Maine Smart Grid Coordinator
NTA Identification, Assessment, and Management

New Power Technologies *Energynet*® Overview

July, 2014

Top Level

- **DER ability to improve grid performance is well-established.**
- **Not all DER is grid-beneficial. Grid-beneficial DER is location and attribute-specific.**
- **Tools and techniques to rigorously identify grid-beneficial DER are proven.**

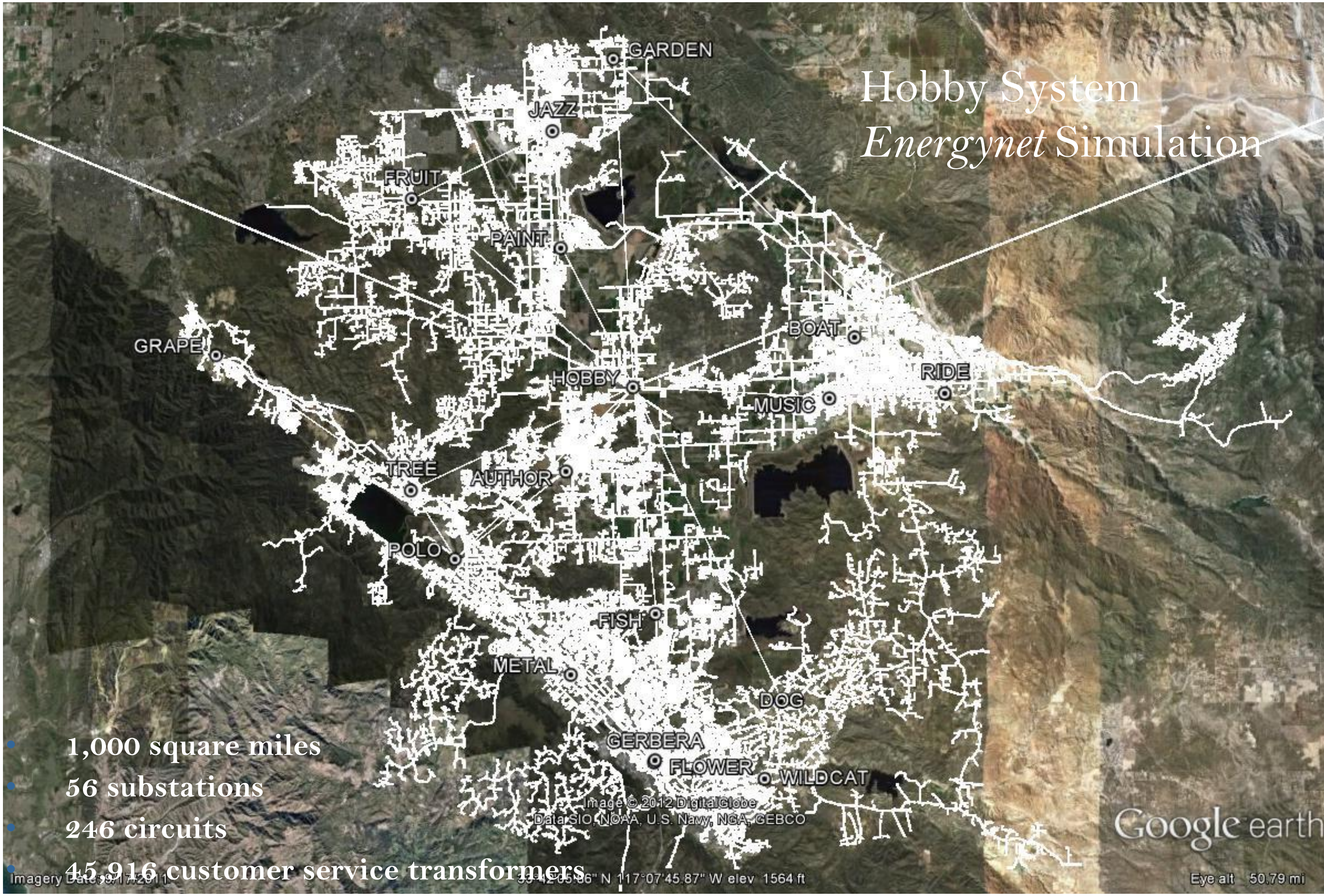
Nomenclature

- **DER (distributed energy resources):**
  - Distributed generation
  - Demand response
  - Storage
  - Close to load

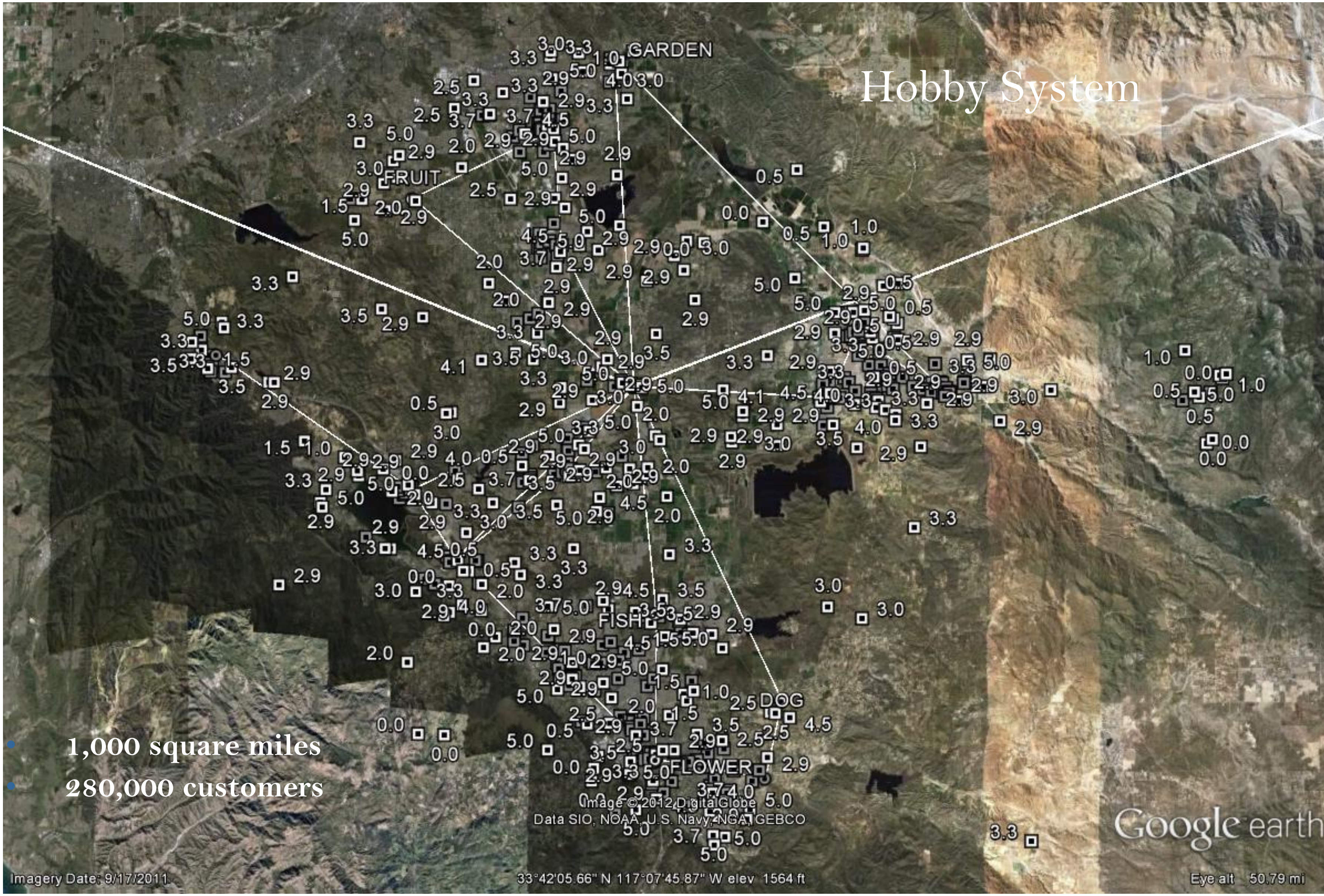
- **Grid (power delivery network):**
  - Bulk electric system
  - Local transmission and sub-transmission
  - Distribution
  - Substations and components
  - Loads and resources

- **Grid performance improvement:**
  - Overload relief
  - Voltage violation relief
  - Reliability improvement (fewer, shorter outages)
  - Loss reduction
  - Power quality improvement
  - Direct, demonstrable, quantifiable

Hobby System
Energynet Simulation

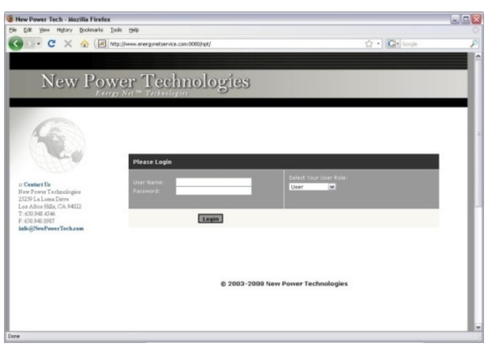


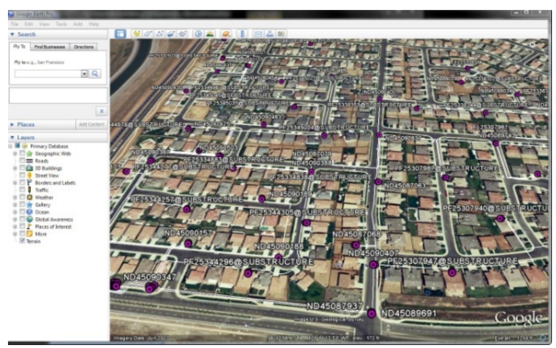
- 1,000 square miles
- 56 substations
- 246 circuits
- 45,916 customer service transformers

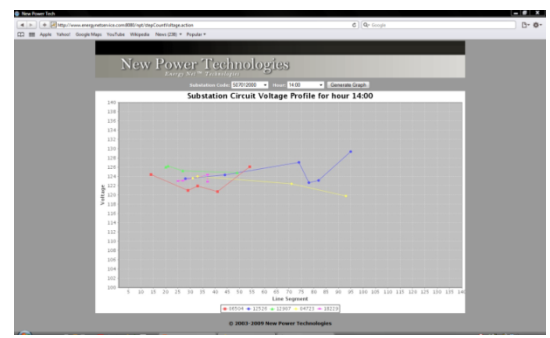

Hobby System
GARDEN
FRUIT
FISH
DOG
FLOWER
1,000 square miles
280,000 customers
Image © 2012 DigitalGlobe
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth
Imagery Date: 9/17/2011
33°42'05.66" N 117°07'45.87" W elev 1564 ft
Eye alt 50.79 mi

Energynet Platform

- **Unified wide-area network model incorporating regional transmission, substations, distribution feeders**
  - **Allows direct representation of individual distributed generation, storage, loads, etc.**
- **Derived with software from existing legacy power system data**
- **Visualization, simulation and analytics**
- **Integrated GIS, field sensing/monitoring, customer metering, market data**
- **Web-based application platform**







Why?

- **Visibility into grid conditions anywhere under any operating condition**
- **Accurate network representation of individual DER**
- **Direct observation of network interaction of DER – impacts and benefits**

Applications and Solutions

- DG interconnection
  - One-click evaluation
  - Regional low-impact site inventory
  - Regional impacts of intensive PV development
- EV charging
  - Network headroom, cluster identification
  - Managed charging – impact minimizing/value maximizing
- Grid benefits of DG, DR, storage
  - network expansion project assessment
  - High-value DER identification
  - Identify DER that can offset otherwise necessary network expansion projects at lower cost
- Regional reliability risk assessment
- Low-cost CVR opportunities
- Wide-area situational awareness with legacy sensors and monitors

Nomenclature

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  - Storage
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  - Loads and resources
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  - Overload relief
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  - Reliability improvement (fewer, shorter outages)
  - Loss reduction
  - Power quality improvement
  - Direct, demonstrable, quantifiable

UPGRADE

NTA

NTA Attributes

- **Offset network load or mitigate voltage violation on…**
- **identified assets of CMP's existing transmission system under…**
- **peak-period electric loading and contingency conditions.**

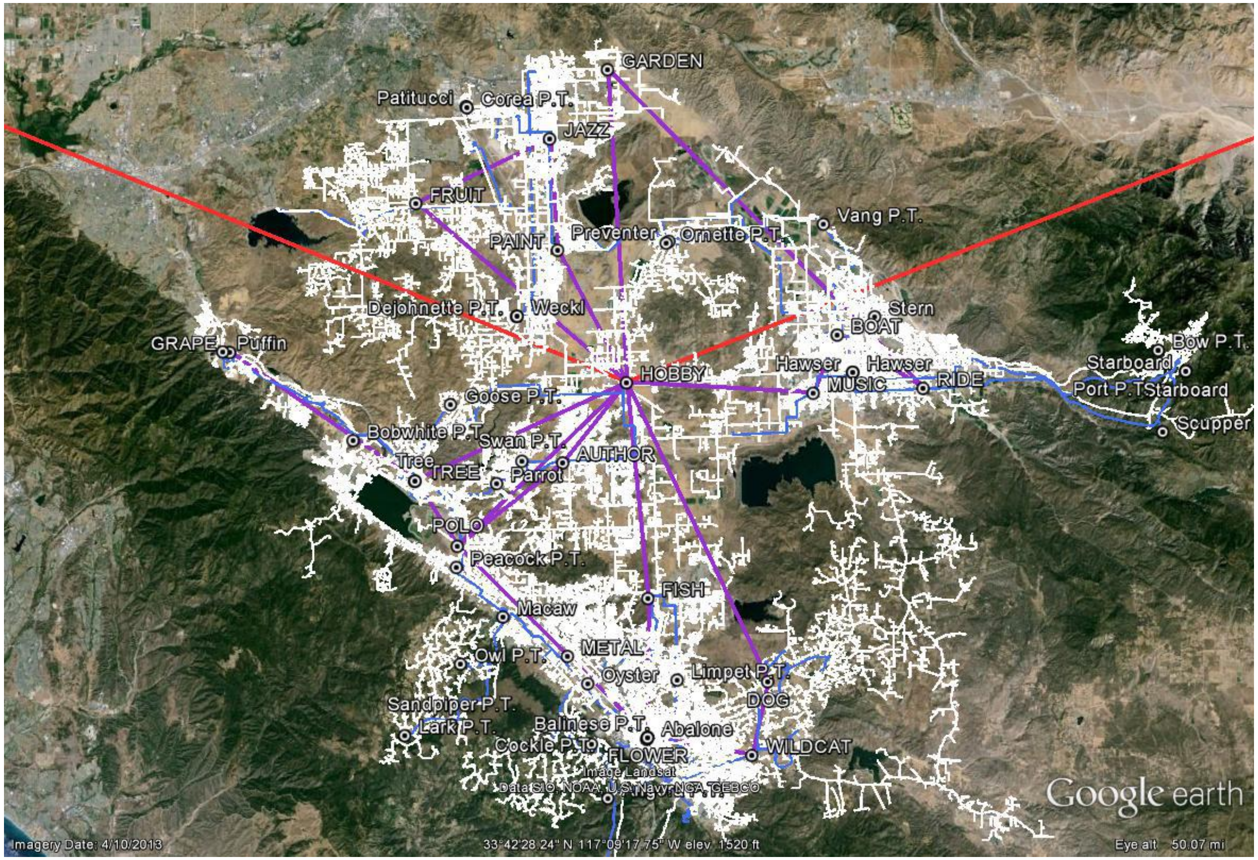
- **Direct relationship between NTA and grid benefits**
- **Benefit-specific, location-specific, time/operating condition-specific**
- **Aggregate capacity/size-specific**

Potential DER Benefits as NTAs

- **Load Relief**
  - **Reduce or offset downstream load to avoid a known or projected thermal overload of power network equipment that would otherwise require a network upgrade.**
- **Reliability Improvement**
  - **Reduce loading-related network component failure rate**
  - **Increase post-contingency load-shift opportunities by increasing network headroom**
- **Voltage Violation Relief/CVR Opportunity/Power Quality Improvement/ Improved Voltage Security**
- **Loss Reduction**
- **Incremental Energy, Bulk Capacity, Reserve Capacity, or AS Capacity**
- **Low-emission/Renewable/Low-carbon Energy or RECs**
- **Customer Benefits/Societal Benefits**

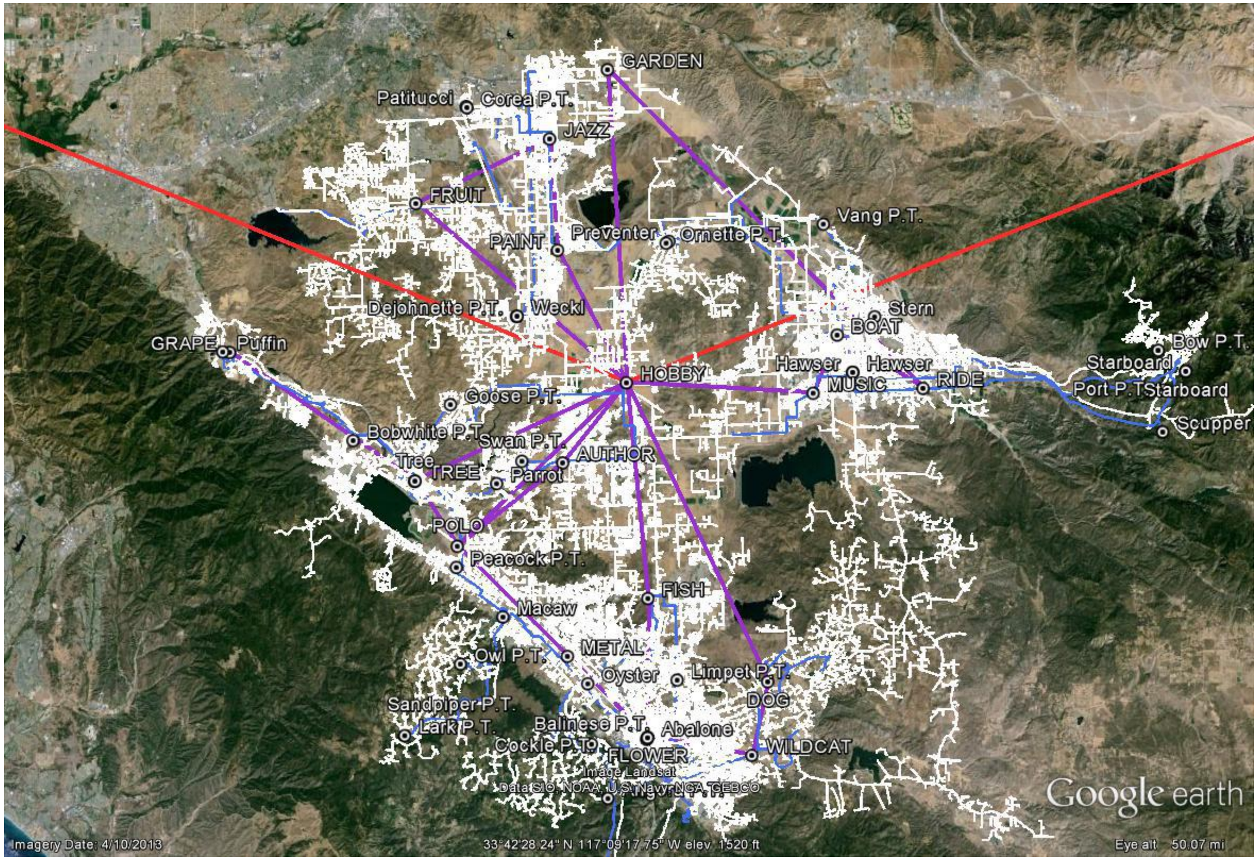
➢ **If you can't measure it and value it, it's not a real benefit.**

"Hobby" System *Energynet* Optimal DER Portfolio



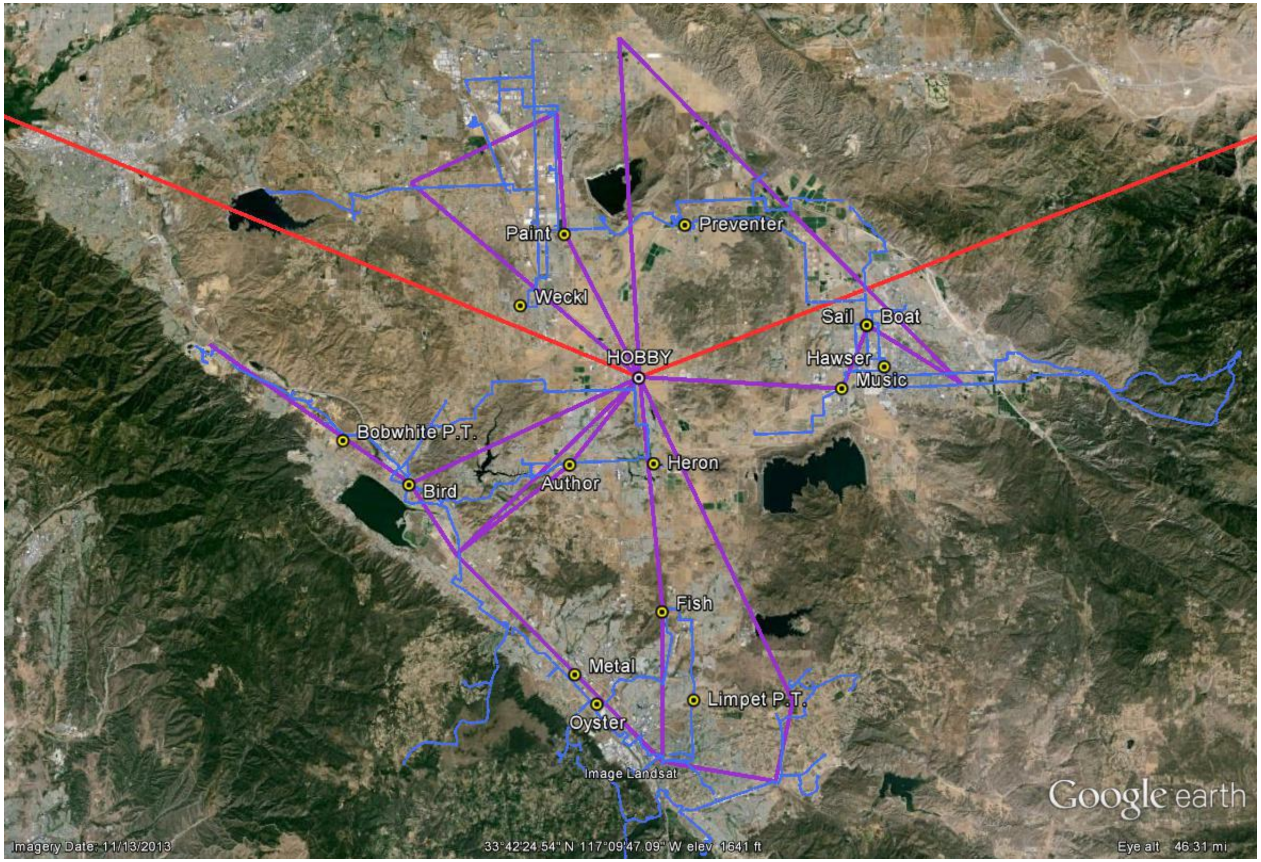
- **Hypothetical DER projects analytically selected for maximum grid benefits, including overload relief and reliability improvement**

“Hobby” System



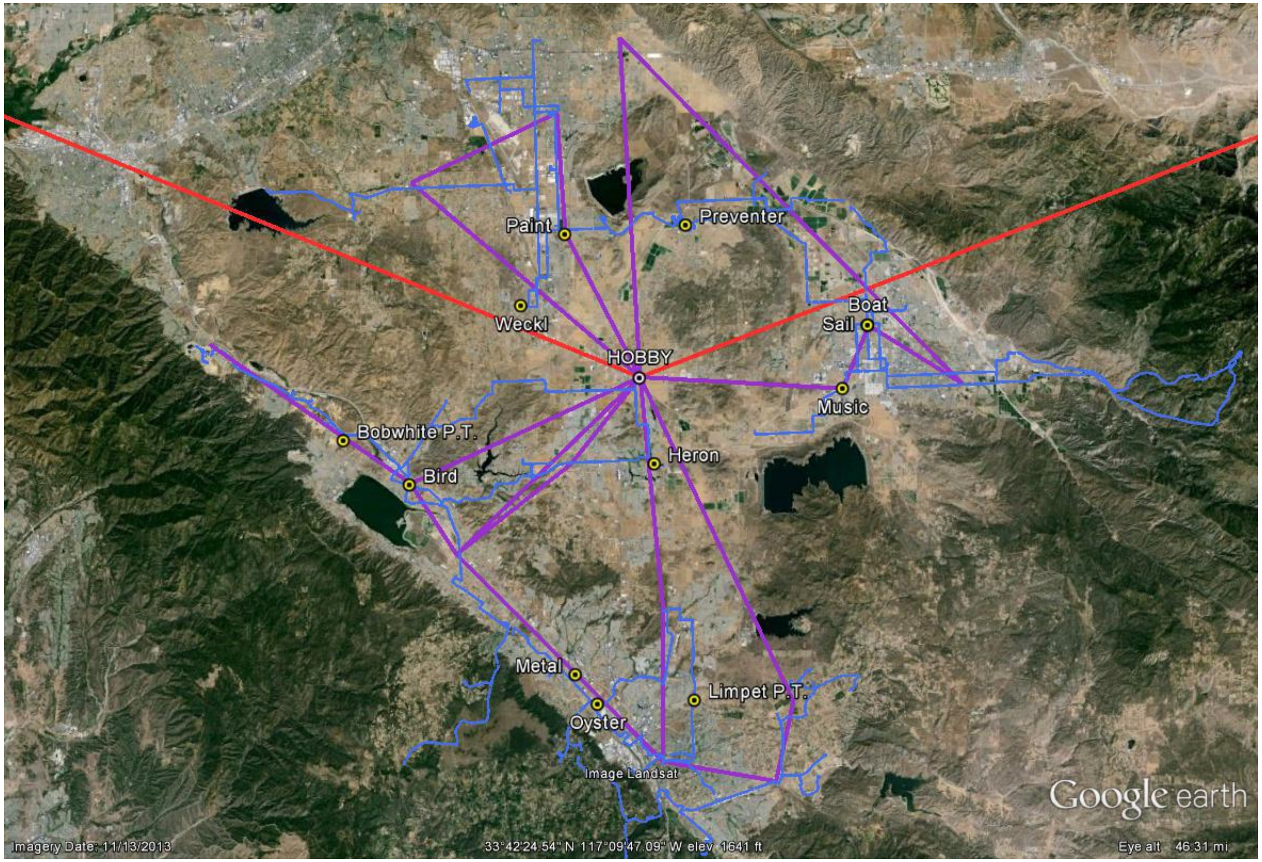
- 500 kV
- 115 kV
- 33 kV
- White: 12kV and lower

Future Case Capacity-Constrained Substations



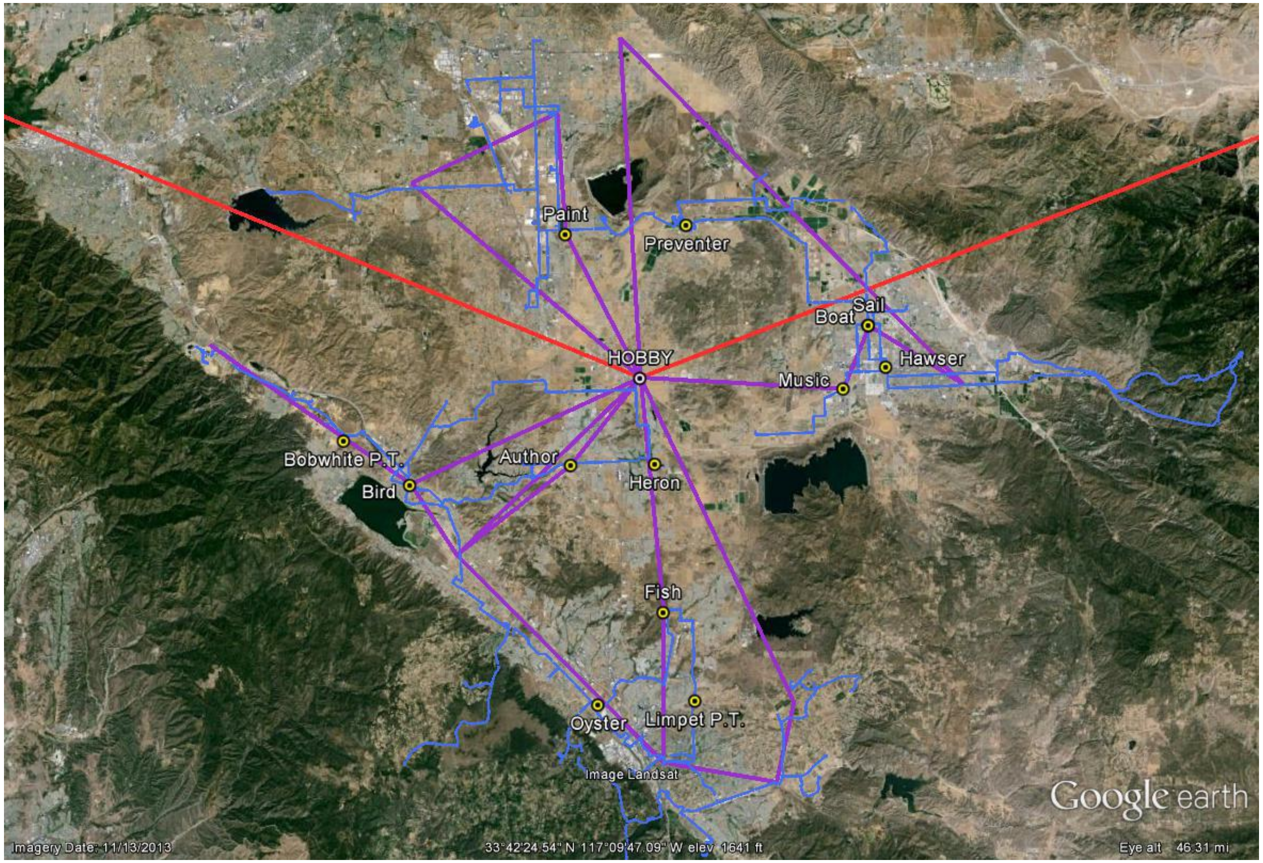
- **Sustained normal-condition loading exceeding normal rating identified in Energynet simulation (*analogous* to needs assessment)**

Substations with Proposed Upgrades

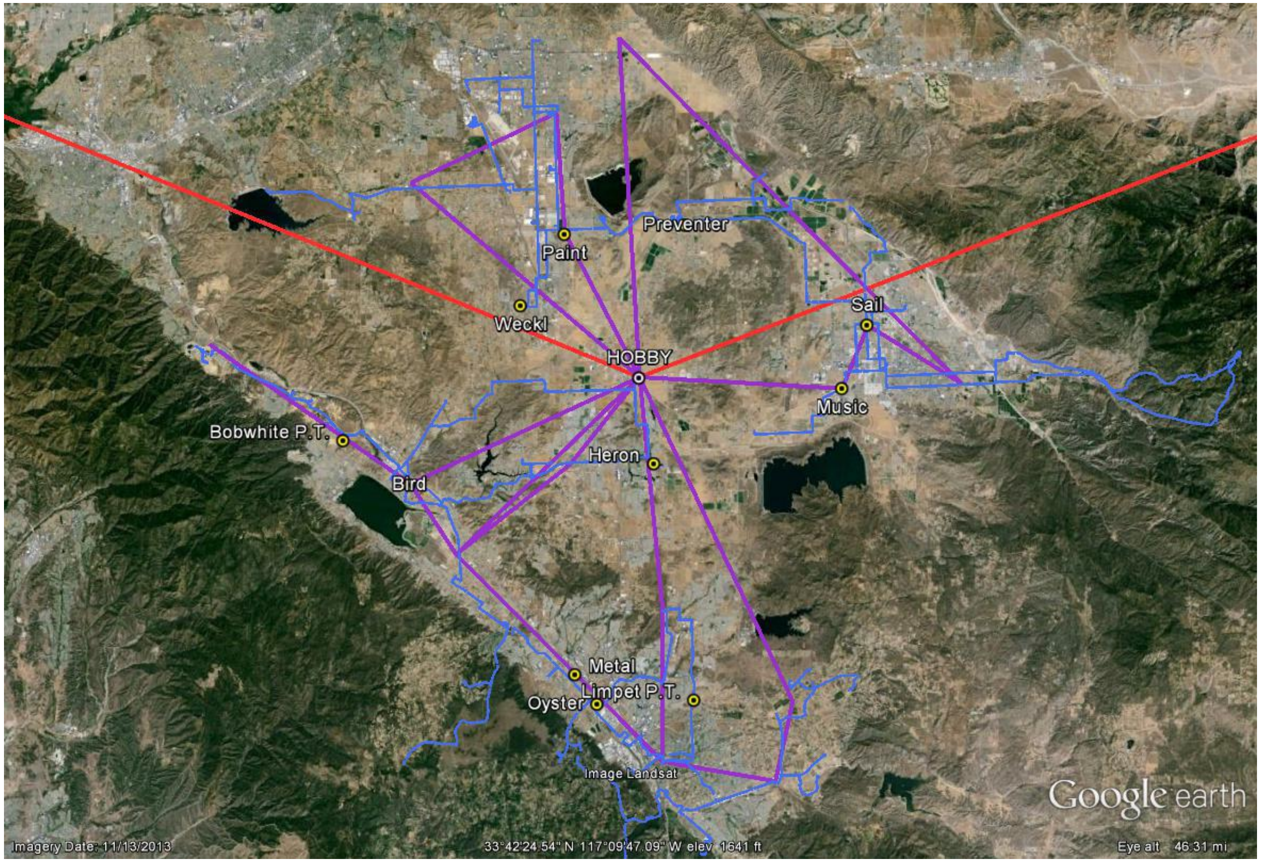


- **Transformer additions, voltage uprates, new substations**

Constrained Substations after Load Rolls



Substations with Constraints Resolved by Upgrades



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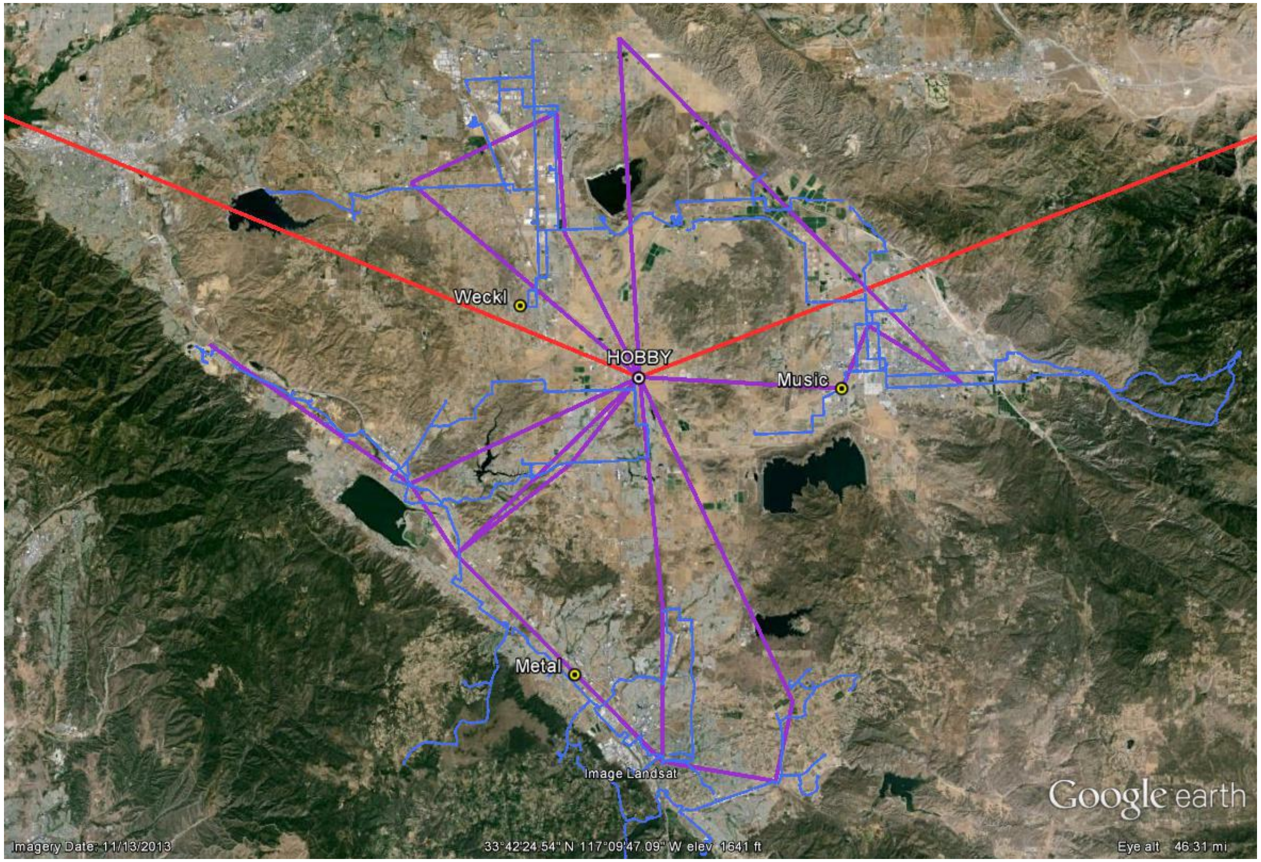
Substations with Constraints Resolved by DER*



- **Hypothetical DER identified primarily for voltage and loss benefits.**
- **Low-penetration DG.**

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Music Substation Constraint

- 27.9 MVA transformer
- 39.5 MVA projected peak load
- 29%, 11.6 MVA overload
- transformer bank addition planned
- - 6.2 MVA from load roll

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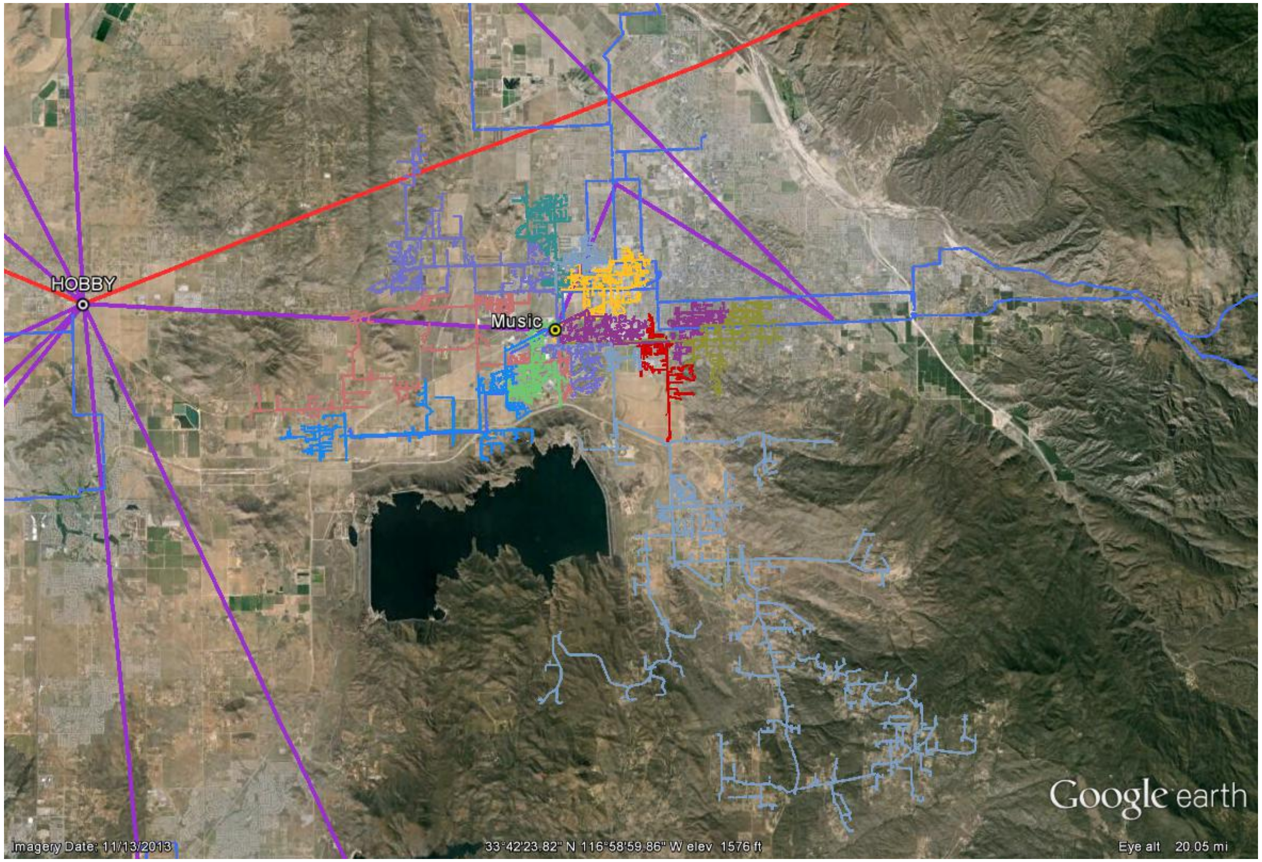
Music Substation and Feeders



- **115/12 kV substation; 14 feeders**

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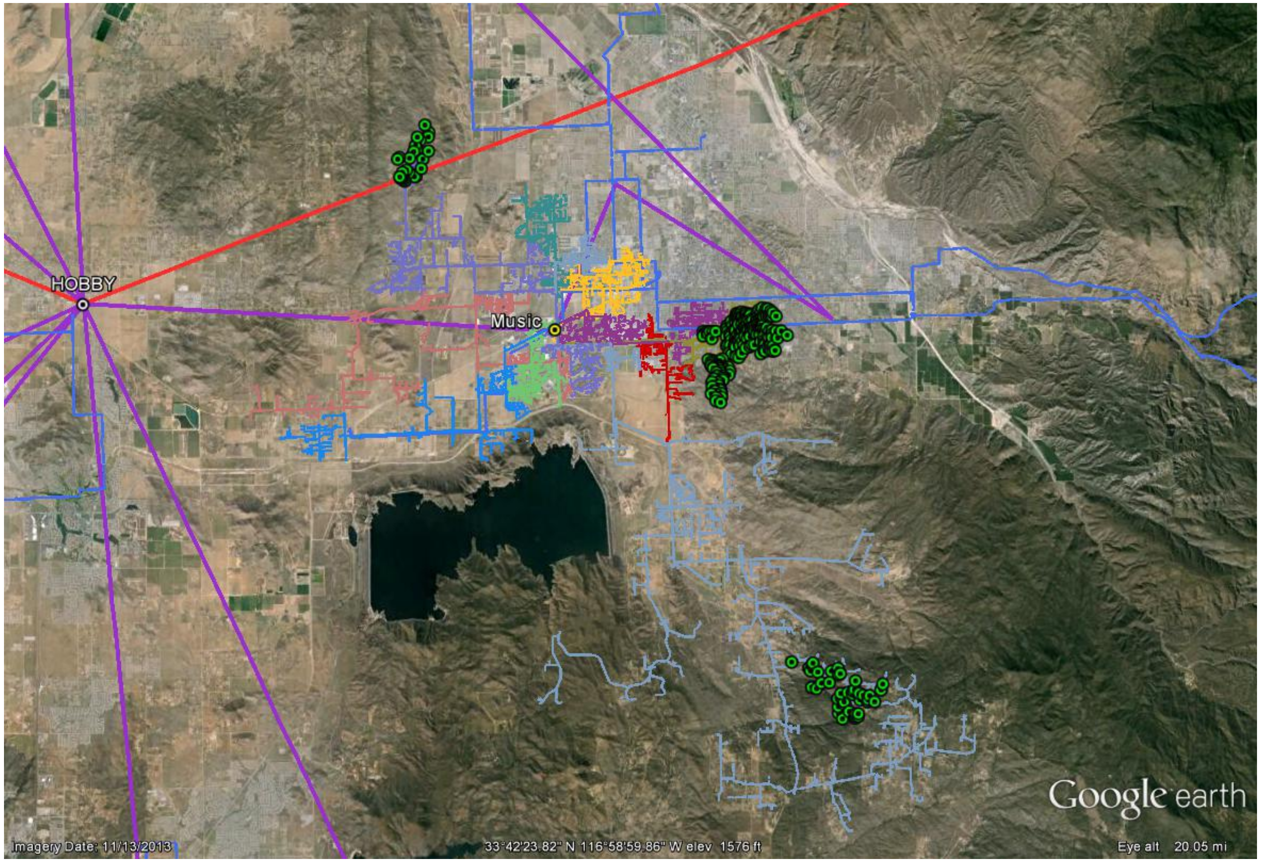
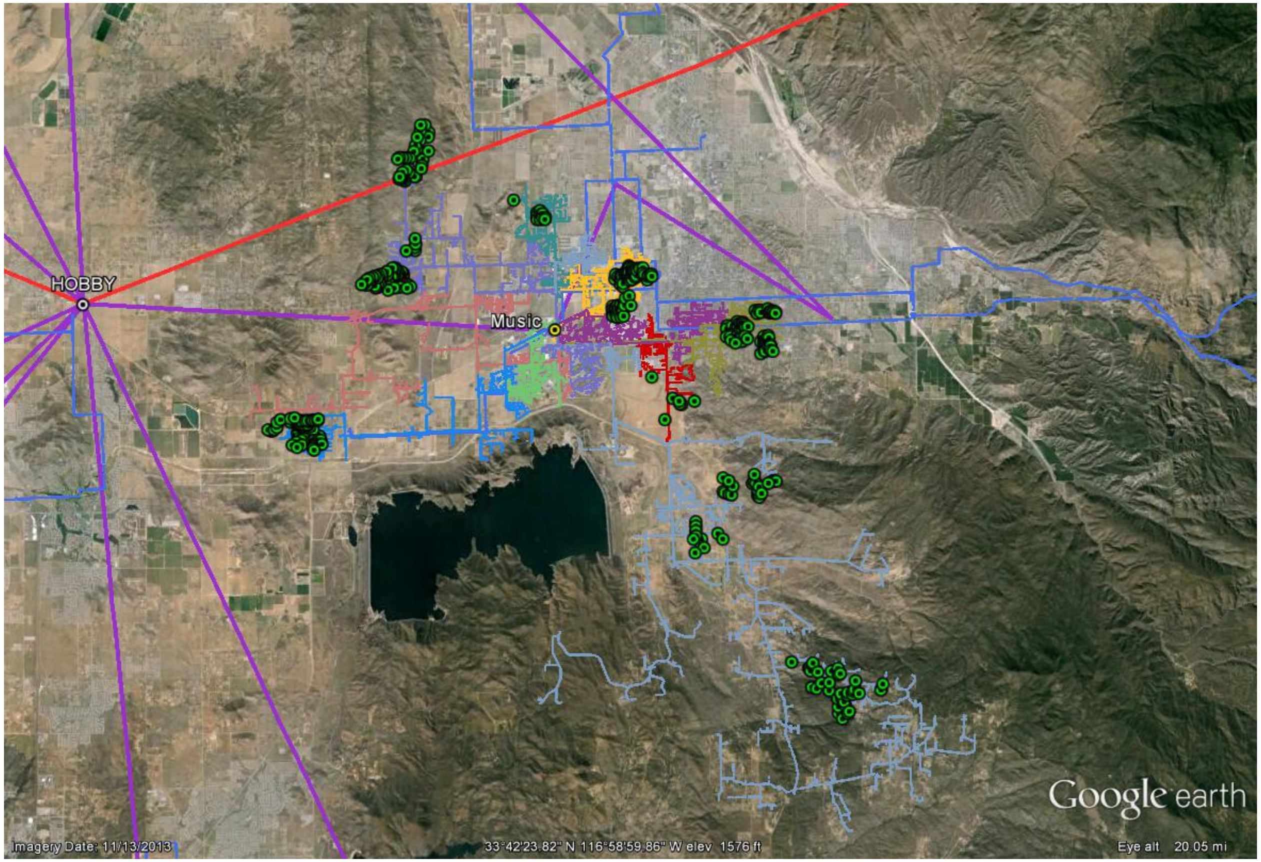
Music Substation DR



- **Bias toward electrically remote, smaller sites**

Music Substation DG



- Bias toward electrically remote, smaller sites, smaller DG projects

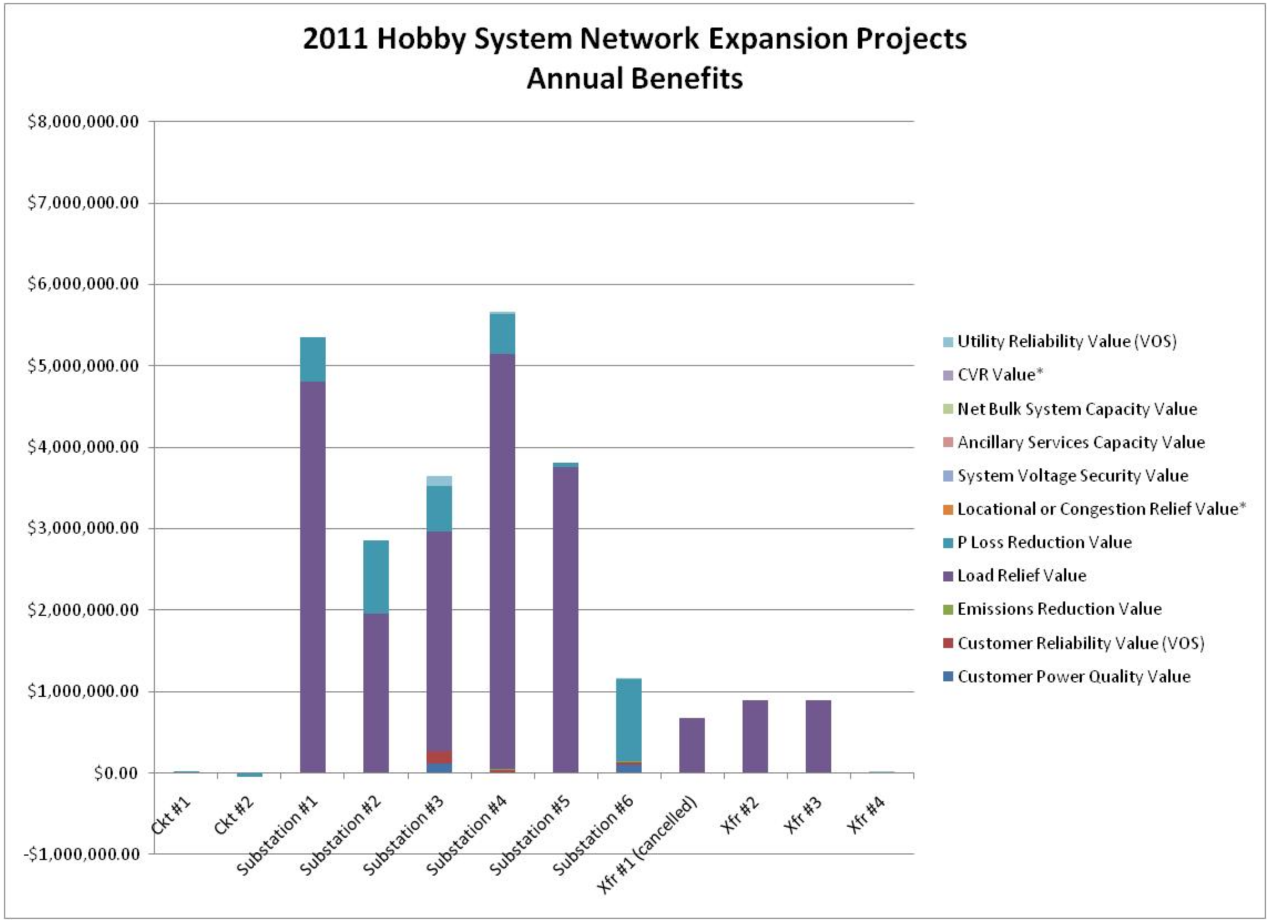
Music Substation DER Projects

- **DR:**
  - 259 projects, 1.01 MW total
  - 97% residential and small business
- **DG:**
  - 327 projects, 4.927 MW total
  - 87.7% residential and small business, 12% medium business and ag, 1 industrial
- **Onsite load and feeder limits on DG => low penetration!**
- **After-the-fact assessment of reliability and load relief benefits**

System-wide Optimal DER Portfolio

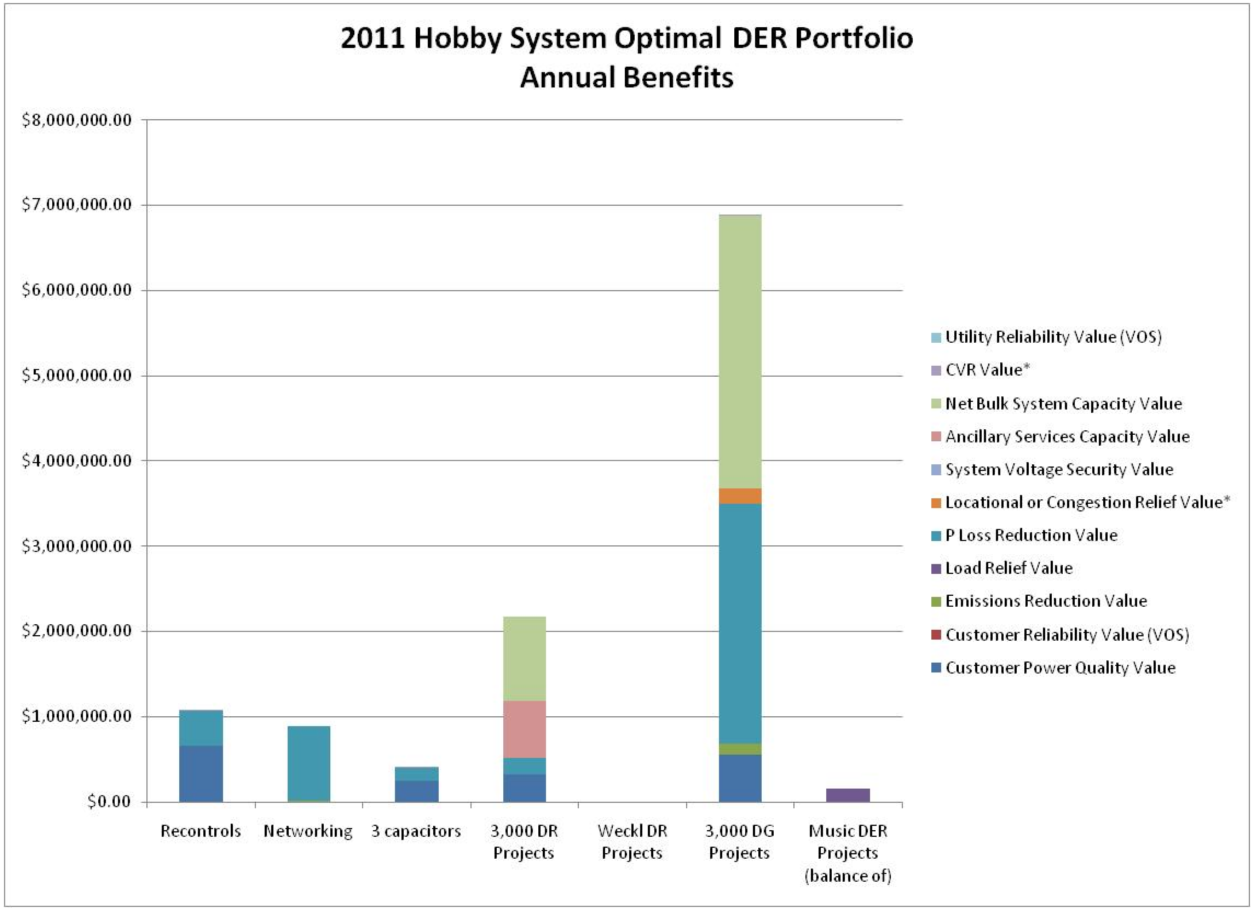
- **DR: 14.93MW, 0.87% of load**
- **DG: 46.86 MW, 2.75% of load**
- **Loss reduction: 5.9 MW**
- **2.2% increase in system-wide minimum voltage**

Grid Benefits of Distributed Resources



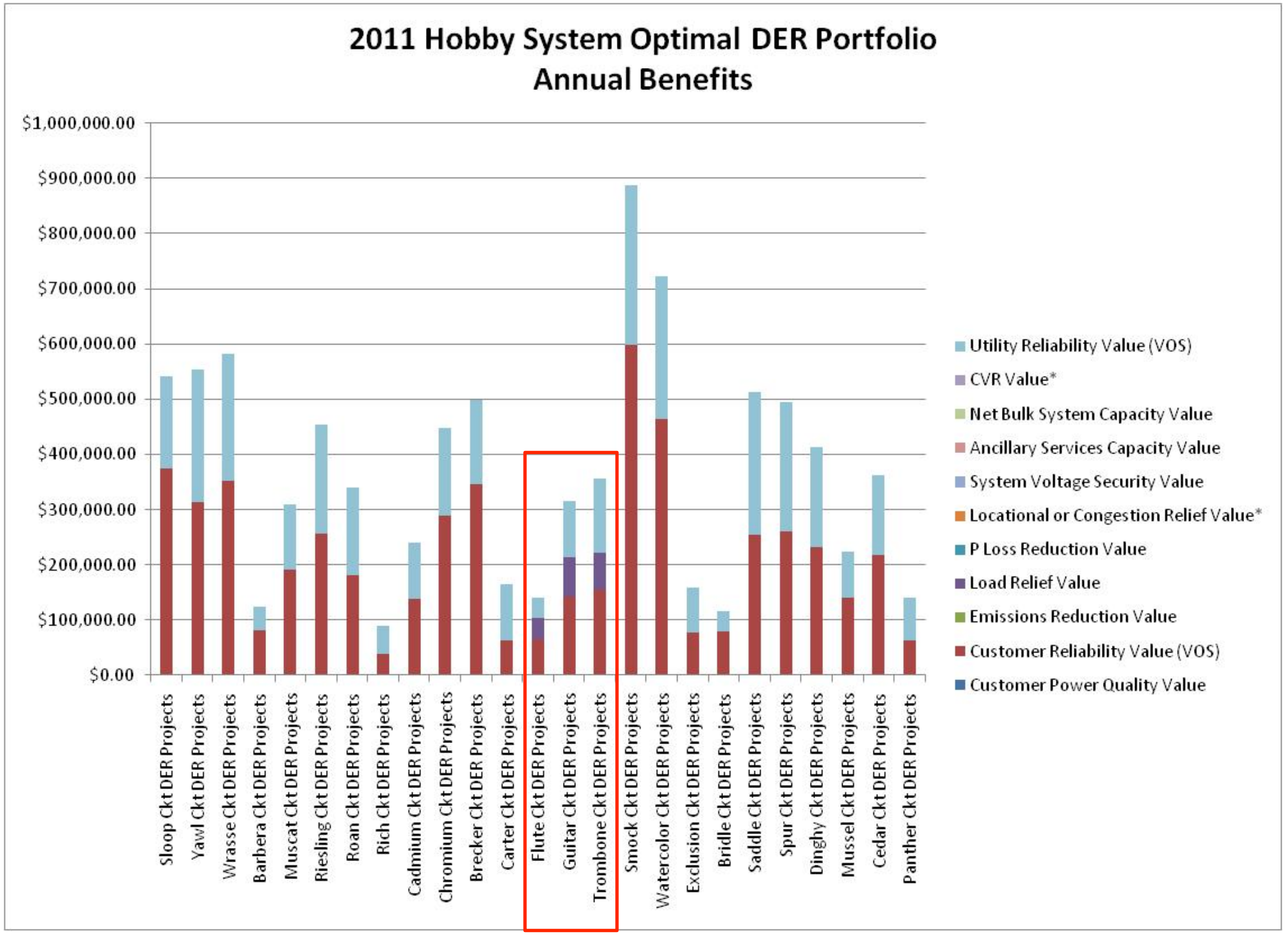
➔ Traditional network expansion project benefits are primarily in load relief

Grid Benefits of Distributed Resources



- ➔ Non-traditional projects can provide significant value, but in different categories, *e.g.* capacity, loss reduction and CVR.

Grid Benefits of Distributed Resources



- ➔ Certain DER projects on certain feeders yield significant value, primarily due to reliability improvement.

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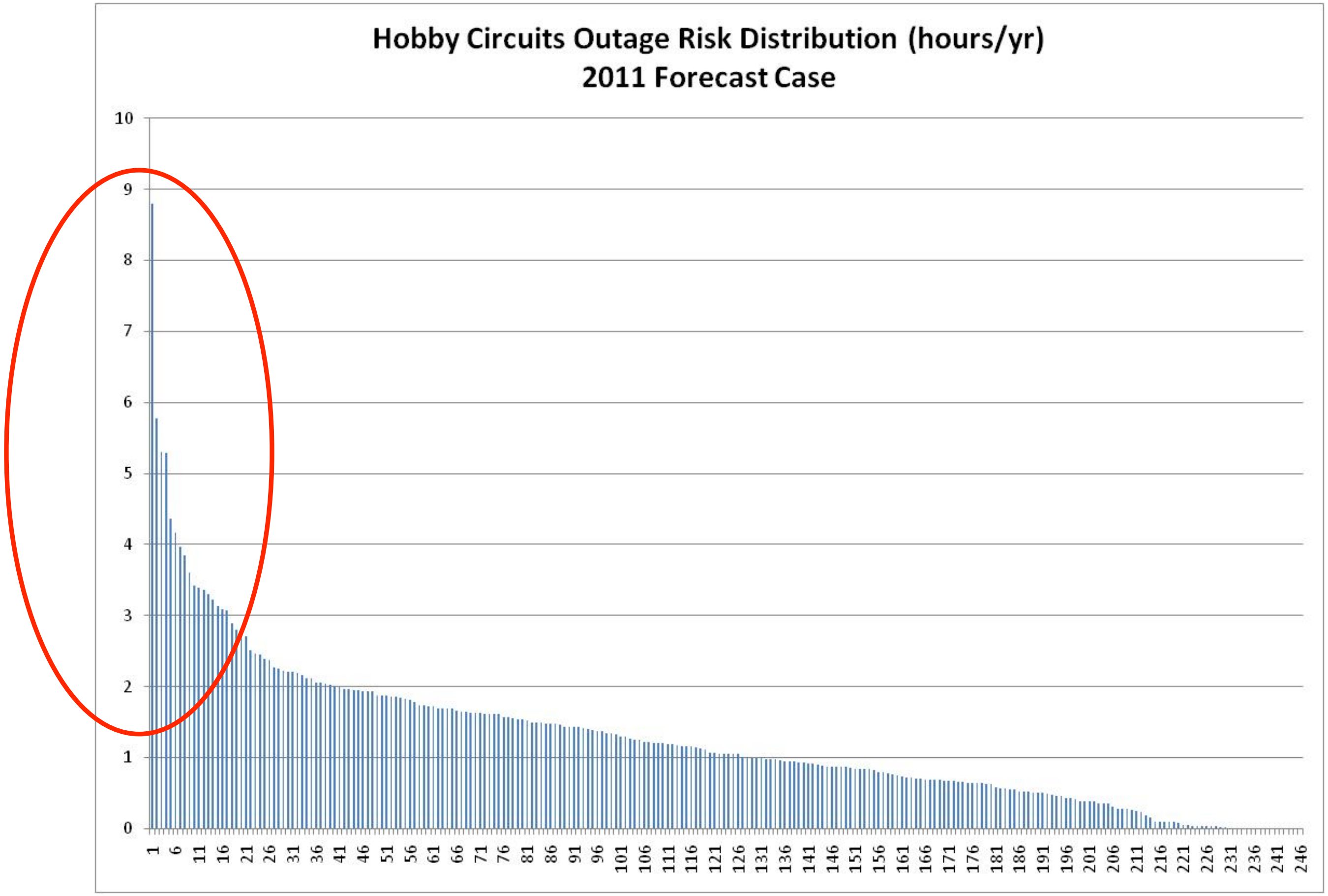
Circuit-level Reliability Assessment



➔ Certain feeders are *much* more vulnerable to random contingencies.

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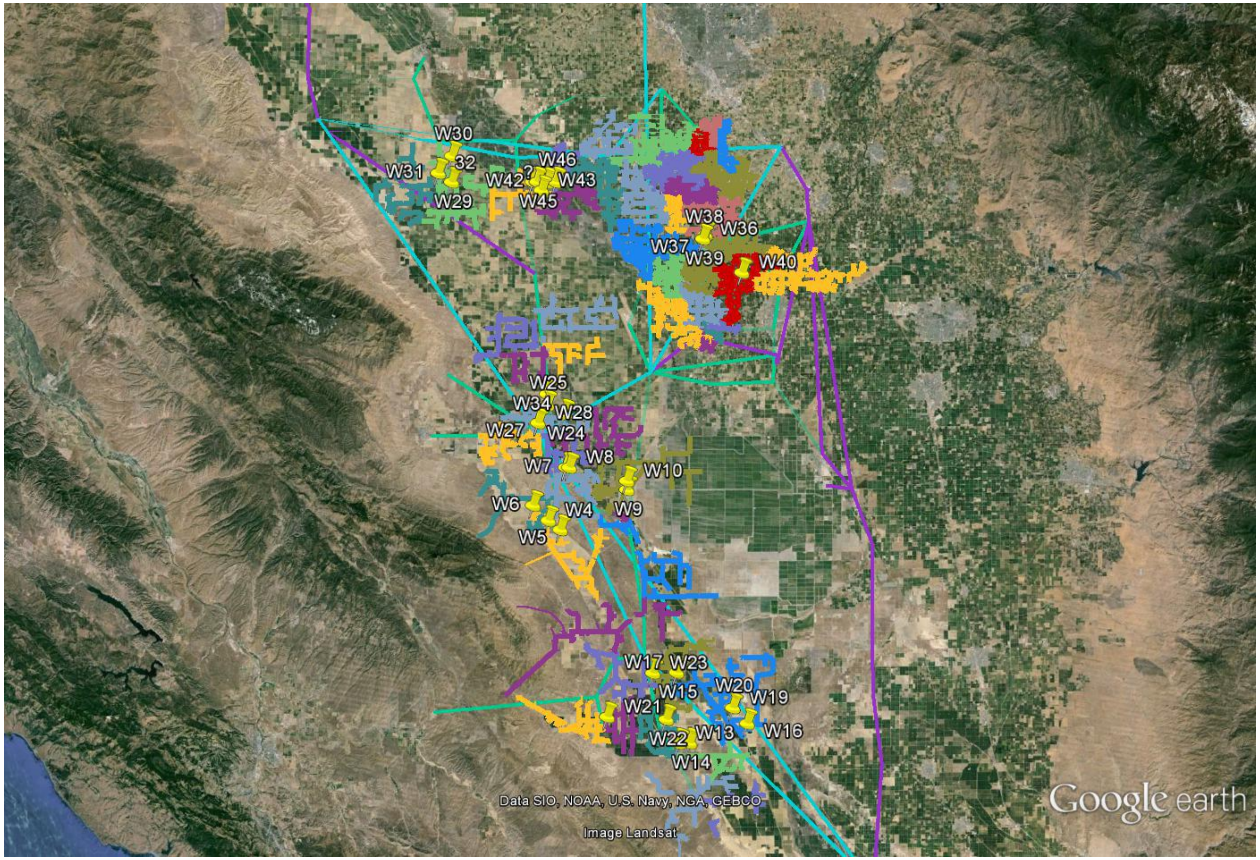
Potential DER Benefits

	Large (250-feeder) utility system	
	Network Operator Benefits	**Customer Benefits**
Loss reduction	$28/yr per customer	
Reduced energy to serve load (CVR)	$18/yr per customer	
Improved reliability	$20/yr per customer	$13/yr per customer
Avoided marginal capital projects	$68 per customer/10 yrs	
Improved power quality		$7/yr per customer

Relevant Findings

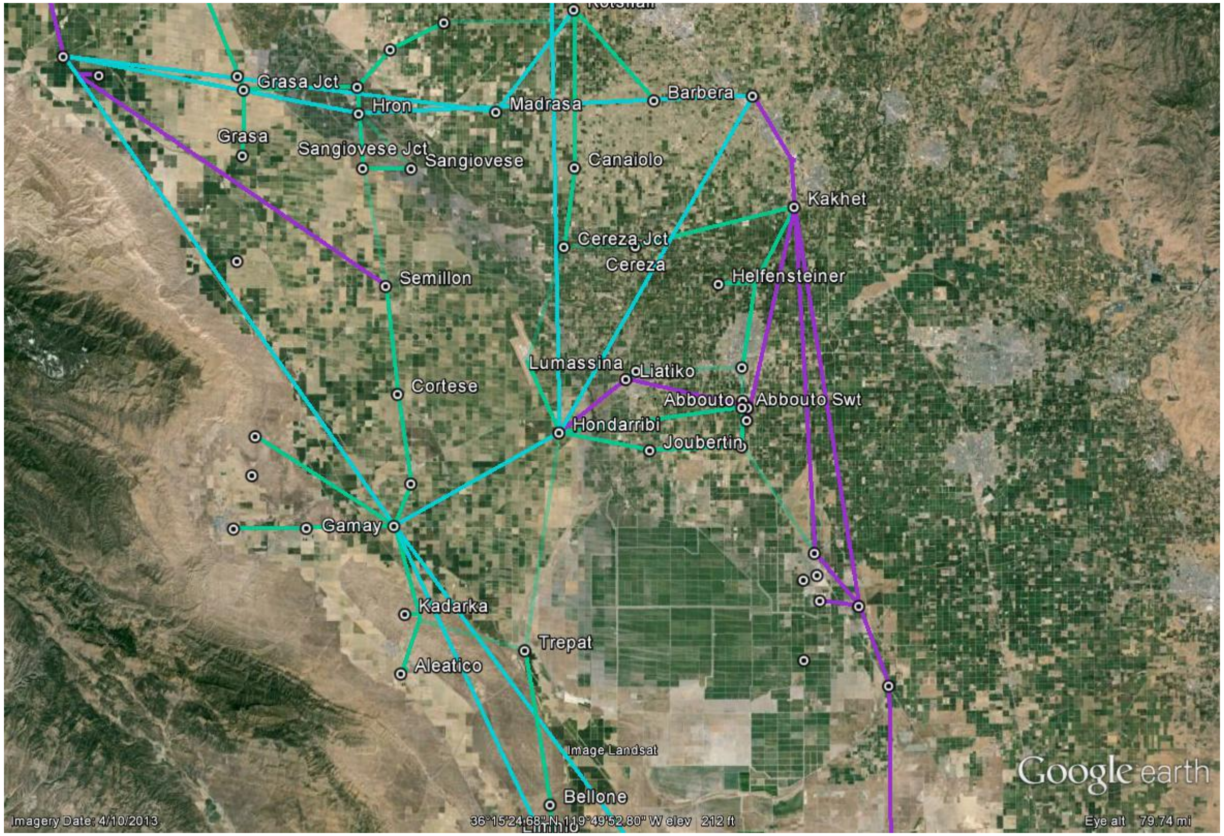
- **DER can benefit power delivery system performance.**
- **DER project location and attributes matter. A lot.**
- **These beneficial DER projects can be identified and their benefits quantified and valued.**
- **Relieving overloads is only one potential benefit category.**

“Vineyard” System *Energynet* DG Evaluation



- **DER (PV in this case) at high “penetration” levels**

Vineyard Regional Transmission



- 230 kV
- 115 kV
- 70 kV

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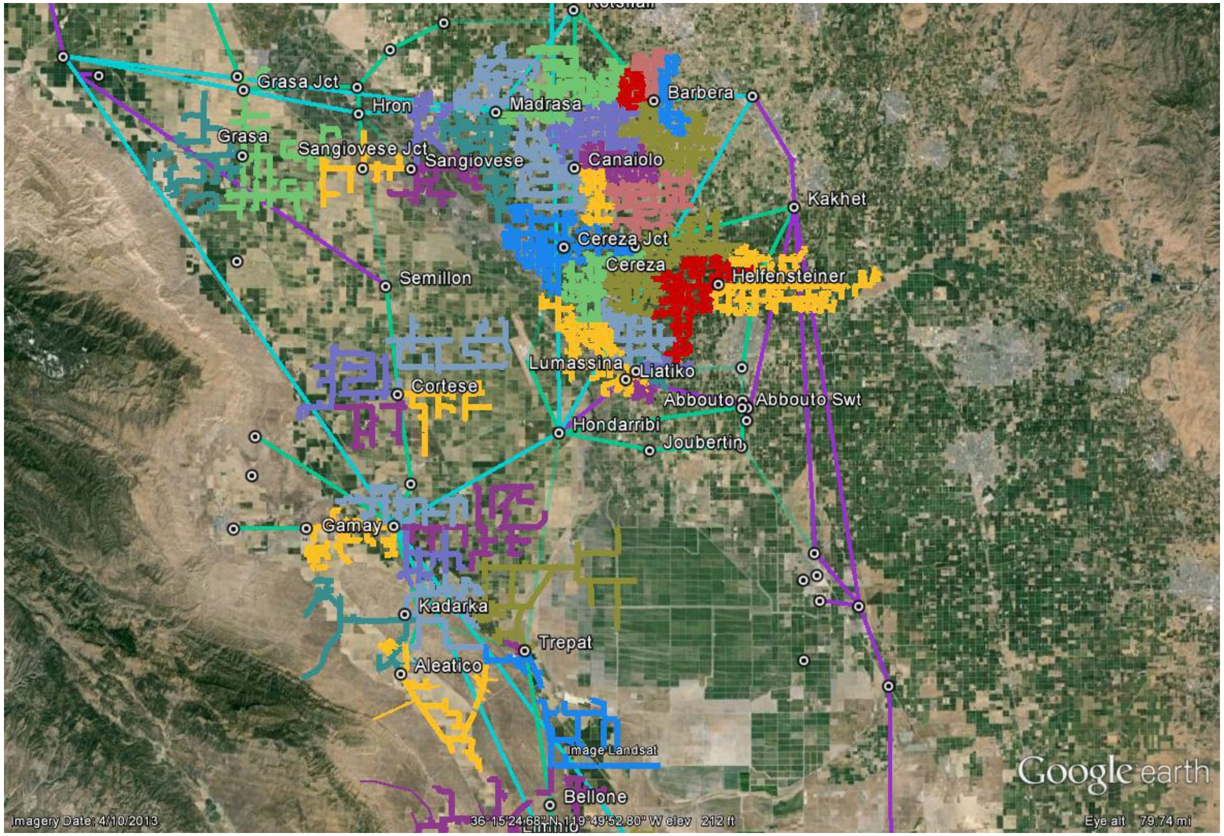
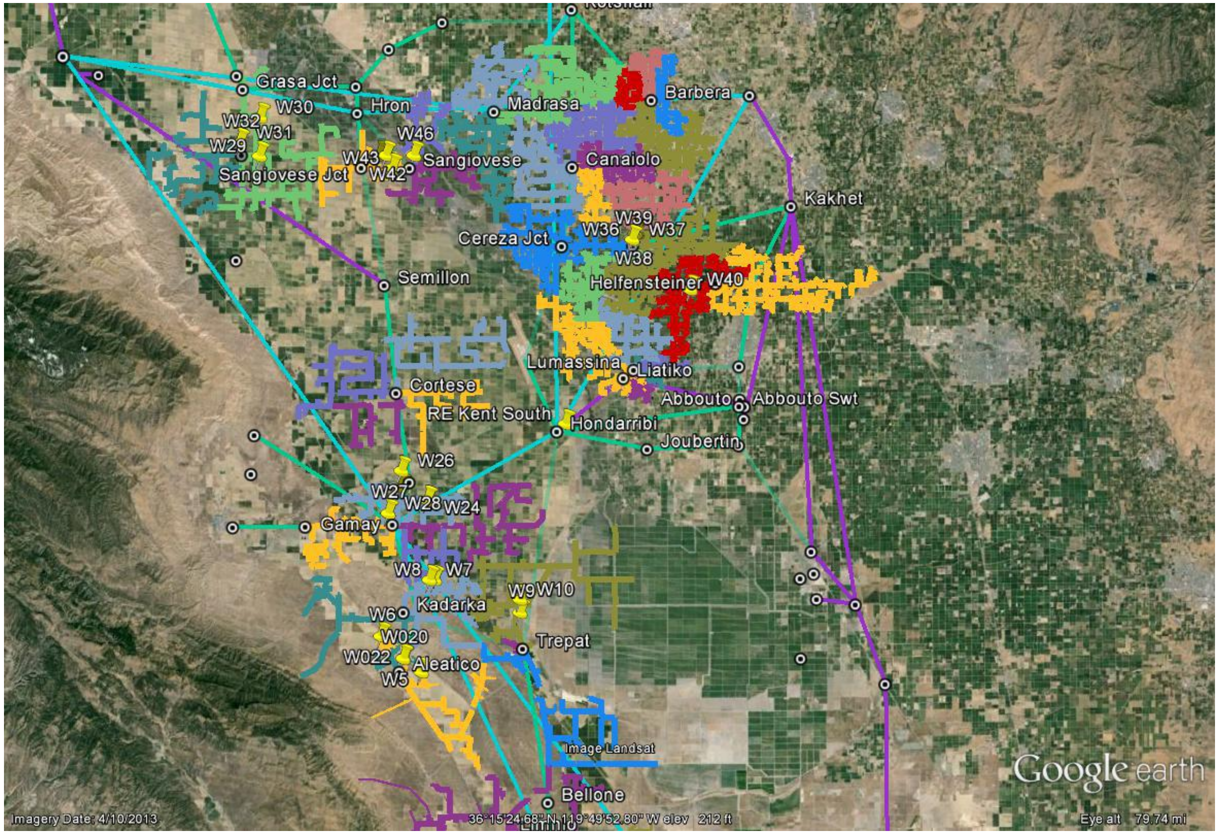
Vineyard *Energynet*



- **26 substations**
- **51 distribution feeders (12kV and 21 kV)**

Vineyard Wholesale PV Interconnections



- **46 individual distribution-connected wholesale PV projects**
- **Approx. 80 transmission-connected PV projects**

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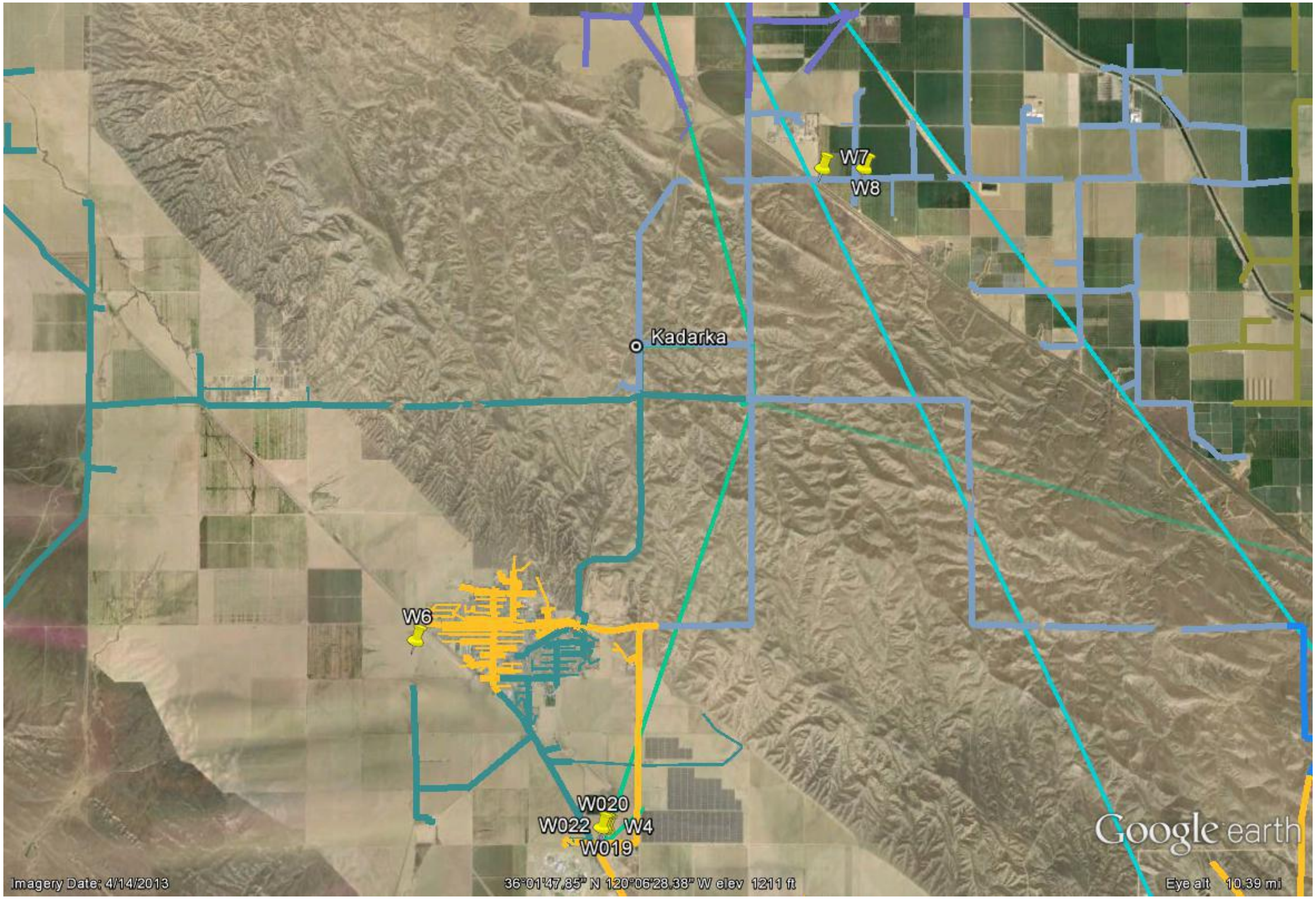
Kadarka Substation

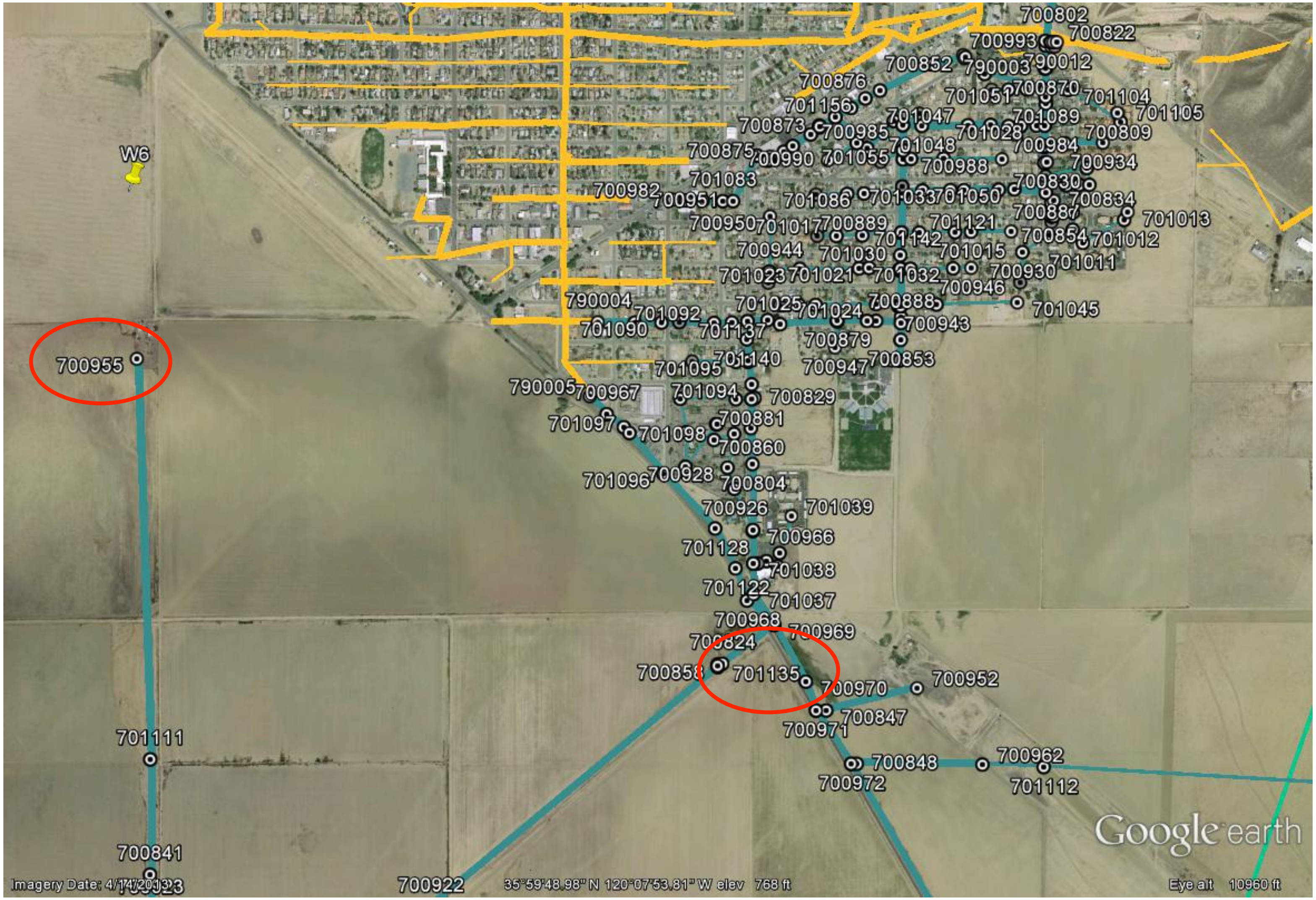


Kadarka Substation

- **70 kV/12kV**
- **10.6 MVA transformer rating**
- **7.9 MW peak load**

DG Project	Size	Share of Substation Transformer Peak Load	Feeder Overload Potential	Maximum Voltage Impact
W7	3 MW	38%	No	2.2%
W8	3 MW	38%	No	2.2%
W6 (@700955)	10 MW	127%	Yes	11.4%
W6 (@701135)	10 MW	127%	Yes	2%

Project W6 Alternates



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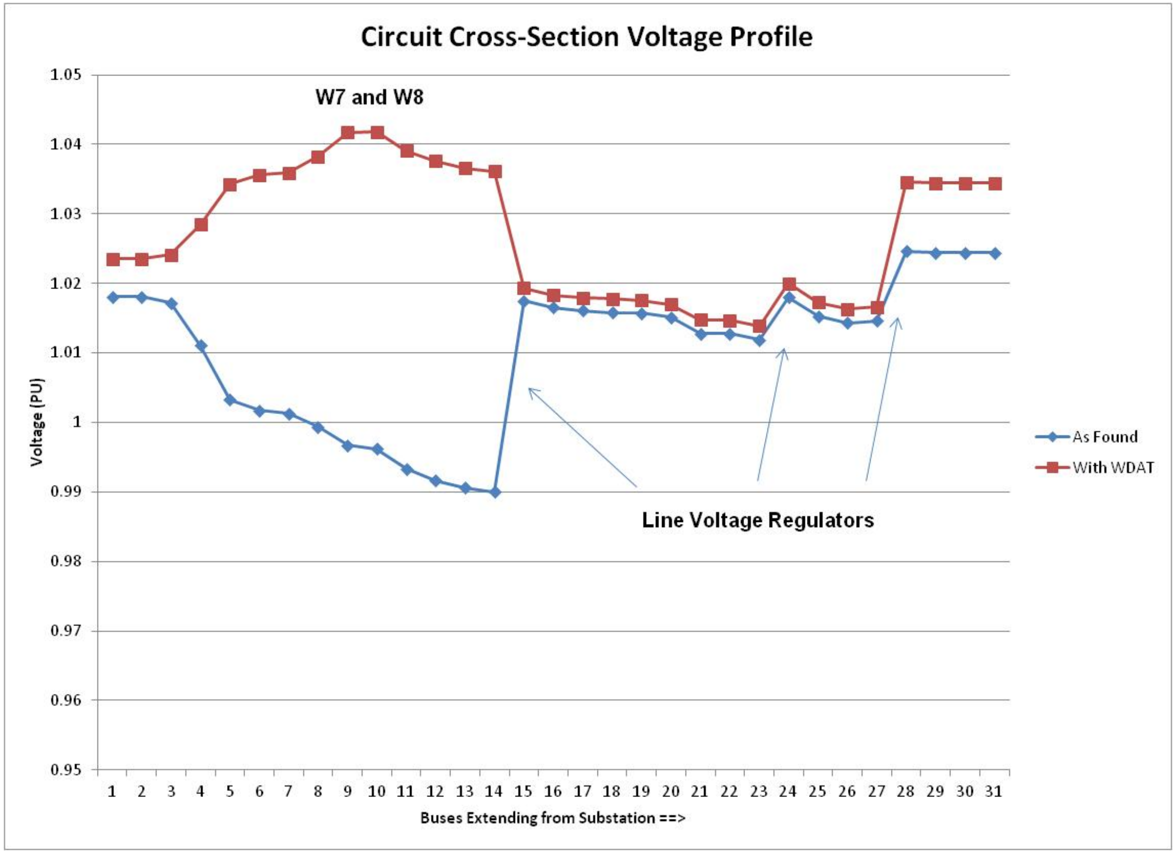
Feeder Voltage Regulation
Confines Feeder Steady-state Voltage Impacts

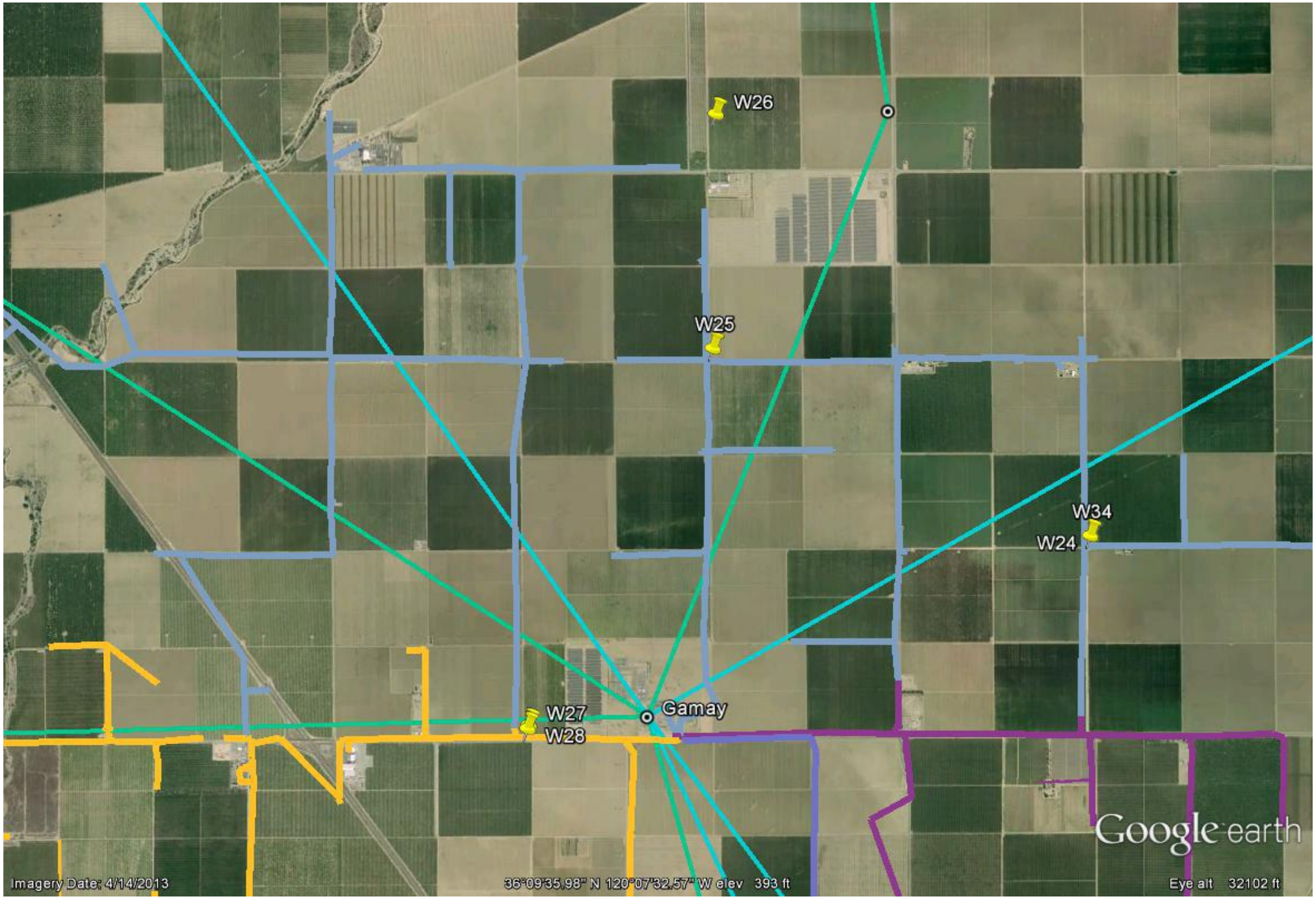


- 4% voltage rise at W7 and W8 projects' point of interconnection in distribution feeder.
- No voltage change at substation or further out feeder.
- Overall "flatter" feeder voltage profile.

As-found
With PV projects added

Four projects: Two feeder-connected, two substation-connected; total 46,000 kW

Gamay Substation



Gamay Substation

- **230 kV/12kV**
- **44.5 MVA + 17.63 MVA transformer rating**
- **20.2 MW + 14.1 MW peak load**

DG Project	Size	Share of Substation Transformer Peak Load	Feeder Overload Potential	Maximum Voltage Impact
W28	2 MW	14%	No	0.2%
W27 (alt 1)	5 MW	35%	No	0.5%
W25 (alt)	10 MW	22.5%	No	2%
W26 (alt)	5 MW	11%	No	5.1%
W27 (alt 2)	5 MW	11%	Yes	5.6%

Bonarda Substation

Bonarda Substation

- 70 kV/12kV
- 12.5 MVA transformer rating
- 7.0 MW peak load

DG Project	Size	Share of Substation Transformer Peak Load	Feeder Overload Potential	Maximum Voltage Impact
W14	12 MW	170%	No	3.9%
W22	10 MW	143%	Yes	23%
W13	12 MW	170%	N/A	1.6%

Relevant Findings

- **Wholesale PV development can and does result in "penetration" far exceeding 15% of load.**
- **Feeder export, transformer reverse flow and transmission reverse flow (i.e., local generation *exceeding* local load) are common.**
  - Reverse flow may impact the function of certain devices.
- **Feeder voltage impacts of variable generation are modest as long as interconnections are not "weak."**
- **System voltage impacts are damped by distribution feeder voltage management**
- **Potential for feeder and substation transformer overload under light load or loss of load.**
- **Fully-coupled distribution and transmission-level modeling permits more accurate representation of system impacts of high-penetration distribution-connected generation.**

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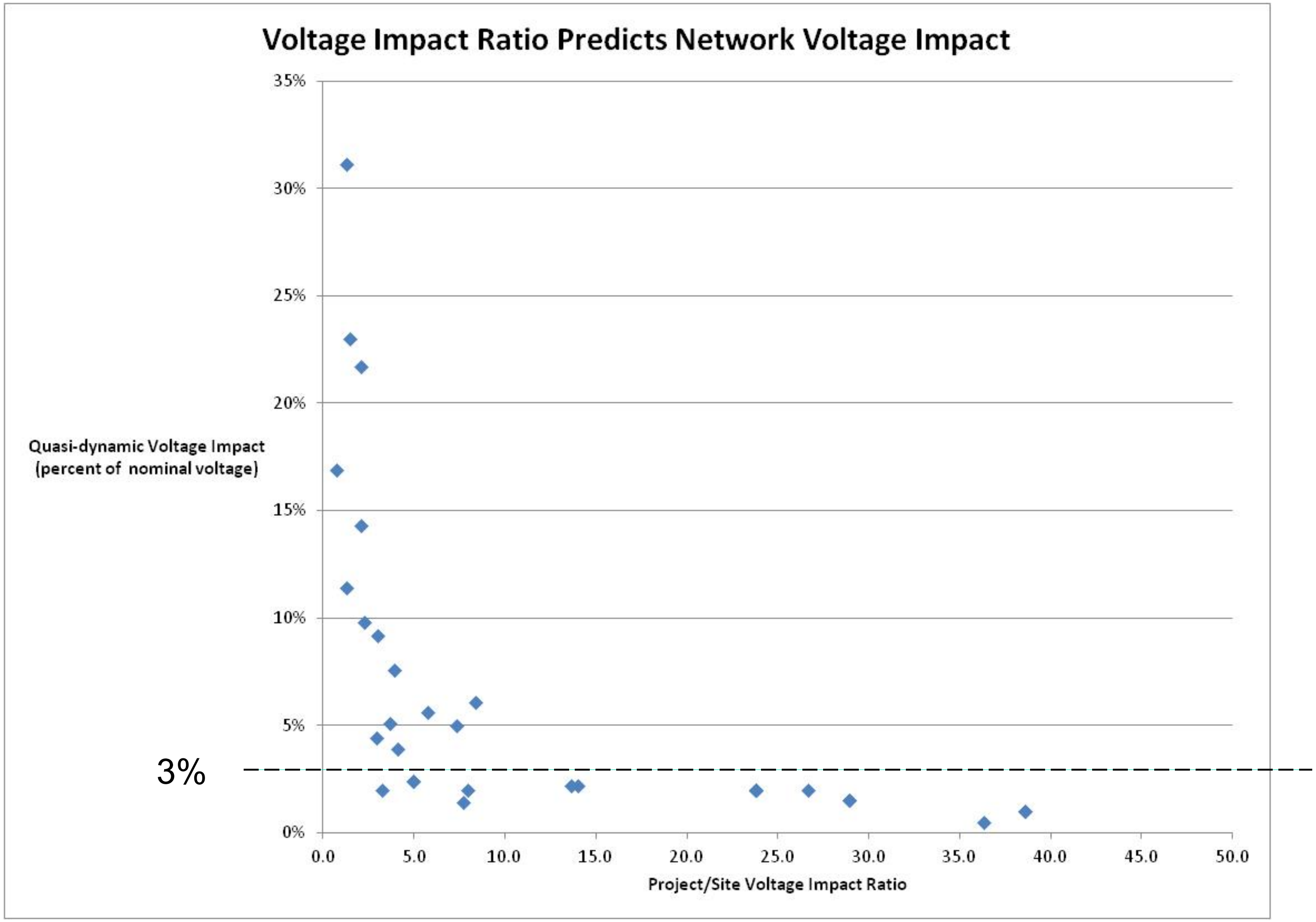
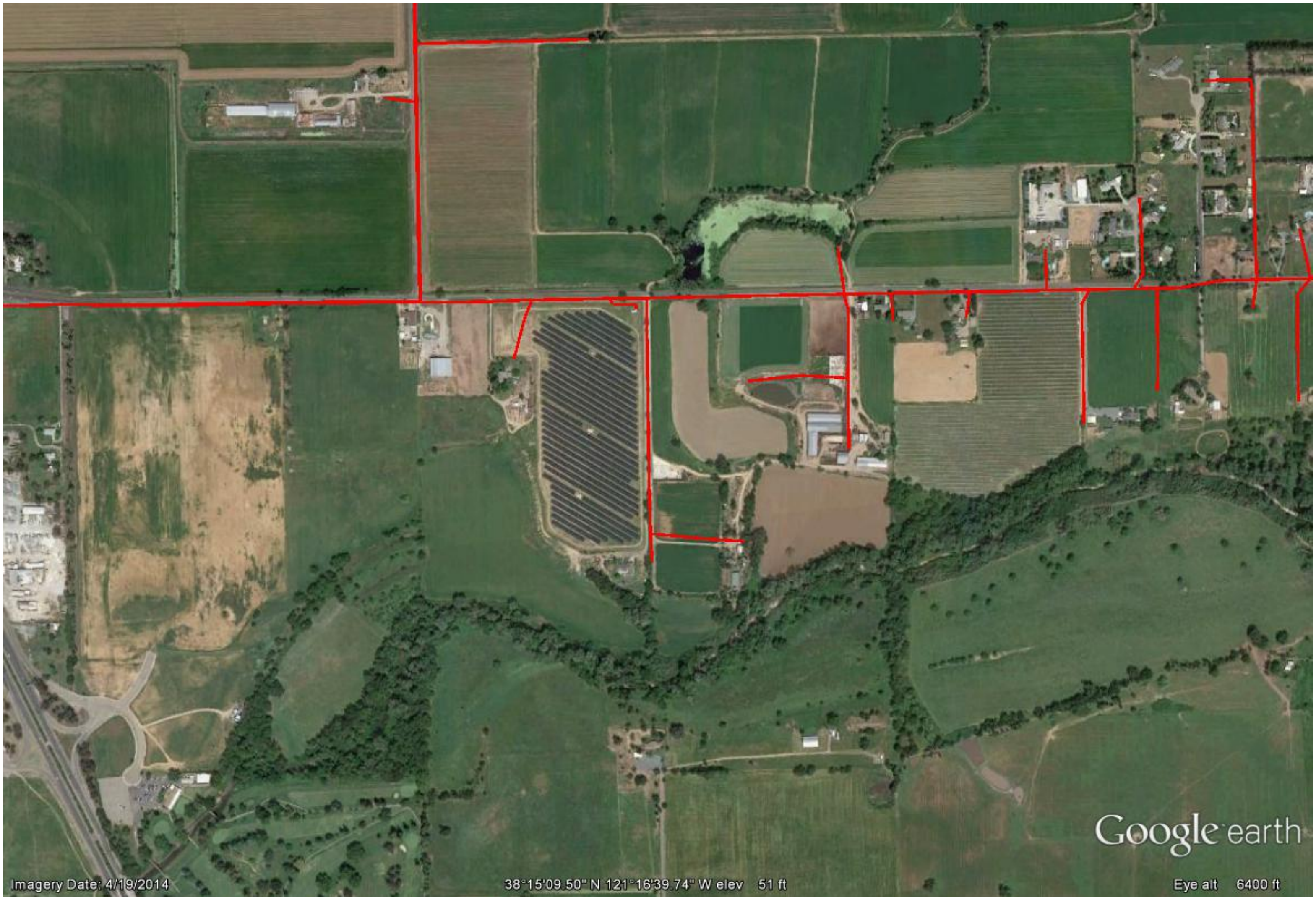
"Stiff" Locations Limit Quasi-dynamic Feeder Voltage Impacts of Variable PV Output

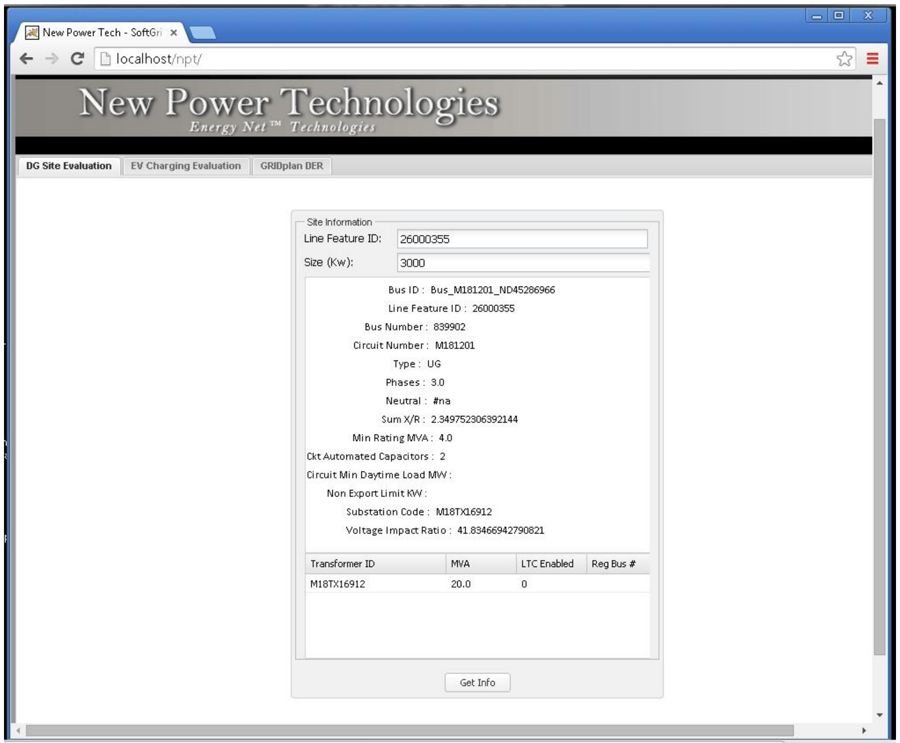


Voltage Impact Ratio = Utility Source SC (MVA) @ PCC ÷ Project Rated Output (MVA)

DG Site Evaluation App – 3 MW PV on 12 kV Feeder



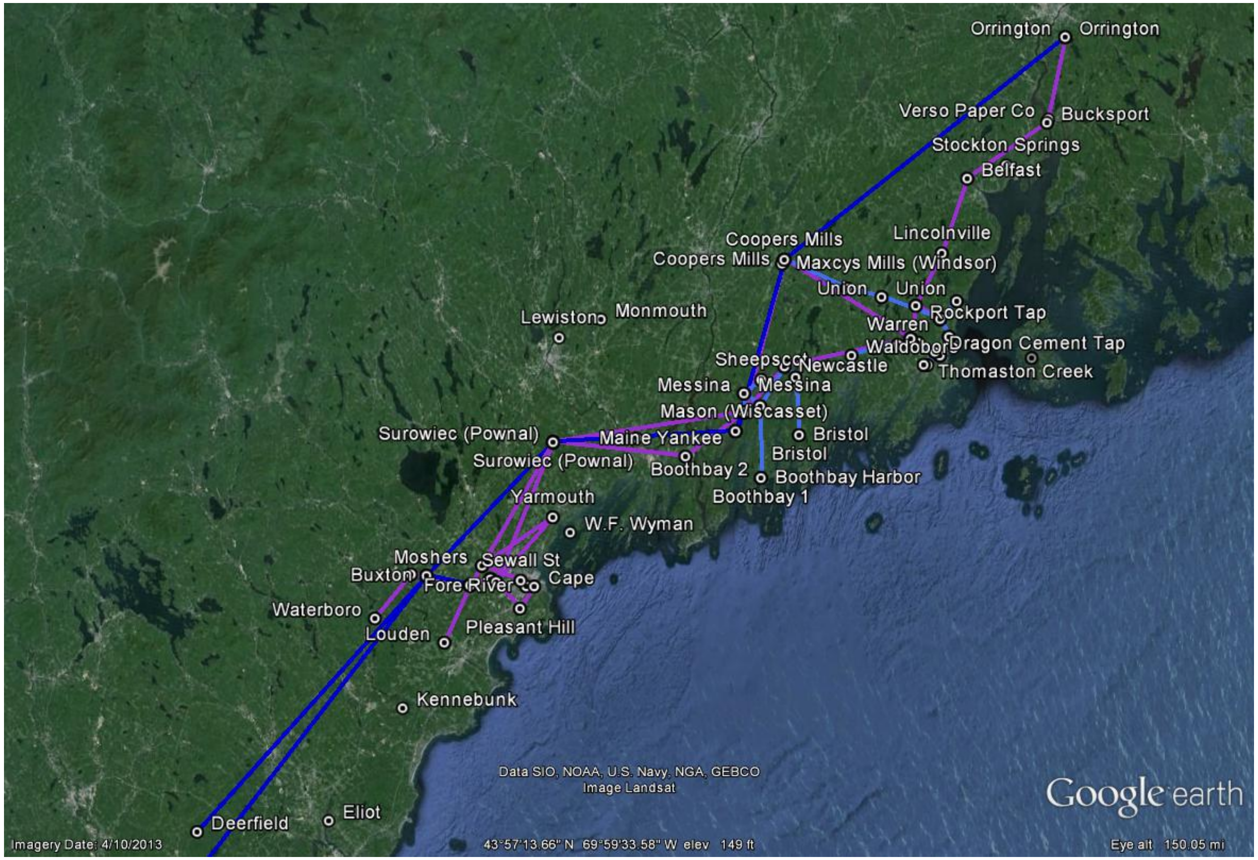
DG Site Evaluation App – 3 MW PV on 12 kV Feeder



- > feeder non-export limit
  - Total PV = 119% of feeder connected load
- ✓ < min upstream line rating
- ✓ 3ϕ location
- ✓ Feeder voltage regulation
- ✓ Voltage Impact Ratio > 20
- ✓ Max voltage impact: 1%

➢ **Site-specific, multi-variable assessment in one click**

Maine Power System



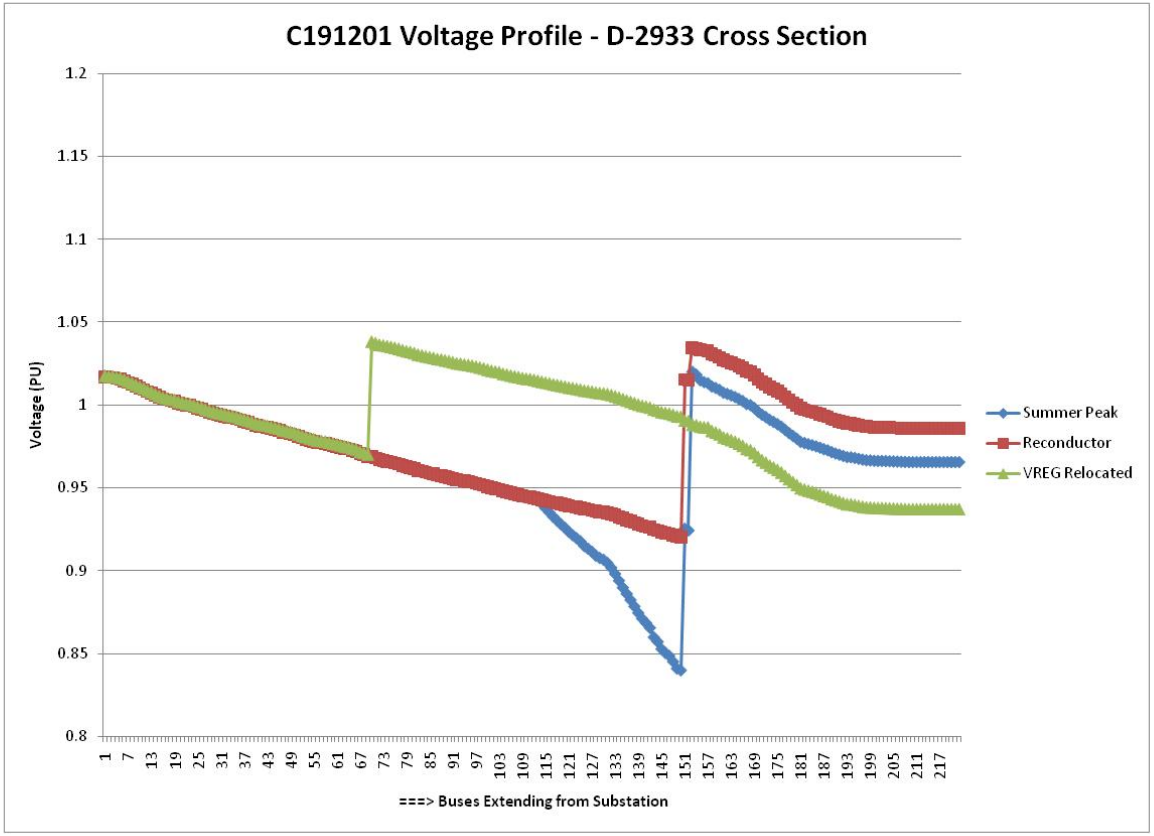
- **345 kV**
- **115 kV**
- **34.5 kV**

Conclusion

- **DER can contribute to grid performance.**
- **Not all DER is grid-beneficial.**
  - **Location-specific**
  - **Size and characteristic - attribute-specific**
  - **Operational alignment with grid conditions**
- **Given identified grid needs, it is possible to rigorously identify the locations and attributes of the most valuable DER and quantify their direct benefits.**
- **Distribution feeders can accommodate DG as a significant share of load – with attention to interconnection sites and network characteristics.**
- **Under the right circumstances DER can offset network load; it can also provide diversity under contingency conditions and other utility and societal benefits.**

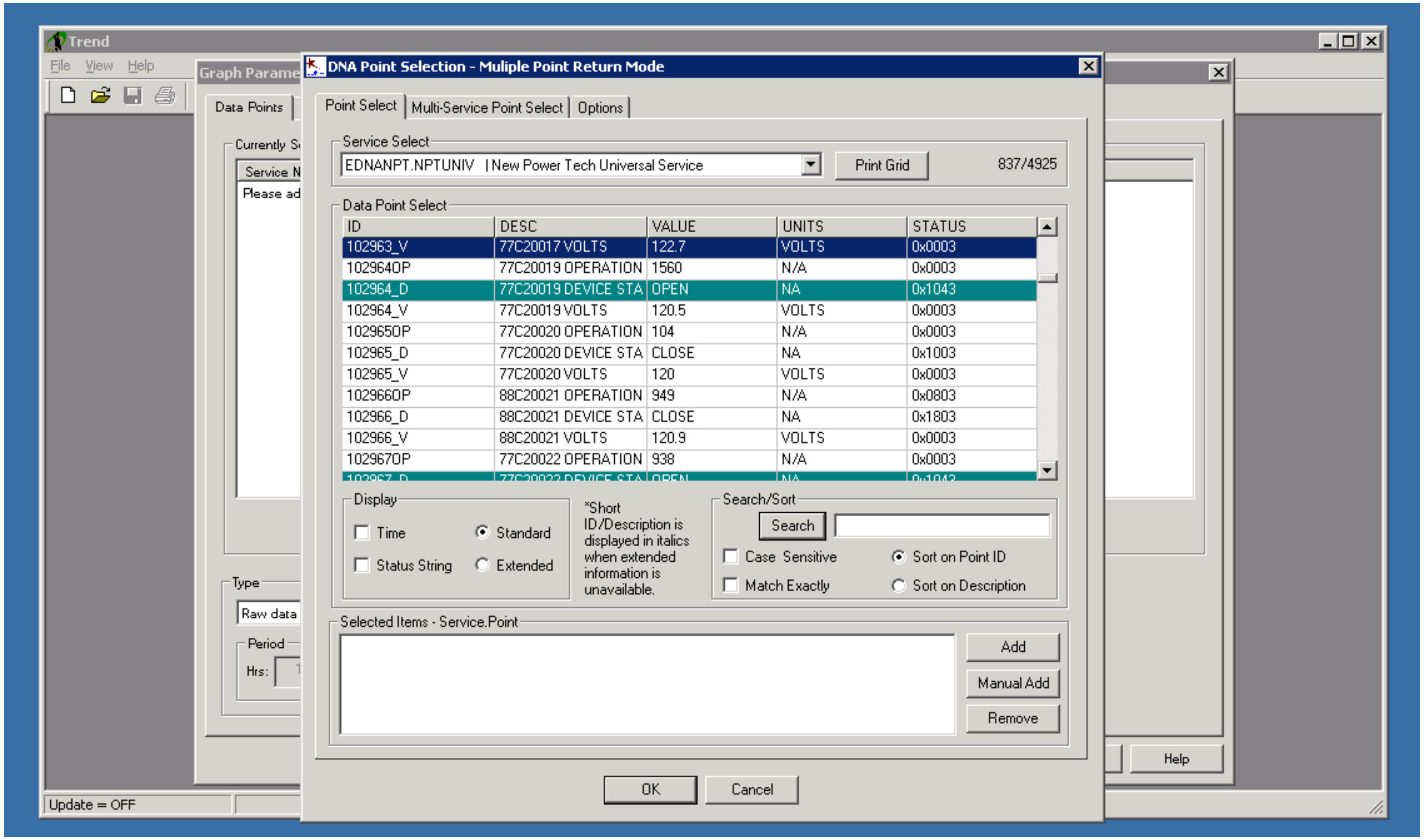
Supplemental Slides

Project Assessment - C191201 Reconductoring



➔ The impacts of individual projects are directly observable.

Wide-area System Monitoring Integration: Turning data into understanding



Existing tabular data without topological cues

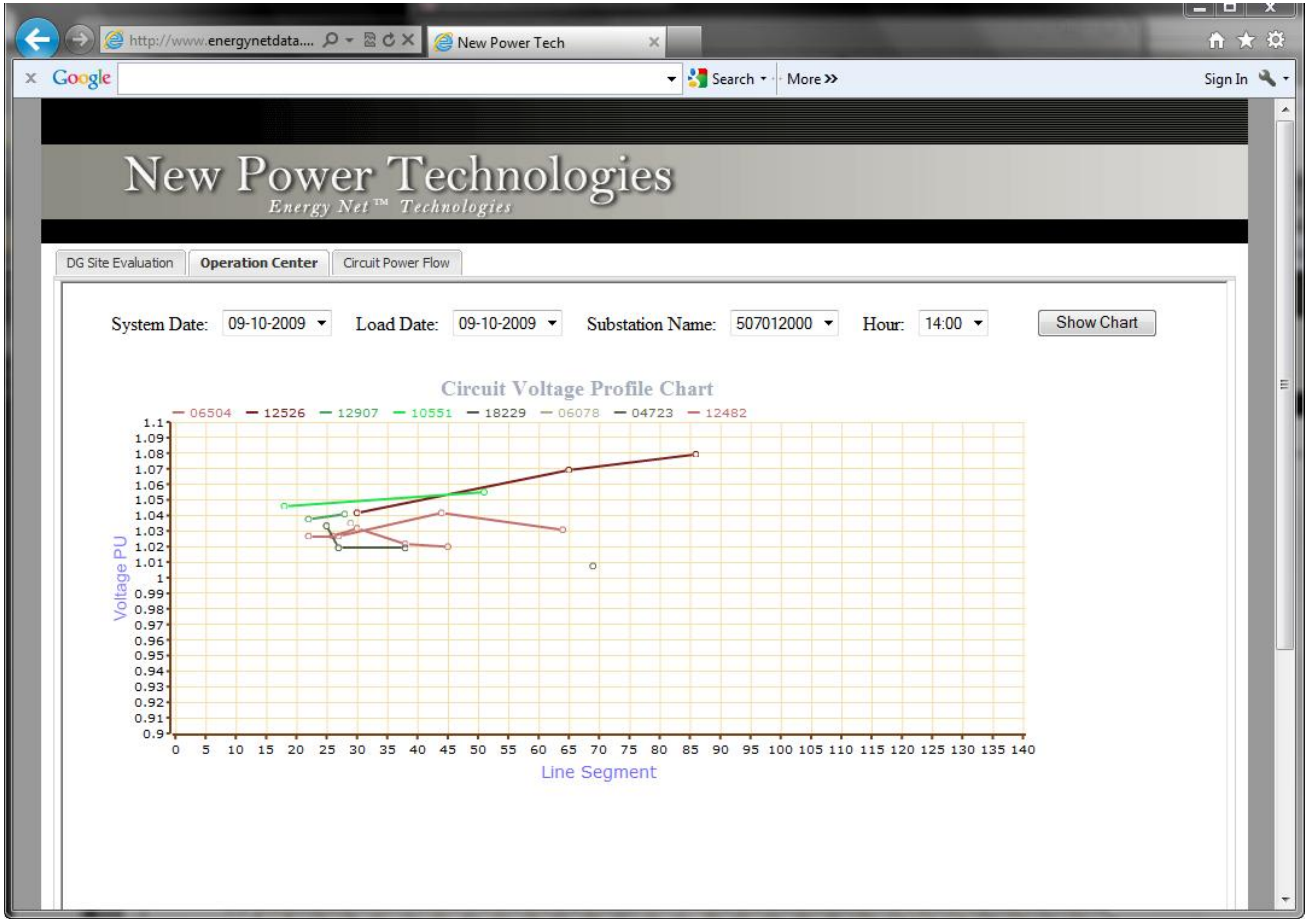
Wide-area System Monitoring Integration: Strategic augmentation for consistent "density"

- **LineTracker™ monitoring augmentation in Energynet-targeted locations:**
  - Enhanced sensing capability (real and reactive power sensing)
  - Legacy communication systems integration (DNP3)
  - Legacy data systems integration
  - Consistent "monitoring density"

➢ **Low-cost "Wide Area Situational Awareness" functionality**

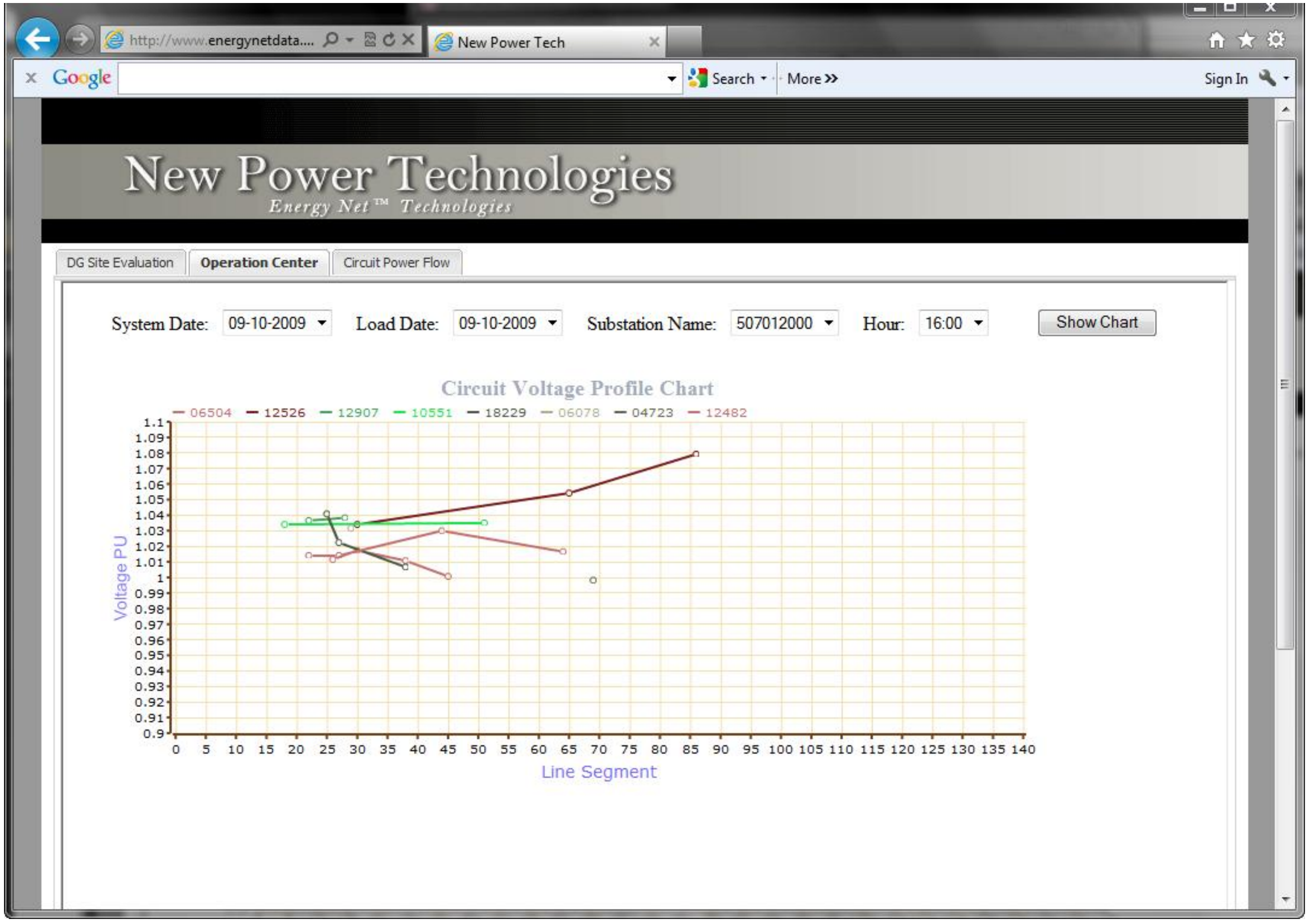
Source: GridSense

Wide-area System Monitoring Integration: Topological context => situational awareness



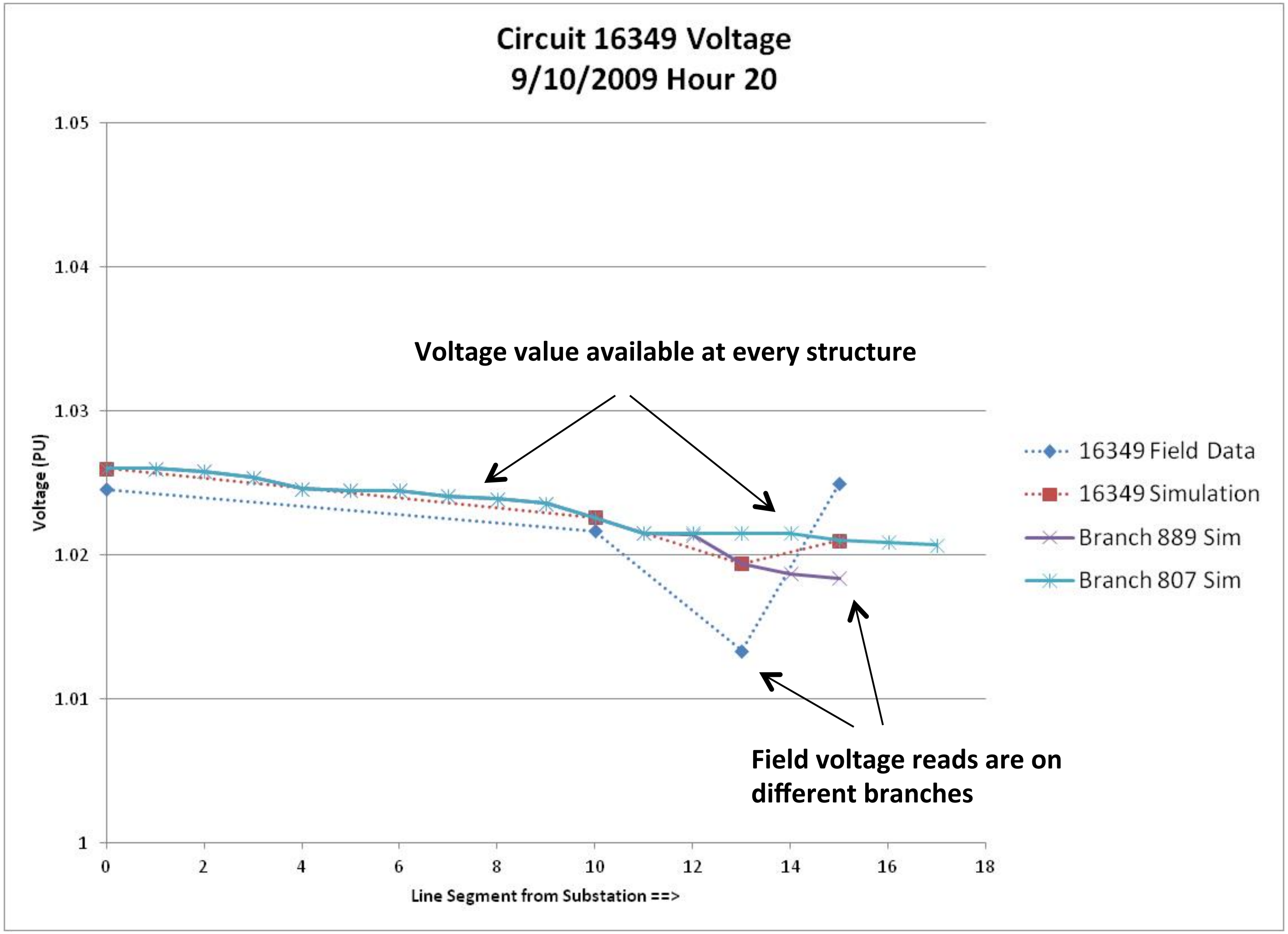
Continuously-read Pi System or eDNA data mapped to Energynet topology

Wide-area System Monitoring Integration: Topological context => situational awareness

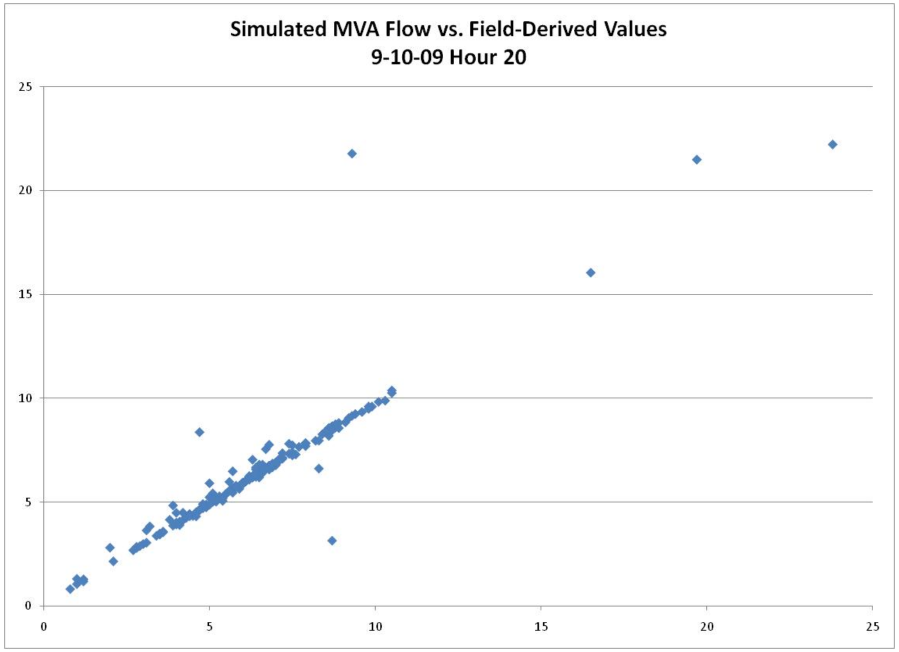


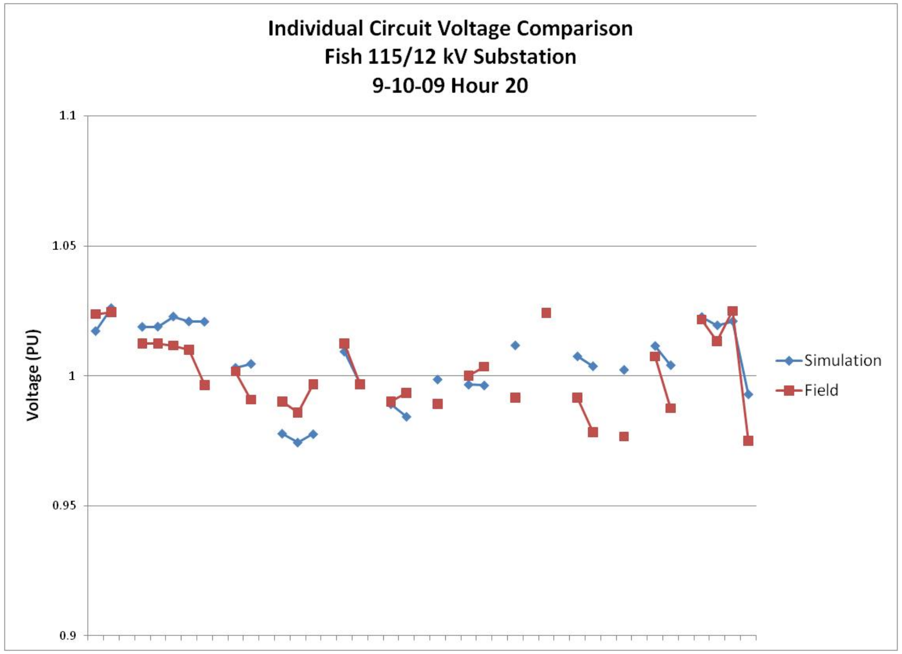
Continuously-read Pi System or eDNA data mapped to Energynet topology

Wide-area System Monitoring Integration: *Energynet* simulation => device level visibility



Energynet Simulation a Validated Predictor of Actual System Conditions





- Simulation voltage results within 2% of field data reads at ~650 widely-dispersed locations
- Area model produced from raw data in one month
- Area model updated in one day using secure web file transfer

Energynet Deployments

- **SMUD**
  - > 750 feeder systemwide commercial deployment (competitive award)
  - DG siting, EV charging, GRIDplan DER apps
  - Elk Grove #1 system (competitive commercial pilot, 2010)

- **PG&E**
  - "Vineyard" system (51 feeder integrated T&D simulation)
  - Regional impacts of high PV penetration (CEC)
  - 5 circuits; high EV penetration area (LAHFT)
  - EV Charging app (2012)

- **Southern California Edison**
  - "Hobby" system (246 feeder integrated T&D simulation)
  - "Mountain" system (190 feeder integrated T&D simulation)
  - Full-scale demonstration; simulation validation (2004-2009)
  - Legacy sensors for a wide-are monitoring network and situational awareness
  - DG siting app (2010)

- **Silicon Valley Power**
  - 48 feeder integrated T&D simulation; proof of concept demonstration (2003-2005)

References

1. **Regional/Transmission & Distribution Network Impacts Assessment for High-Penetration Wholesale PV, Evans, P. (New Power Technologies), CEC-500-2014-xxx (unpublished); 2014.**

2. **Integrated Transmission and Distribution Model for Assessment of Distributed Wholesale Photovoltaic Generation, Evans, P. (New Power Technologies; California Energy Commission, CEC-500-2013-003; 2013.** <http://www.energy.ca.gov/2013publications/CEC-200-2013-003/CEC-200-2013-003.pdf>

3. **Verification of Energynet® Methodology, Evans, P.; California Energy Commission, CEC-500-2010-021; 2010.** <http://www.energy.ca.gov/2010publications/CEC-500-2010-021/CEC-500-2010-021.PDF>

4. **Optimal Portfolio Methodology for Assessing Distributed Energy Resources for the Energynet; Evans, P., California Energy Commission, CEC-500-2005-096; 2005.** <http://www.energy.ca.gov/pier/project_reports/CEC-500-2005-096.html>

Notices

The Energynet platform and its applications are protected under US Patent No.s 7,860,702 and 7,398,194 and patents pending.

About…

New Power Technologies is dedicated to moving advanced energy technologies from theory to practical application. The company's *Energynet*® technologies enable power delivery network analysis and management with unprecedented transparency, precision, and ease of integration to support high-performance and high-efficiency network operation and planning.

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