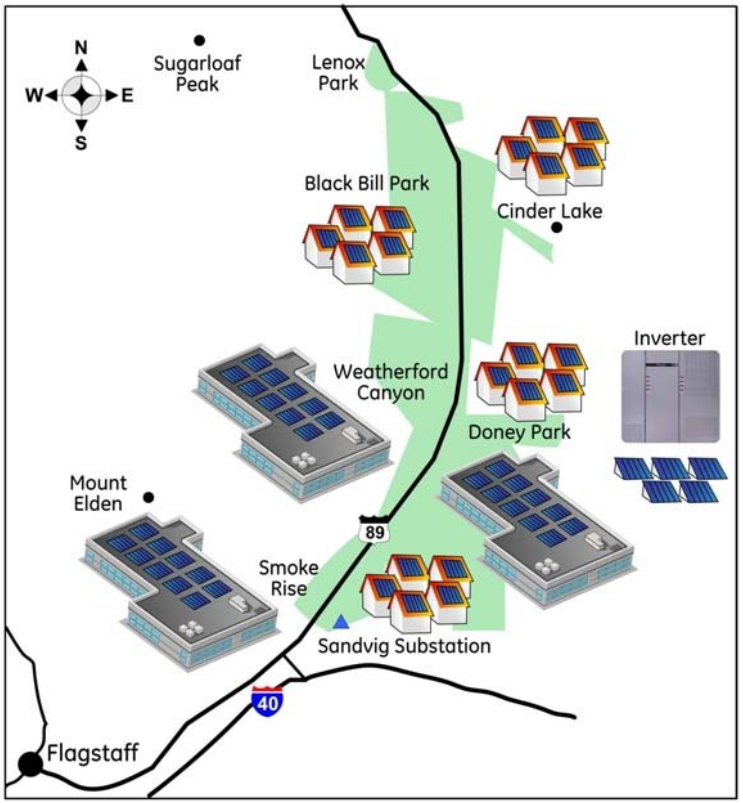
Energy Storage Project

- Partners- Electrovaya & ABB
  - Lithium-Ion battery technology coupled with ABB grid interface
  - 500 kW, 3 hour storage capacity
- Phase I – Elden Substation
  - Shift energy to levelize peak load
  - Test local and remote operation
- Phase II – Doney Park PV Site
  - Regulate energy to reduce short-term PV variability
  - Provide distribution support functions (Volt/Var support, etc)
- Schedule
  - System installation Q3 2011
  - Phase I- Q4 2011 – Q2 2012
  - Phase II- Q3 2012 – Q4 2012
  - Final report ~2013

Looking Forward

Study Next Steps

- Feeder Modeling with High Penetration PV
- Grid Support Modeling
- Feeder Model Validation & Extrapolation
- PV deployments finalized



CONTACT & MORE INFO

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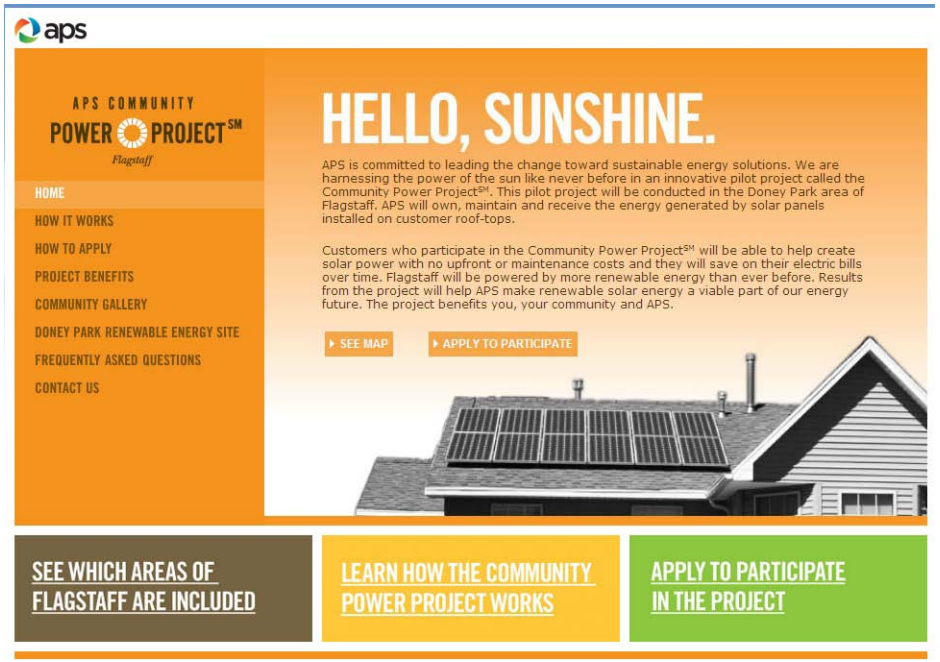
APS High PV Penetration:
http://www.aps.com/main/green/choice/solar/highpenetration.html

Community Power Project – Flagstaff:
http://www.aps.com/main/various/CommunityPower/index.html

Q &A