Incorporating DER Benefits in Power Delivery System Planning

New Power Technologies *Energynet*® Overview

January 8, 2015

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 (generation and demand response, four quadrants)
  - ➢ Close to load
- **Grid (power delivery network):**
  - Bulk electric system
  - Local transmission and sub-transmission
  - Distribution feeders and elements
  - Substations and components
  - Loads and resources

Nomenclature

- **Grid performance improvement ("benefit categories"):**
  - Reliability improvement (fewer, shorter outages)
  - Resiliency improvement (reduced exposure to major events)
  - Loss reduction (system efficiency)
  - Emission reduction, carbon reduction
  - Fuel diversity
  - Load relief (avoided or deferred infrastructure costs)
  - Reduced utility operating costs
  - Voltage violation relief
  - Power quality improvement
  - Expanded CVR opportunity
  - Incremental capacity (RA capacity, local RA capacity)
  - Incremental energy
  - Incremental ancillary services capacity

➢ **Demonstrable, directly attributable, quantifiable, priced**

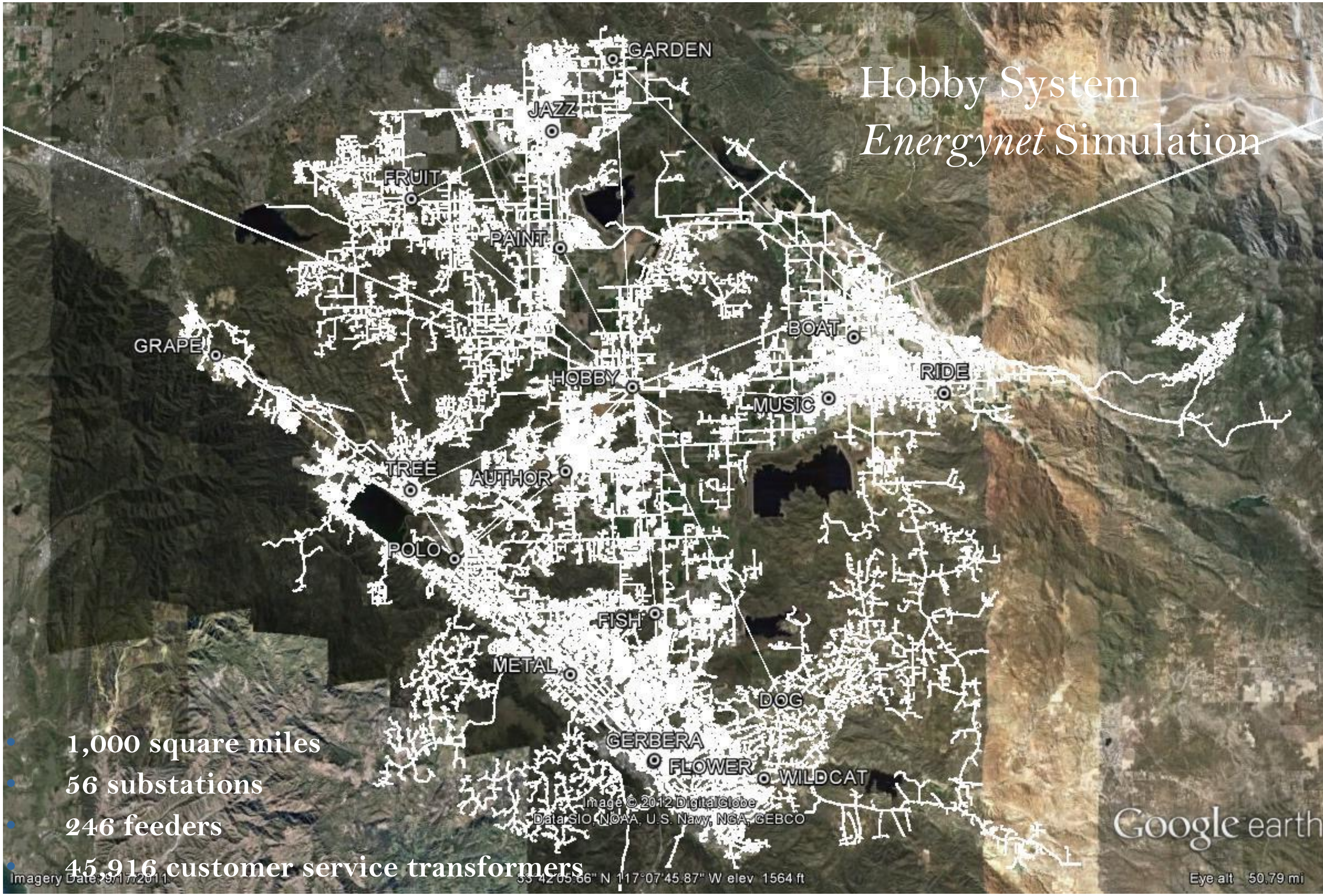
➢ **If you can't measure it and price it, it is not a real benefit**

Nomenclature

- **Pricing (valuing) network benefits:**
  - **Direct, demonstrable result of one or more individual DERs**
  - **Avoids a [network operator] cost that will or would be incurred**
  - **Someone [customer] is willing to pay more**
  - **Economic damage function (VOS)**
  - **Location-specific**

➢ **We are spending customers' money**

Hobby System
Energynet Simulation



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

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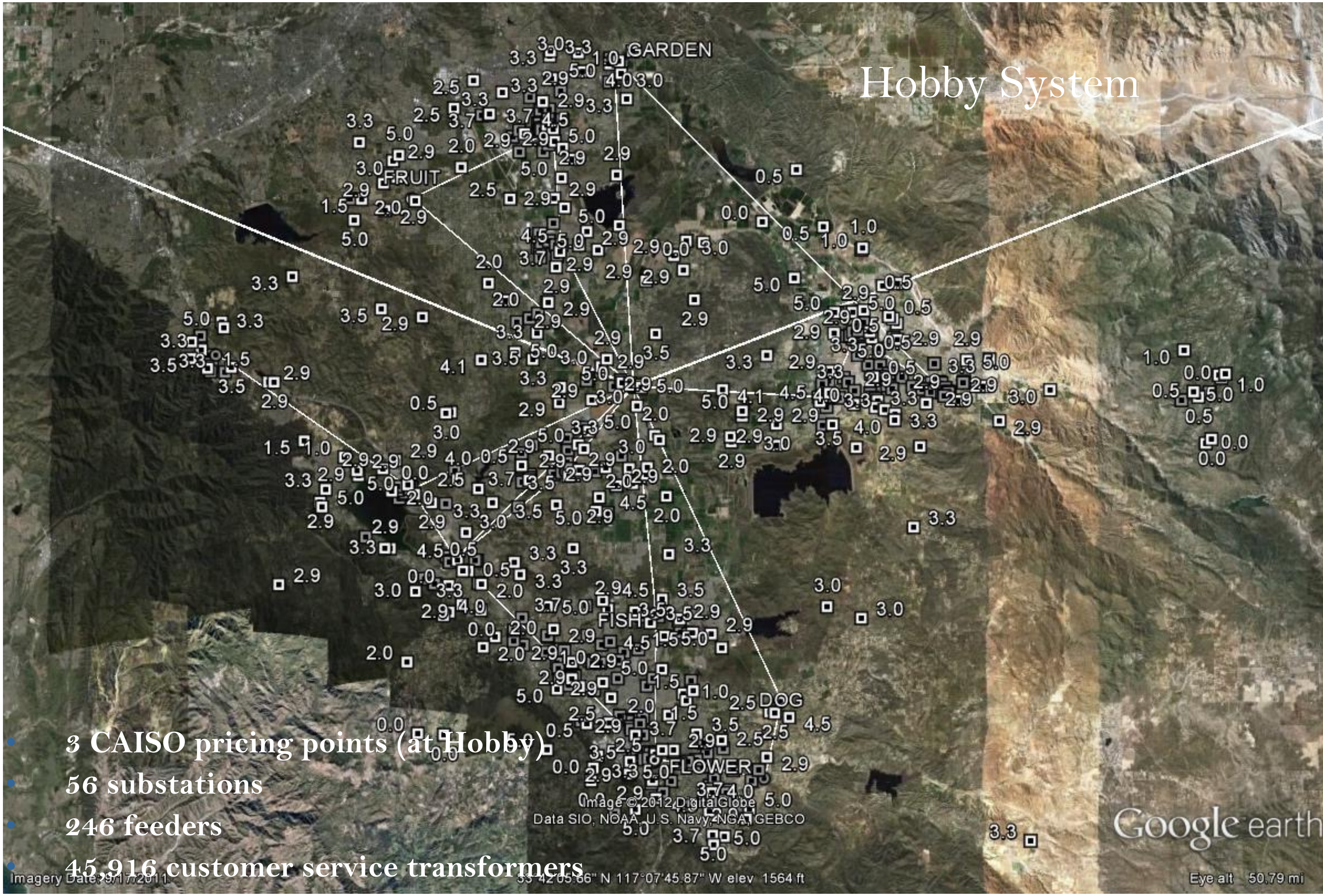
Hobby System



- 3 CAISO pricing points (at Hobby)
- 56 substations
- 246 feeders
- 45,916 customer service transformers

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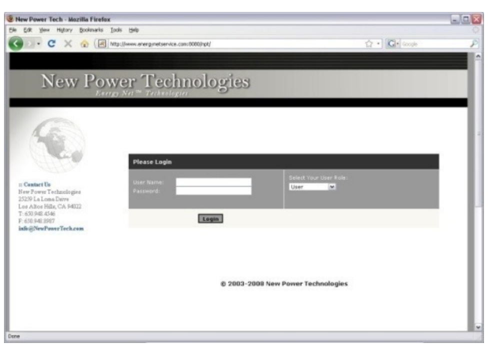
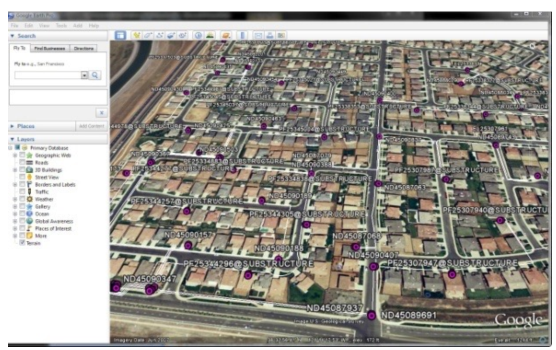
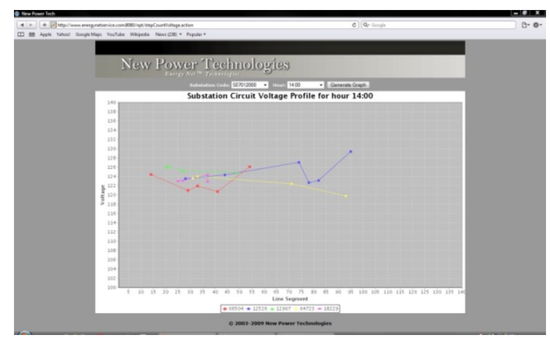
Energynet Platform

- **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

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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**
  - High-value DER identification
  - Identify DER that can offset otherwise necessary network expansion projects at lower cost
  - Network expansion project assessment
- **Regional reliability risk assessment**
- **Low-cost CVR opportunities**
- **Wide-area situational awareness with legacy sensors and monitors**

AB 327 DRP "Use Case" [from MTS WG]

- Expand the use of customer-side, distributed resources to…
  - provide local generation capacity needs (i.e., local RA capacity)
  - defer or avoid network infrastructure investments
  - provide safety benefits
  - provide reliability benefits
  - provide "other" grid savings or cost reductions
- Identify 'optimal' locations for DER deployment [to provide these benefits]

➢ Direct relationship between individual DER projects and policy outcomes

➢ Benefit-specific, location-specific, time/operating condition-specific

➢ Aggregate capacity/size-specific

➢ Local *and* system-level view

Energynet Optimal DER Portfolio Methodology

- **Define an "optimal" portfolio of hypothetical individual DER projects that maximize grid benefits**
- **Quantify the stack of grid benefits directly attributable to each project (i.e., network location)**
- **Re-define the portfolio as conditions change**

➢ **The "location value of DER" is the value of *potential* grid benefits of an optimal DER project at that location**

➢ **Procurement bogey**

➢ **Incentives and/or contractual terms (business model-independent)**

Optimal DER Portfolio Methodology

- **Optimal DER project characterization**
  - Site location
  - Type
  - Size
  - Operating profile
  - Dispatchability
  - Gross benefits and value

  → Procurement incentives and contractual terms

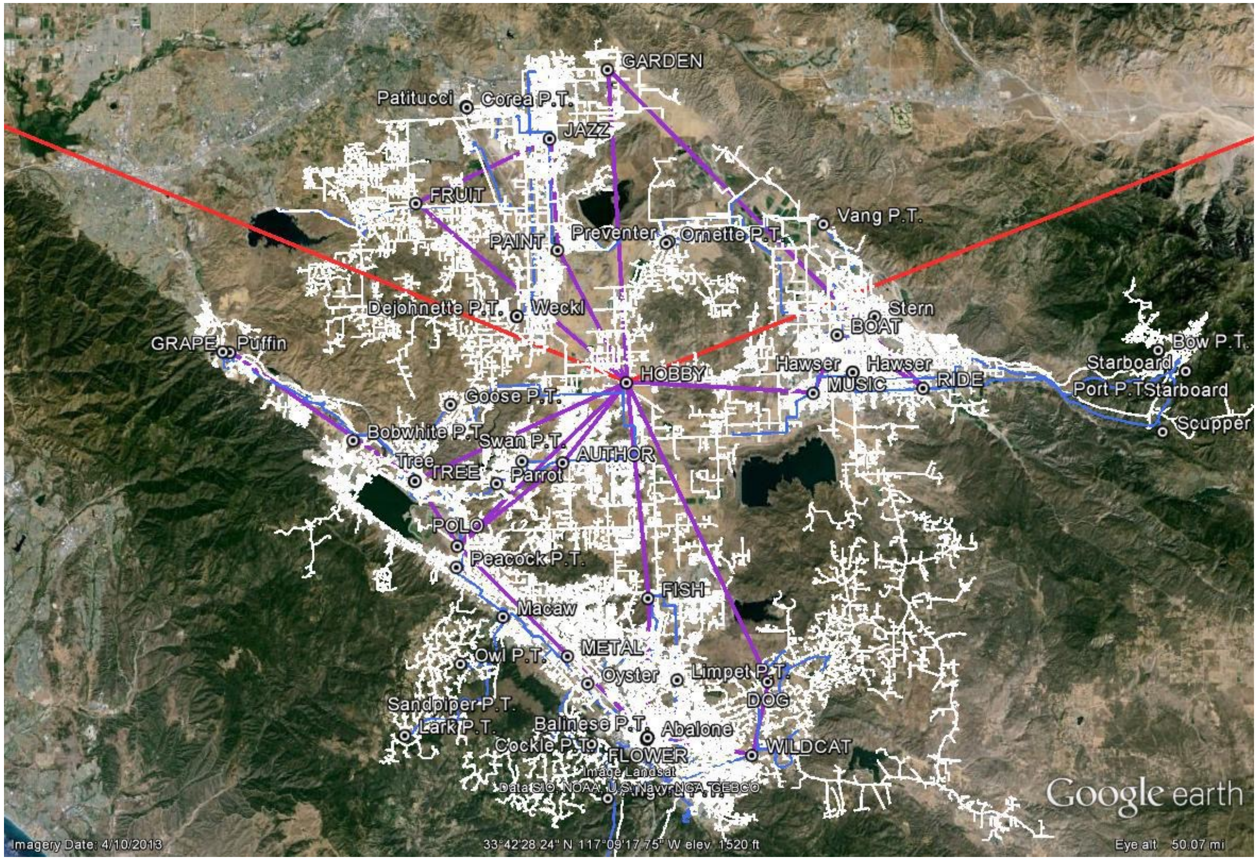
- **DER "loading order"**
  1. Operational settings, load redistribution, capacitors
  2. DR
  3. DG
  4. Storage

- **DER attributes defined by site host customer**

- **Build DER Portfolio**
  - Maximize voltage and loss benefits [subject to non-export DG limits]
  - Local overload relief, reliability enhancement, local capacity

- **Annualized benefits derived from mapping of project operating profiles and varying system operating conditions**

“Hobby” System *Energynet* Optimal DER Portfolio



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

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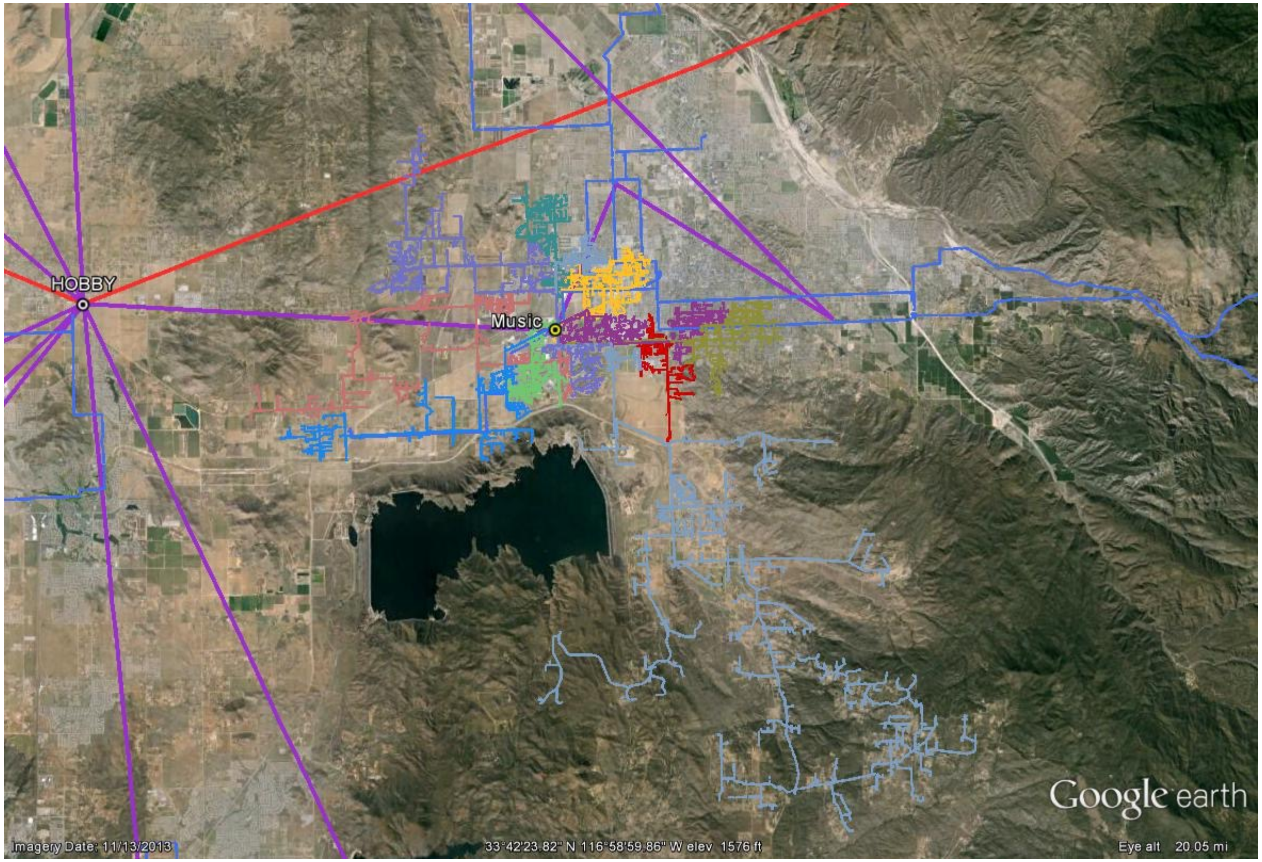
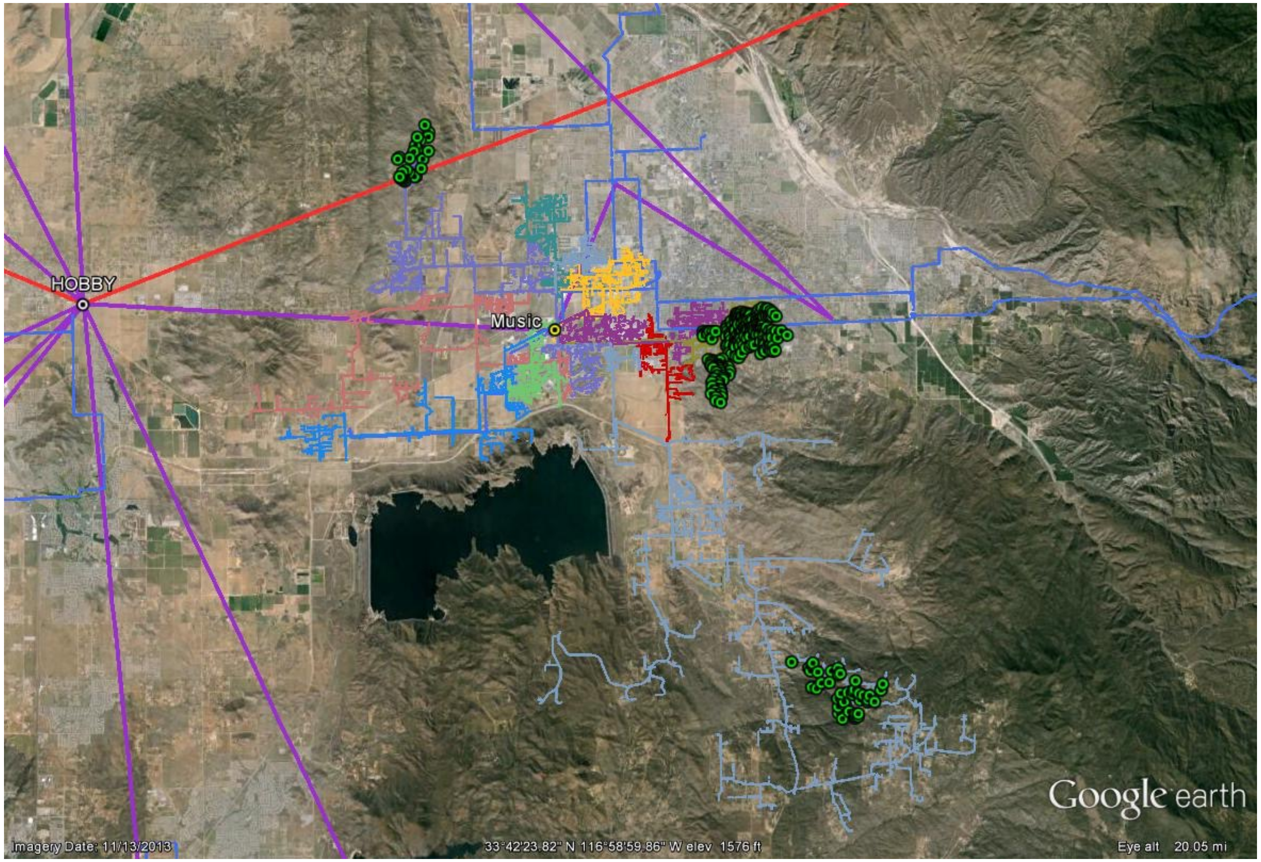
Music Substation and Feeders



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

Music Substation DR



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

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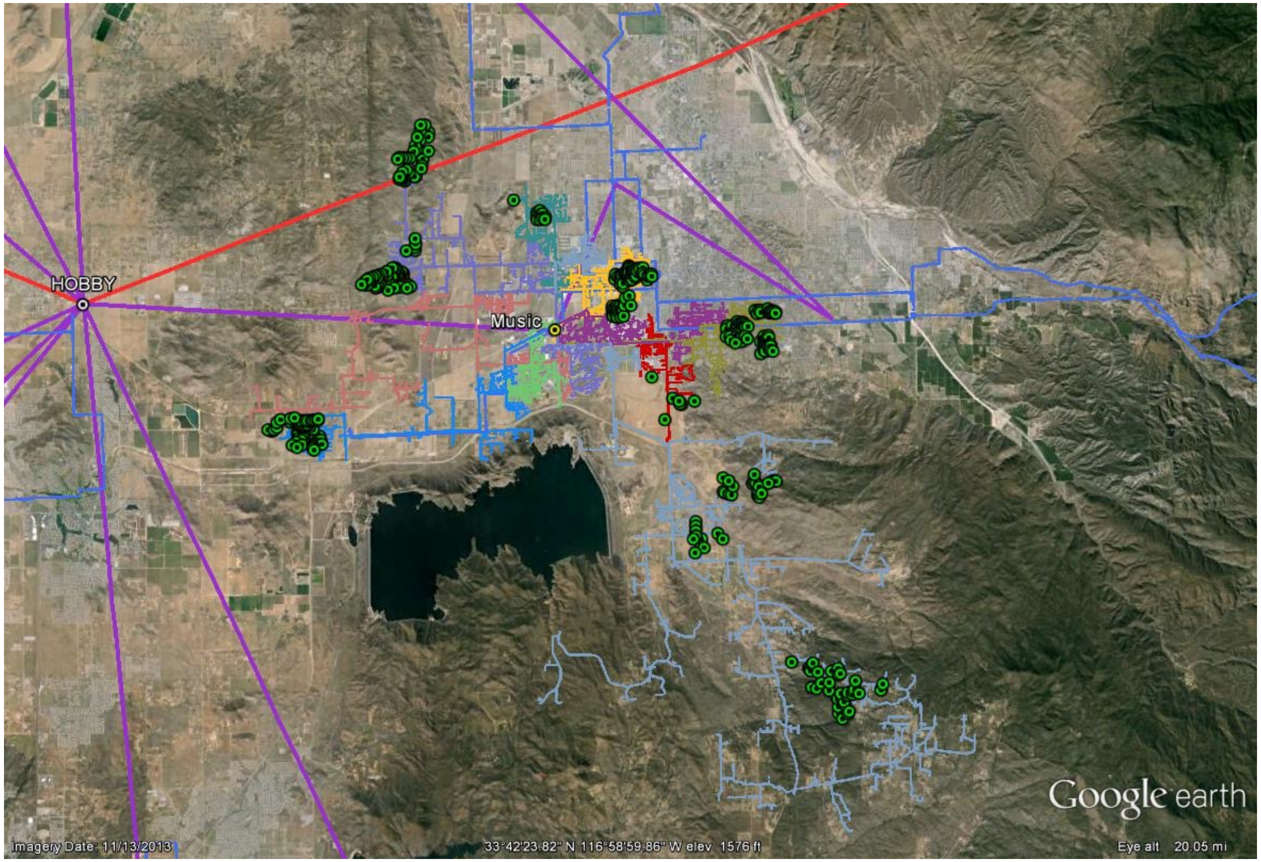
Music Substation DG



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

Music Substation Optimal 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
- **Reduced reliability risk on three feeders**
- **Address 5.4 MW projected substation overload**
- **Loss reduction, voltage, and local capacity benefits**

Hobby System-wide Optimal DER Portfolio

- **DR: 3,000 projects on 55 feeders, 14.93MW total, 0.87% of load**
- **DG: 3,000 projects on 73 feeders, 46.86 MW total, 2.75% of load**
- **Loss reduction: 5.9 MW**
- **2.2% increase in system-wide minimum voltage**

Note: voltage and loss optimization via GRIDfast analytics

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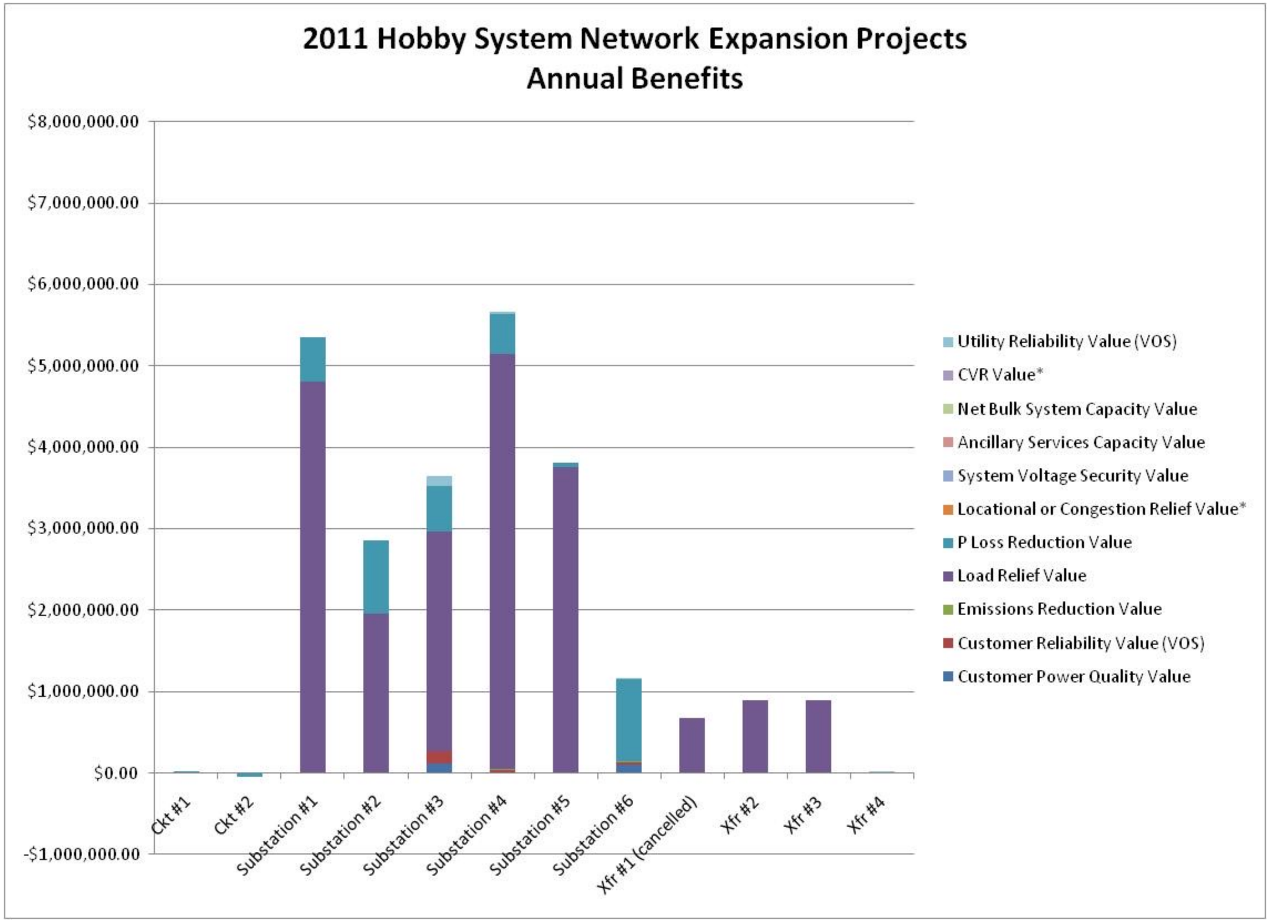
Grid Benefits of Distributed Resources



➔ Traditional network expansion project benefits are primarily in load relief

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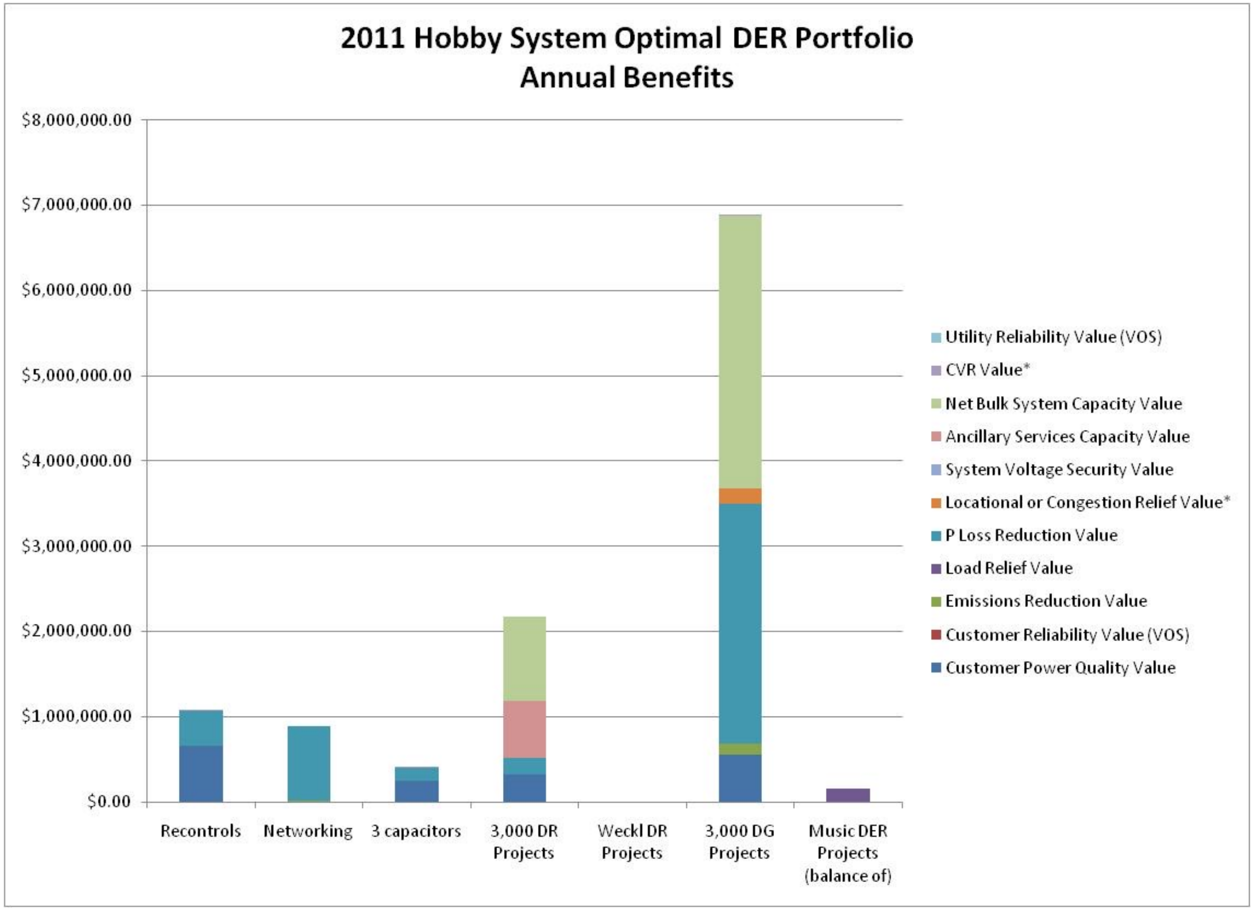
Grid Benefits of Distributed Resources



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

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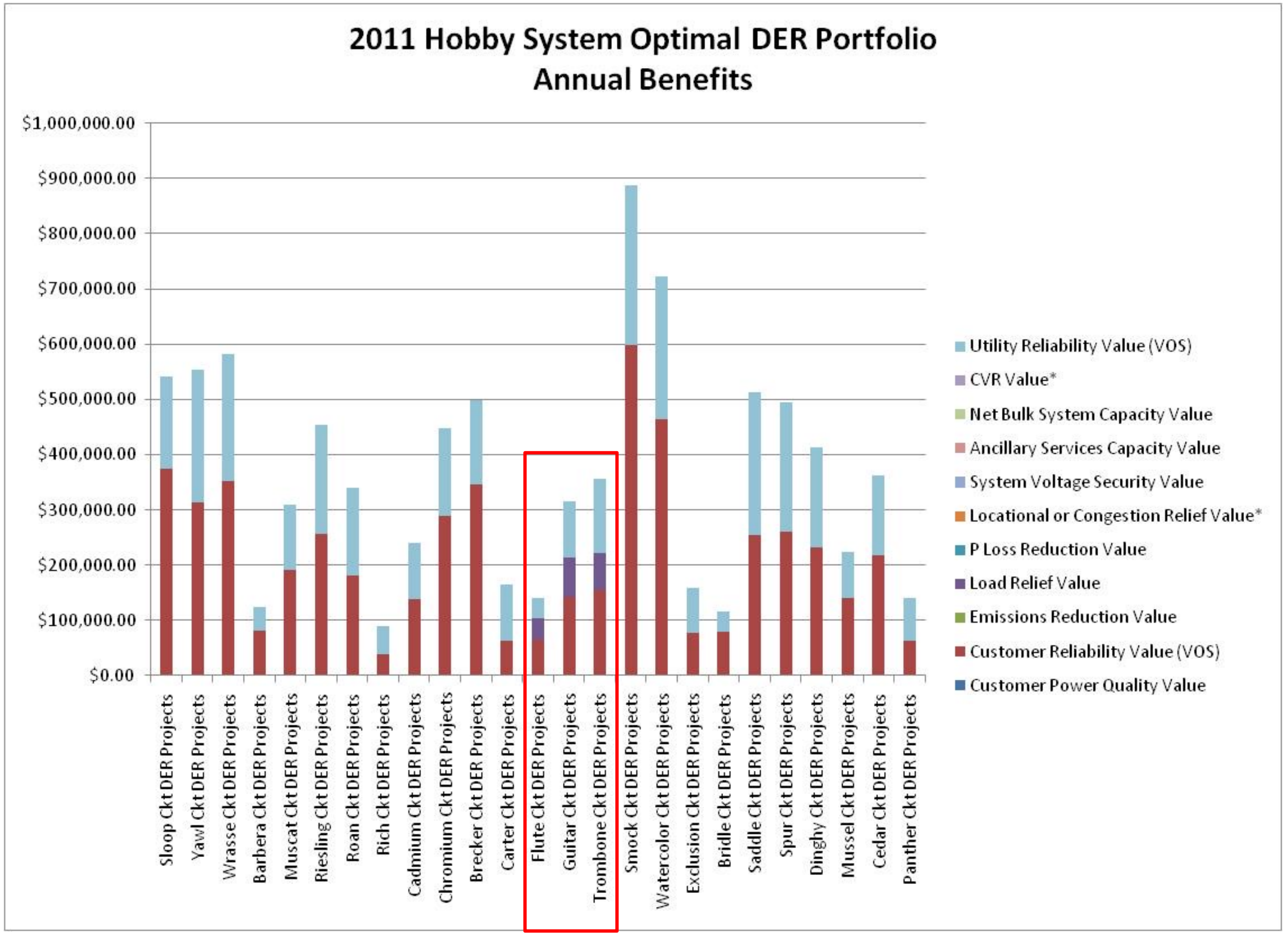
Grid Benefits of Distributed Resources



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

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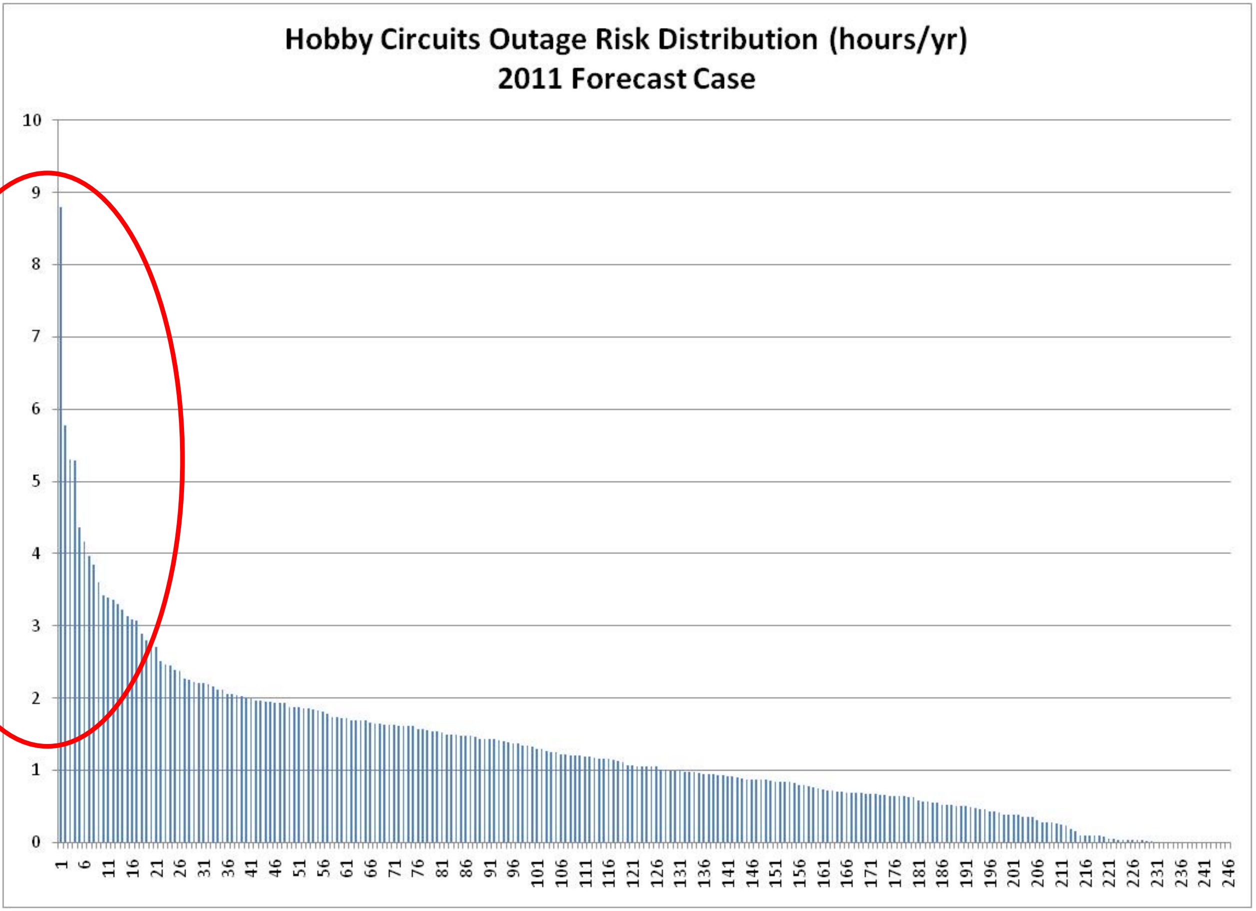
Grid Benefits of Distributed Resources

- **Sample result: four optimal portfolio DG projects at different locations in one feeder**

- **Different size, type, operating profile, and total value of benefits for each "network location"**

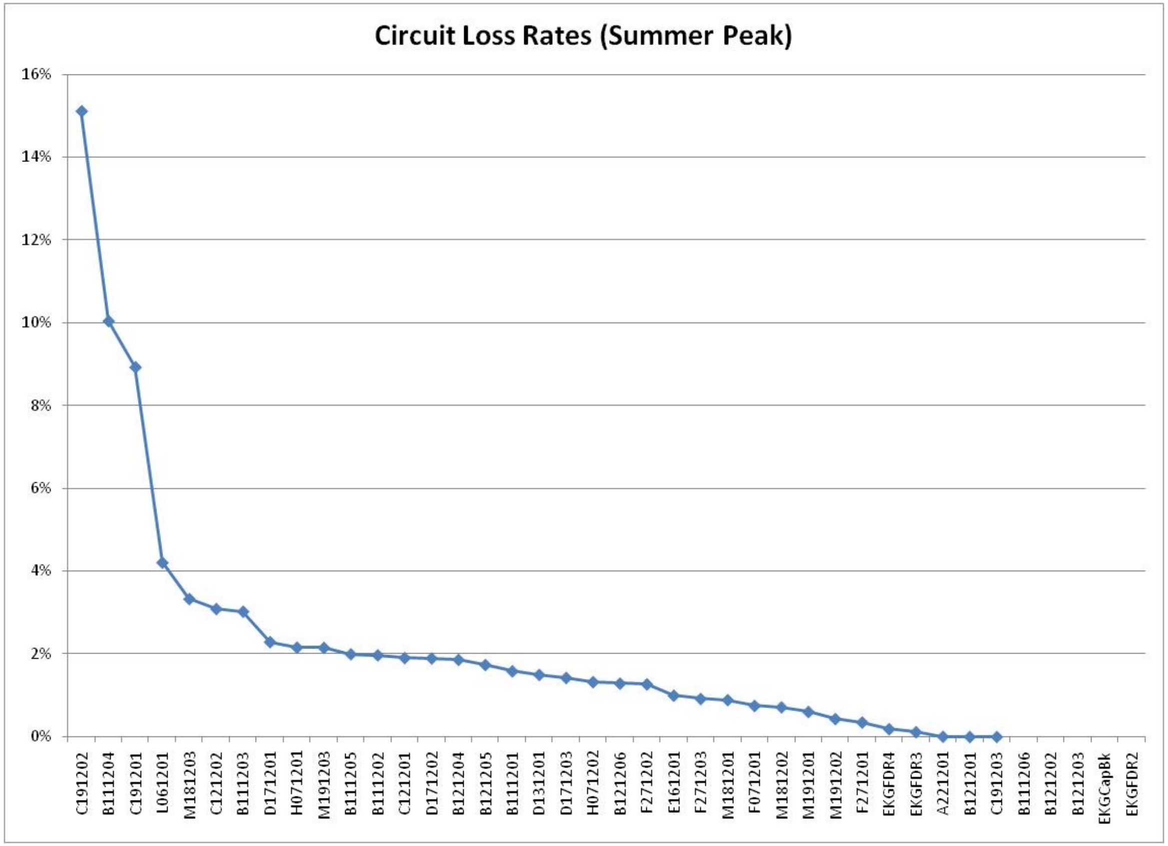
BUS_ID	Project Description	Max MW	Max MVAR	Non-PV Dispatch Profile	Summer Peak Voltage Benefit	Off Peak Voltage Benefit	Total P Loss Value ($/yr)	Total Energy Value ($/yr)	Total Congestion/Location Value ($/yr)	Total Bulk Capacity Value ($/yr)	Total Emission Reduction Value ($/yr)
Bus_15462_2289825E	Residential PV 6.5 kW	0.0065	0		yes	-	537	3,180	32	778	32
Bus_15462_2289826E	Residential PV 1.5 kW	0.0015	0		yes	-	176	734	7	179	7
Bus_15462_2289826E	Residential PV 3 kW	0.003	0		yes	-	1,420	1,468	15	359	21
Bus_15462_2289827E	Residential PV 5.5 kW	0.0055	0		yes	-	1,199	2,691	27	658	30
Bus_15462_P5466675	Medium Business Synchronous Off-Peak 238.2 k\	0.2382	0.1191	Off-Peak	-	yes	1,549	46,672	-	2,897	25

Feeder-level Reliability Risk



- ➔ Targeted DER can reduce reliability risk of those feeders most vulnerable to random contingencies.

Feeder-level Losses



➔ Targeted DER can reduce losses on high-loss feeders

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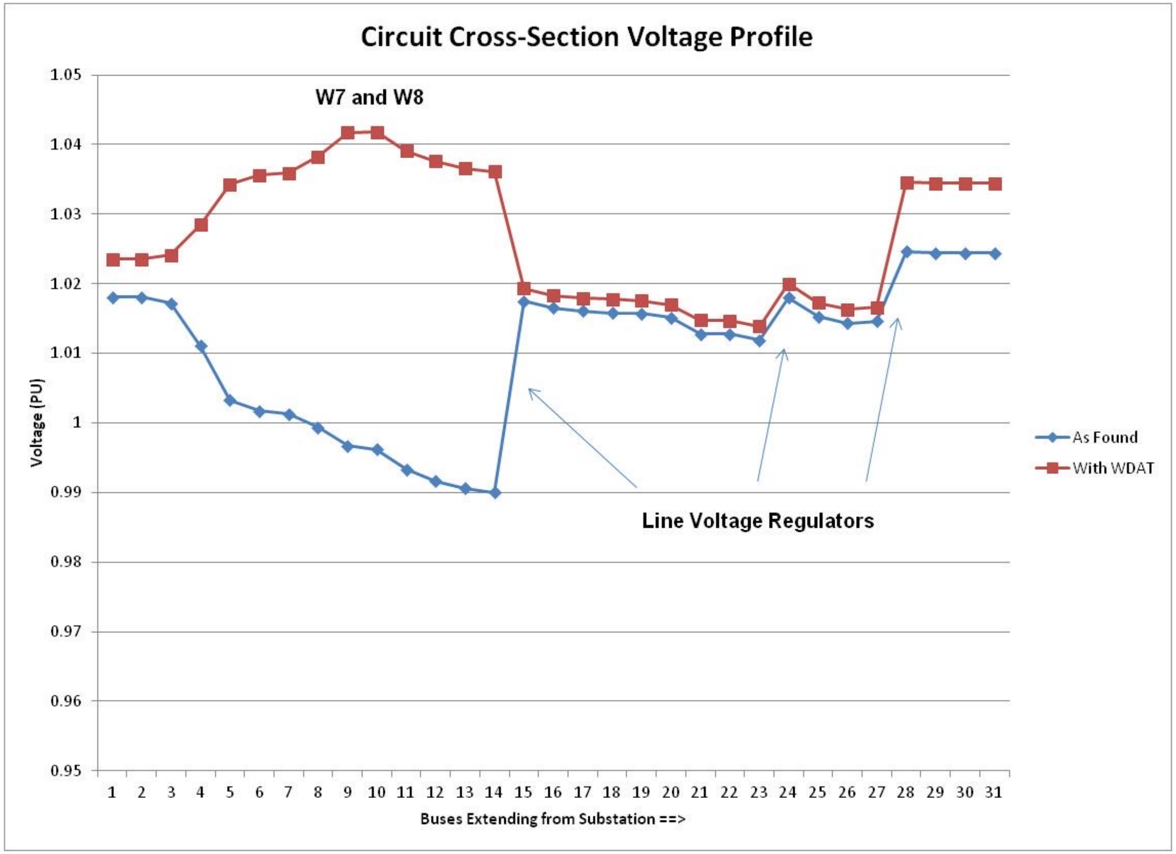
Feeder Voltage Profile and CVR



➔ Targeted DER can flatten feeder voltage profile, enabling more extensive CVR

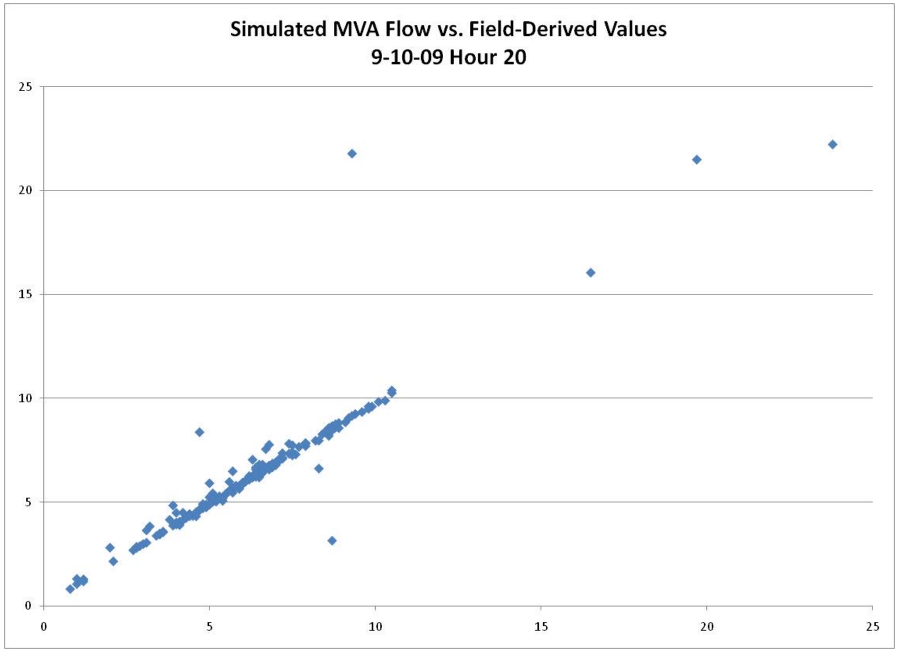
Illustrative Potential DER Benefits

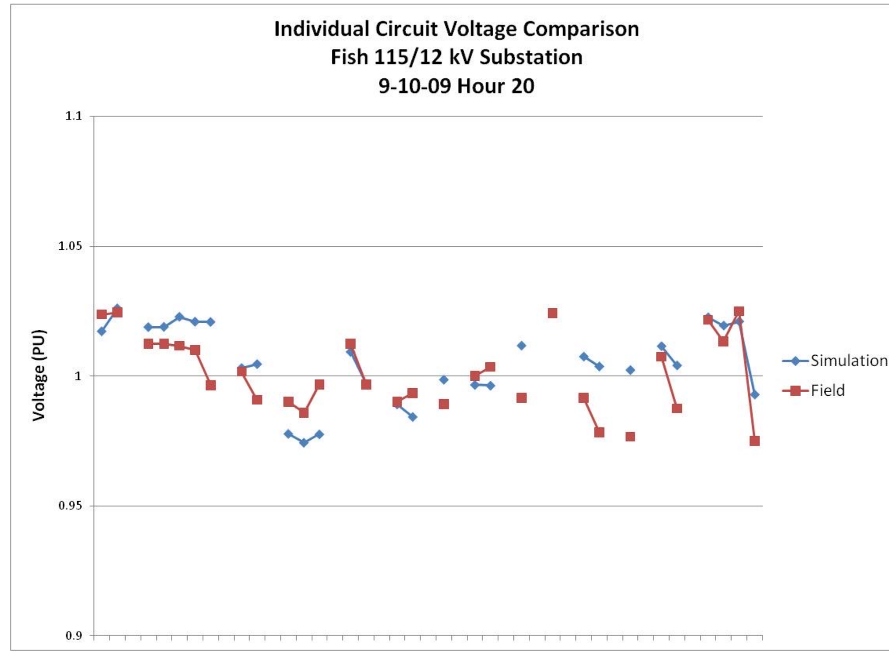
	Large (250-feeder) utility system	
	Network Operator Benefits	Customer Benefits
Loss reduction	$28/yr per customer	
Reduced energy to serve load (CVR)	$18/yr per customer	
Improved reliability	$20/yr per customer	$13/yr per customer
Avoided marginal capital projects	$68 per customer/10 yrs	
Improved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

Relevant Findings on Beneficial DER

- **DER can benefit power delivery system performance.**
- **DER project location and attributes matter. A lot.**
- **Beneficial DER projects can be identified and potential benefits rigorously quantified and valued.**
- **Benefits that persist over many operating conditions/hours yield more value**
- **DER projects providing multiple benefits yield more value**
- **Beneficial DER changes with real additions and changing conditions. Plan to re-assess often.**

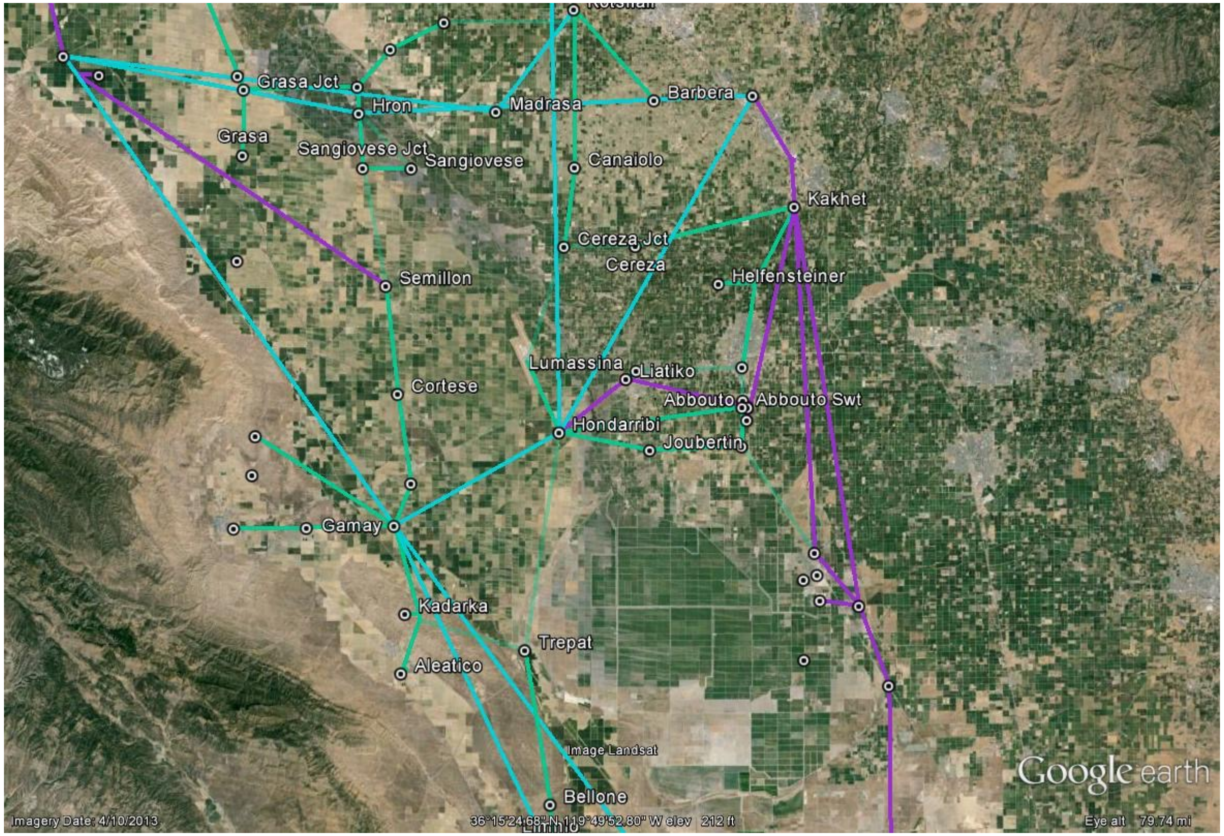
Energynet Simulation a Validated Predictor of Actual System Conditions





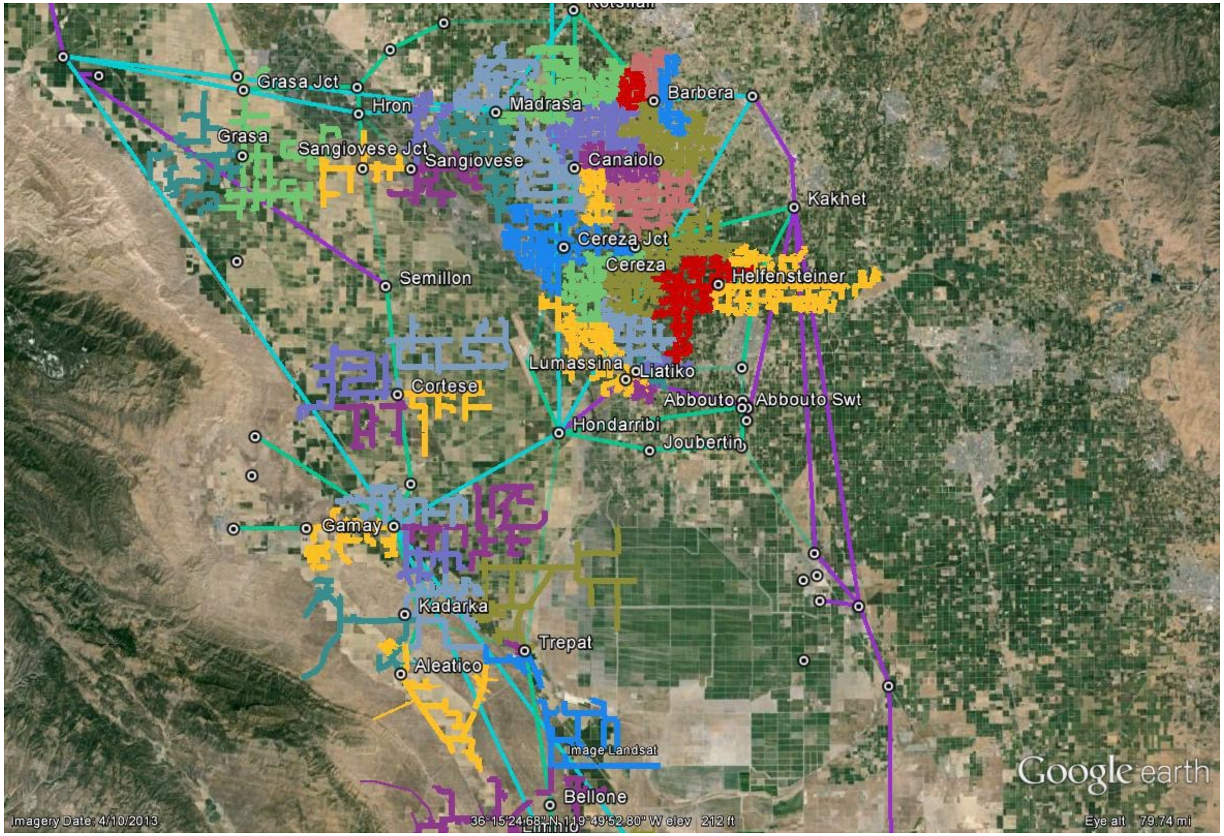
- Simulation voltage results within 2% of field data reads at ~650 widely-dispersed locations
- Area model produced from raw legacy utility data in one month
- Area model updated in one day via secure web file transfer

“Vineyard” Regional Transmission



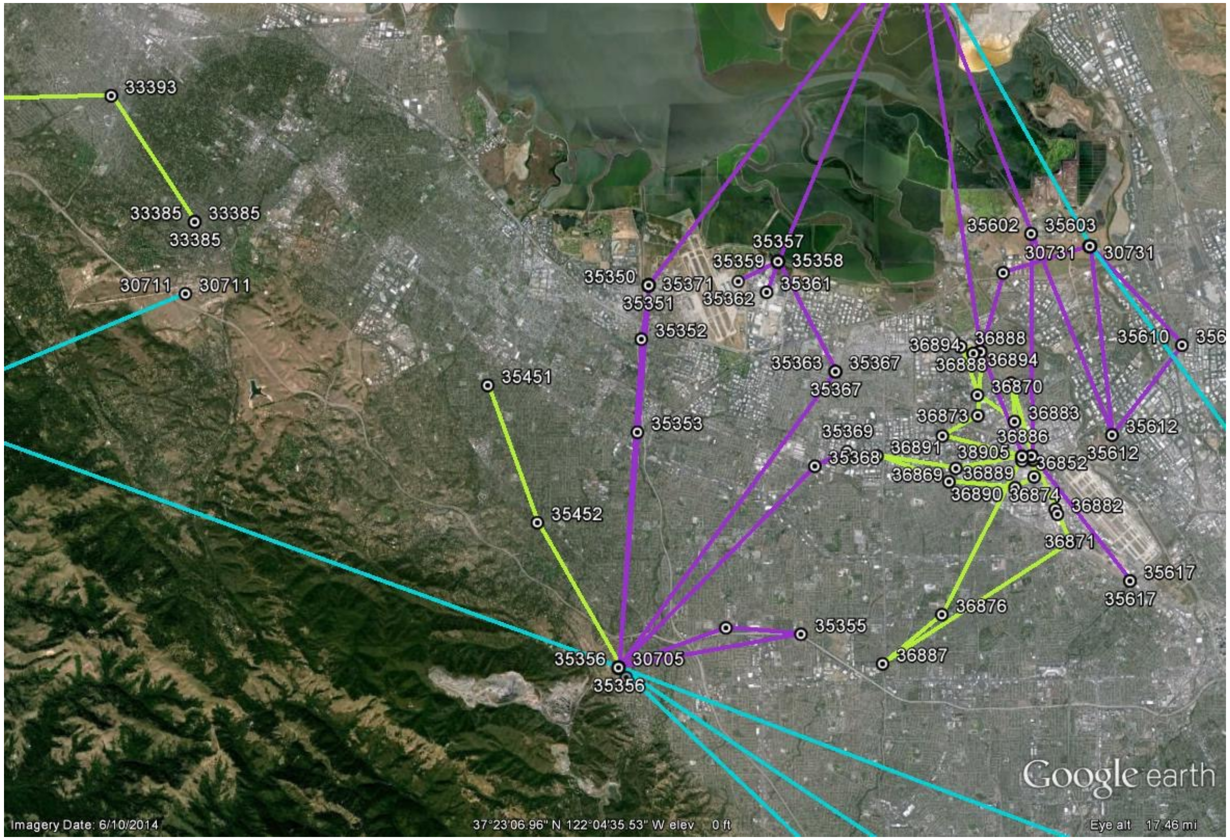
- 230 kV
- 115 kV
- 70 kV

“Vineyard” *Energynet*



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

“Peninsula” Regional Transmission



- 230 kV
- 115 kV
- 60 kV

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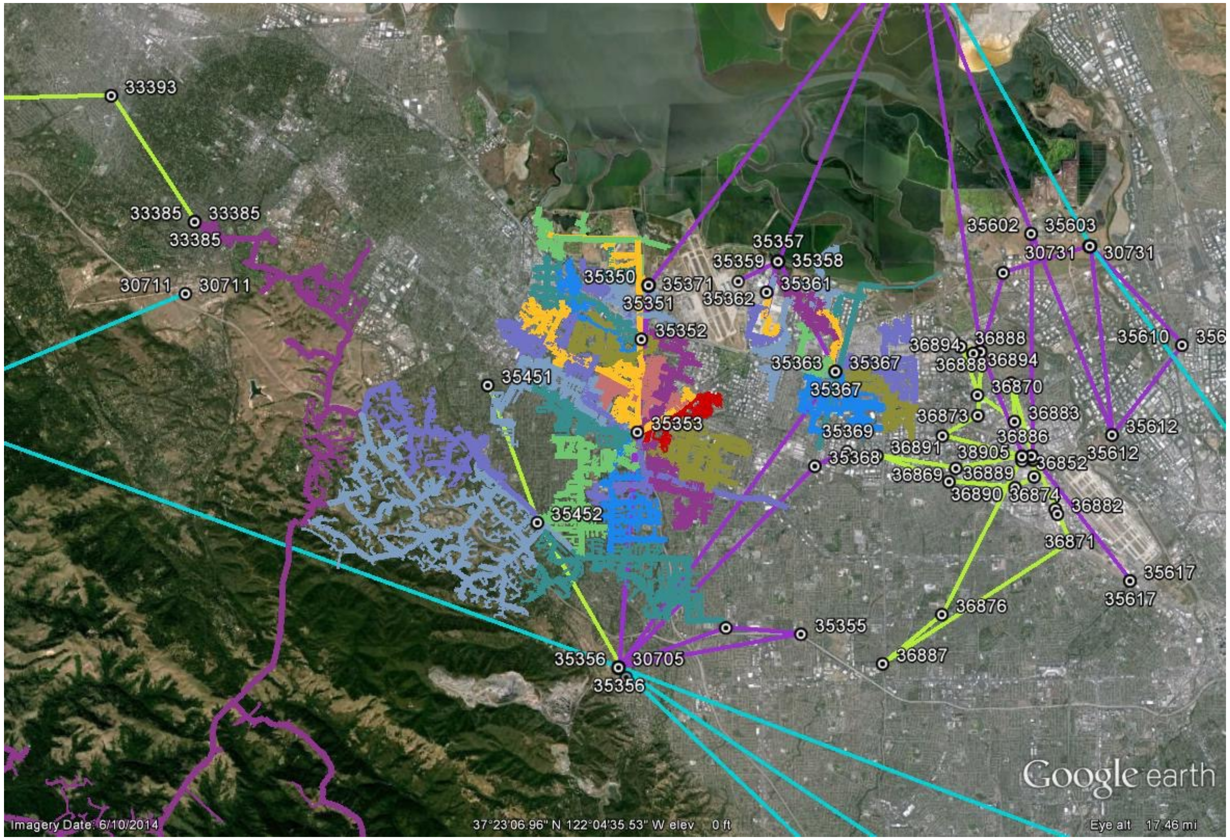
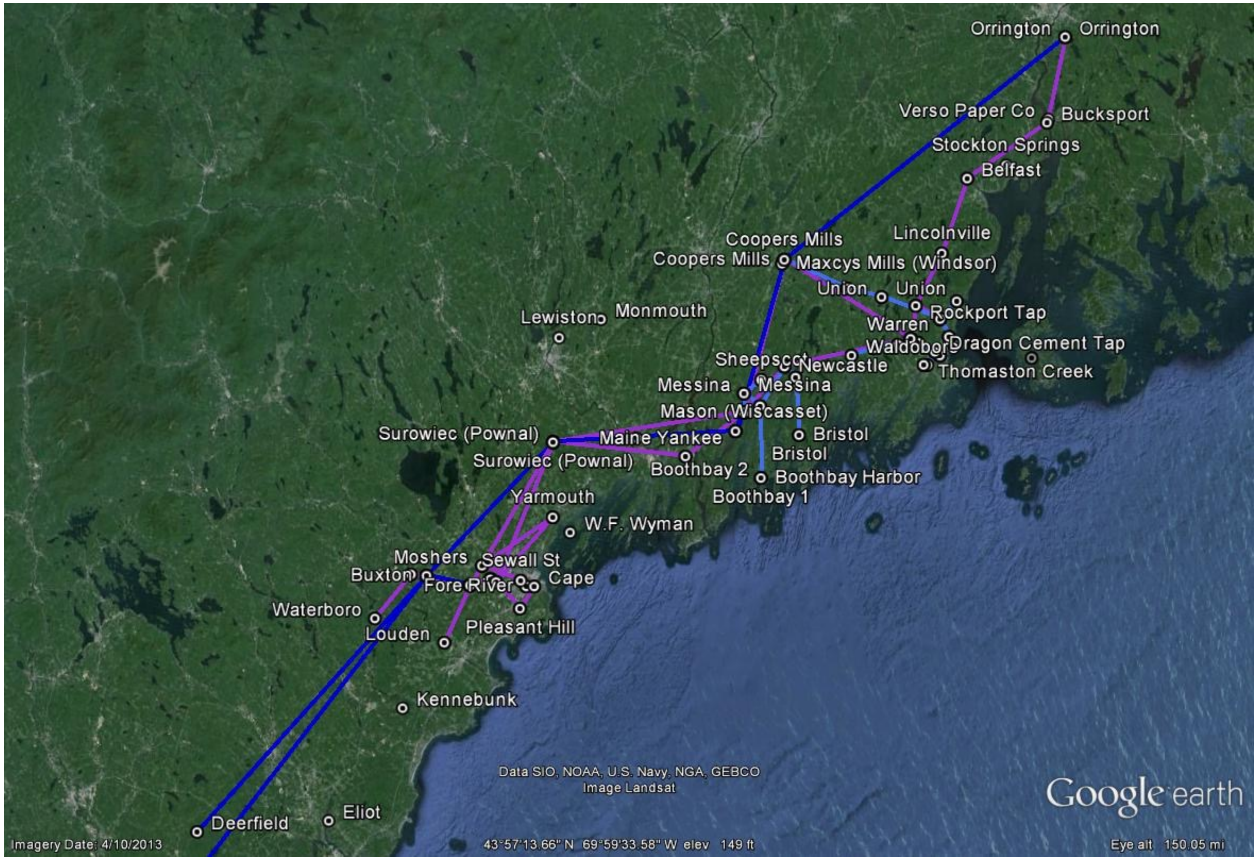
“Peninsula” *Energynet*



- 11 substations (58 CAISO pricing nodes)
- 41 distribution feeders

Maine Power System

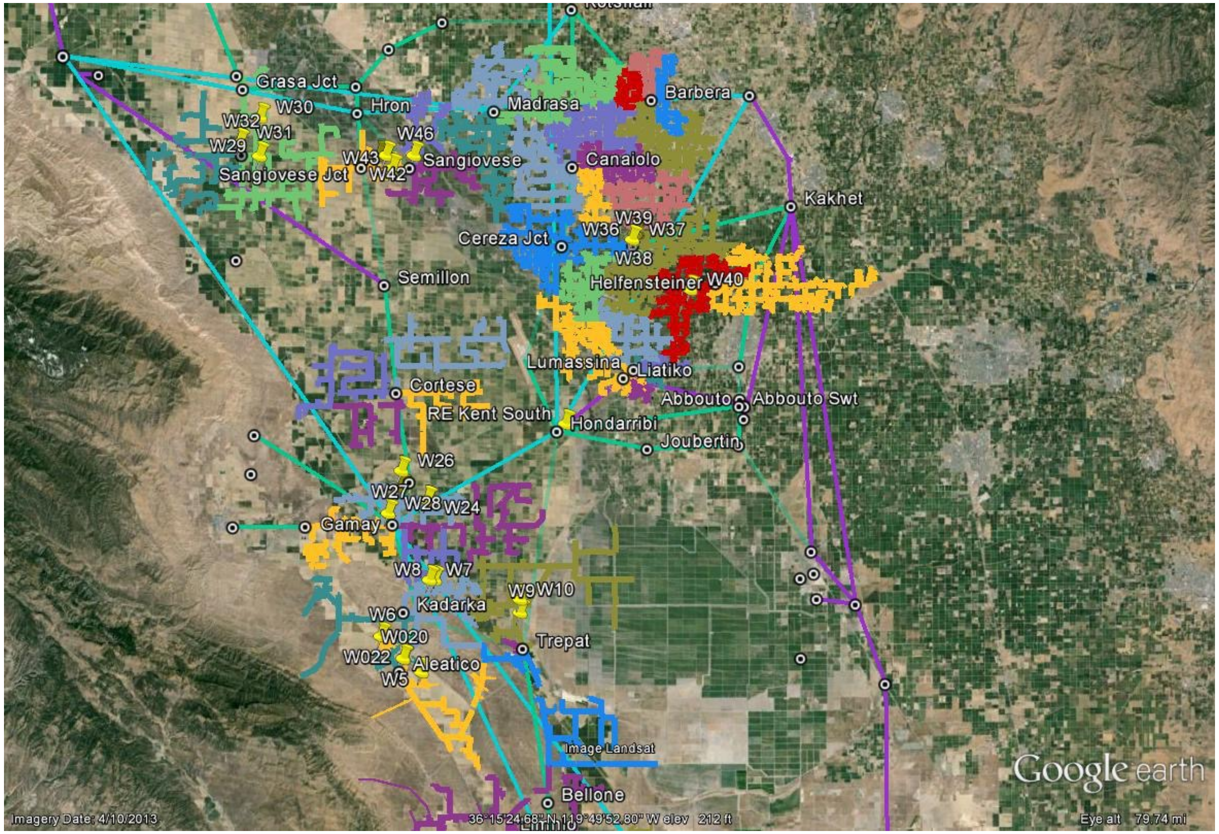


- 345 kV
- 34.5 kV
- 115 kV

Energynet Deployments

- **SMUD**
  - > 750 feeder integrated T&D model commercial deployment
  - 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)

Vineyard Wholesale PV Evaluation



- Regional impacts of DER (PV in this case) at high "penetration" levels
- 46 individual distribution-connected wholesale PV projects
- Approx. 80 transmission-connected PV projects

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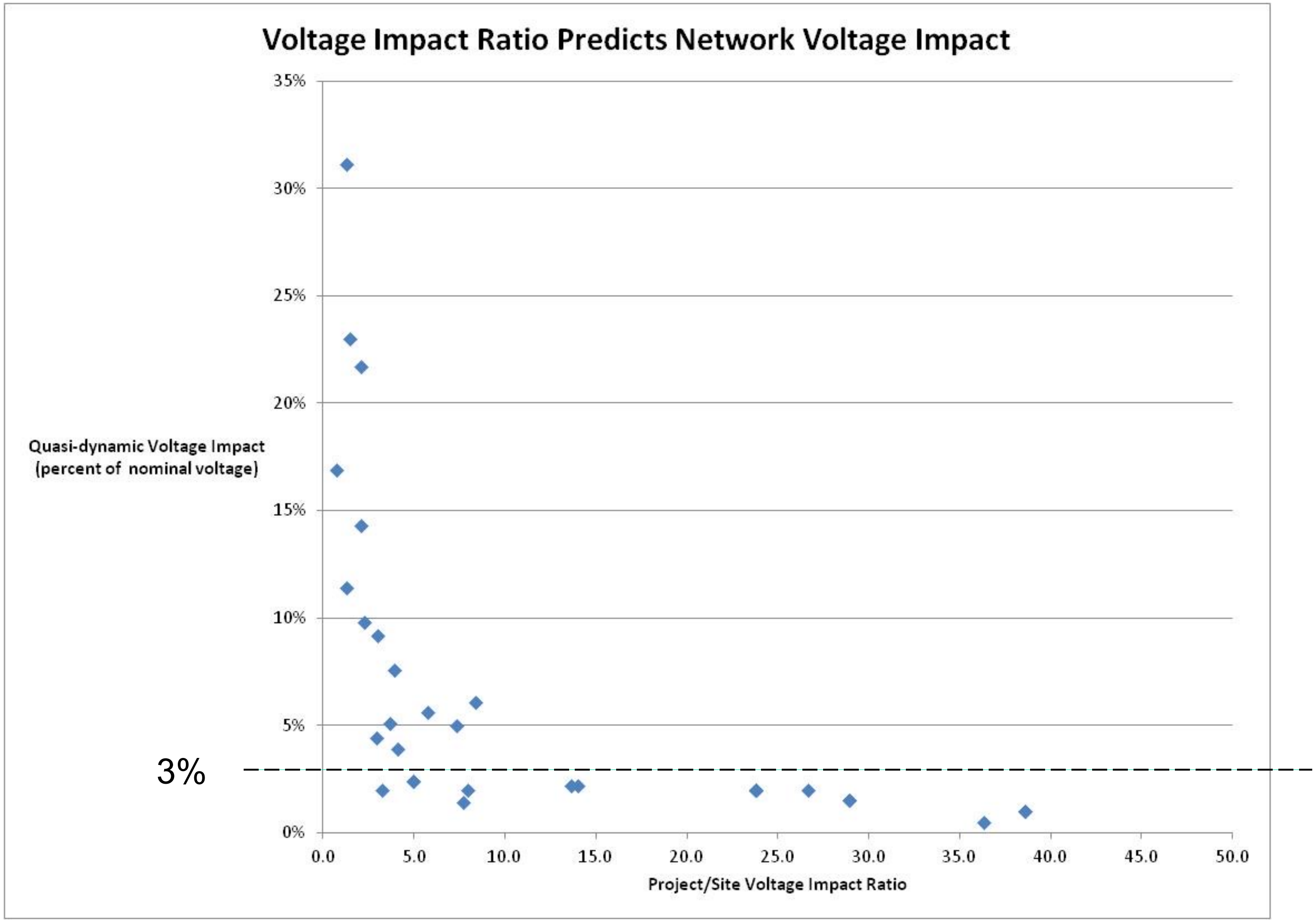
Findings on Feeder DER "Integration Capacity"

- **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 also damped by distribution feeder voltage management**
- **Potential for feeder and substation transformer overload under light load or loss of load.**

"Stiff" Locations Limit System Voltage Impacts of Variable PV Output



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

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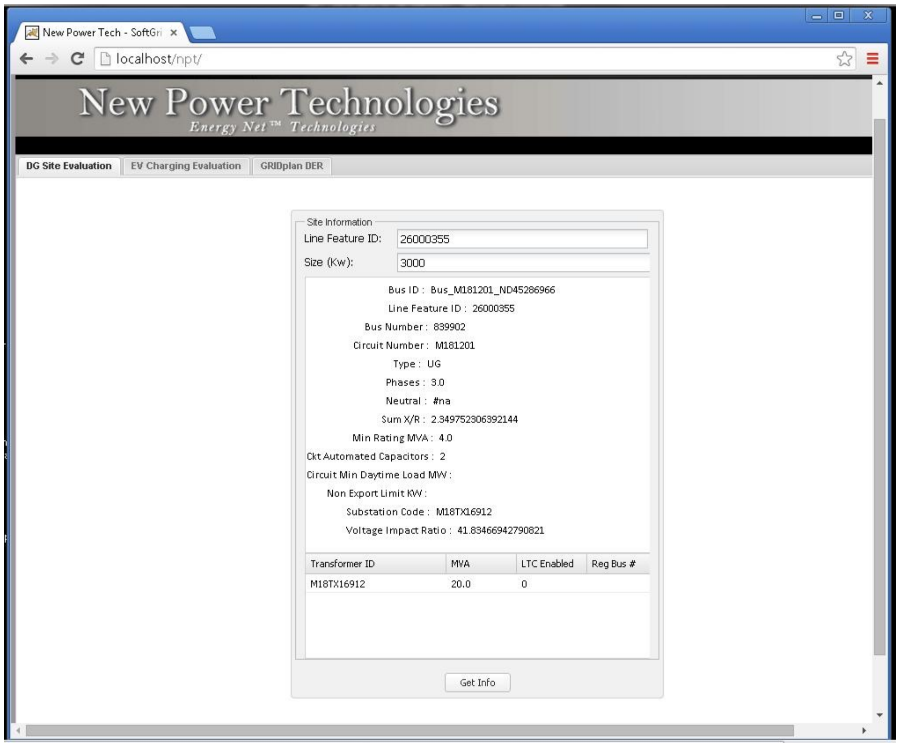
Conclusion

- **DRPs can incorporate rigorous quantification and valuation of direct grid benefits of DER in a broad range of benefit categories by location.**
- **DRPs incorporating DER as a system resource can have regional scope (many substations and DPAs) and full feeder element detail.**
- **Representing DER as connected within their feeders reveals their full impacts and grid benefits.**
- **Not all DER is grid-beneficial.**
  - **Location-specific**
  - **Size and characteristic - attribute-specific**
  - **Operational alignment with grid conditions**
- **Distribution feeders can accommodate DG as a significant share of load – with attention to interconnection sites and network characteristics.**

Supplemental Slides

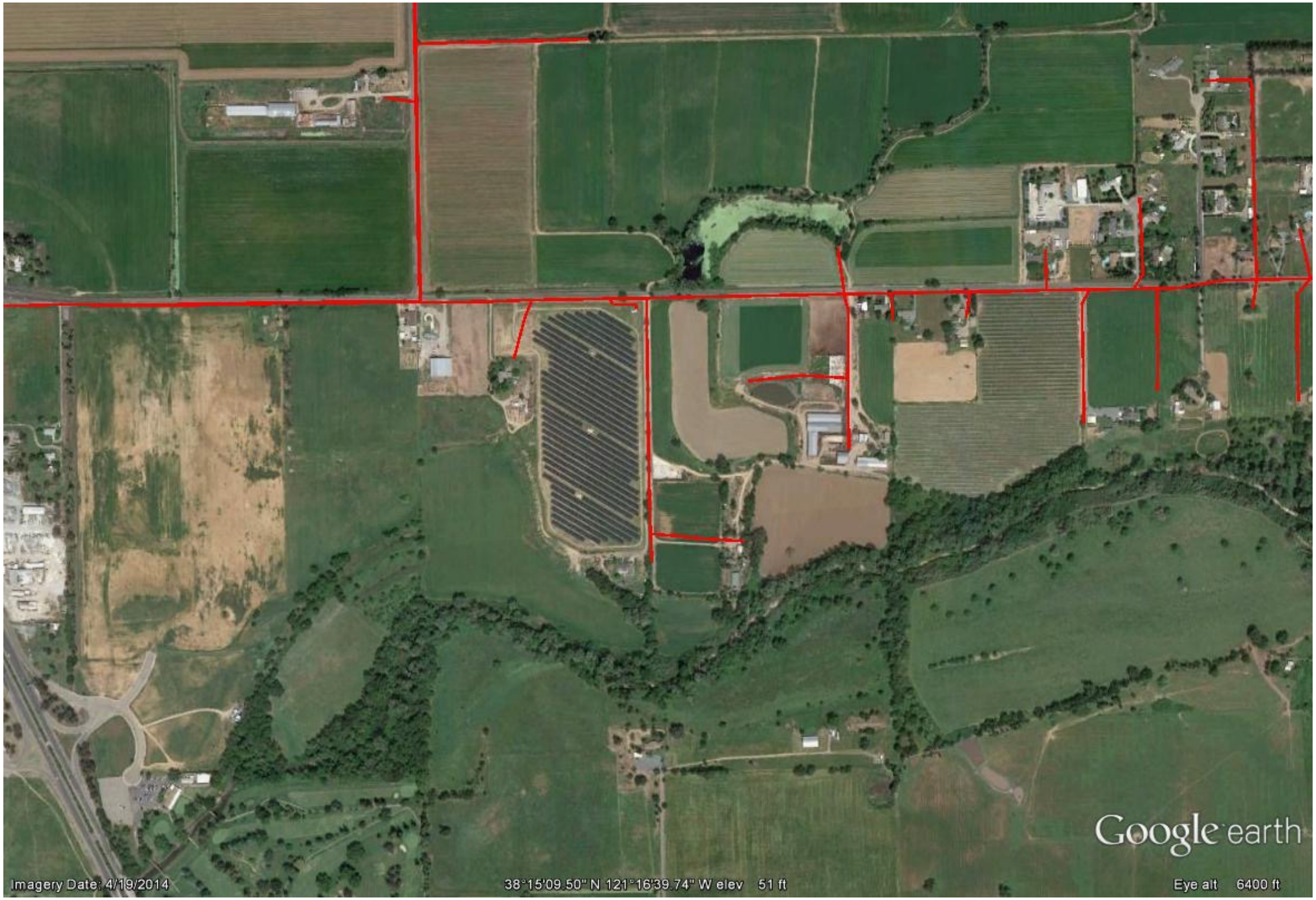
DG Site Evaluation App – 3 MW PV on 12 kV Feeder



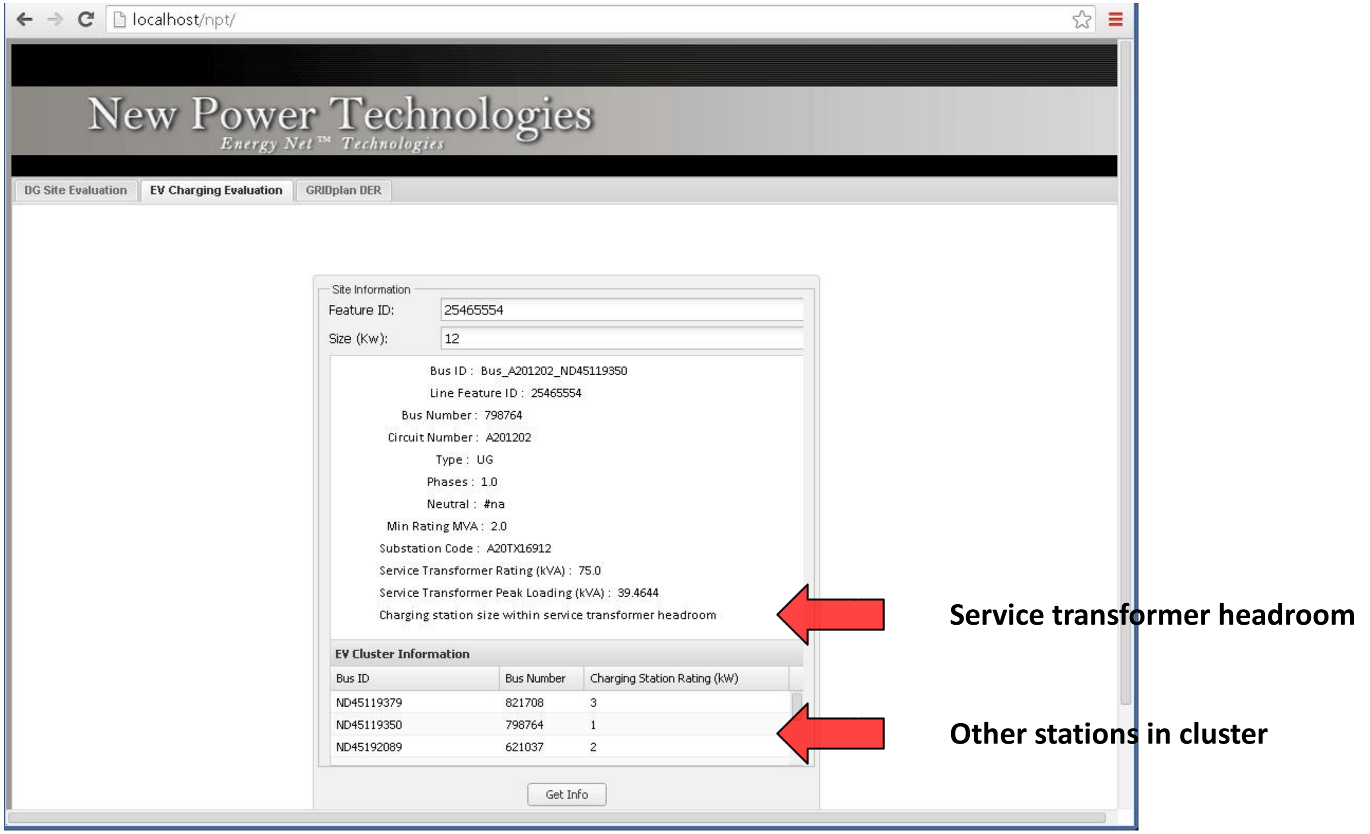
- > feeder non-export limit
  - Total PV = 119% of feeder connected load
- ✓ < min upstream line rating
- ✓ 3ϕ location
- ✓ Feeder voltage regulation
- ✓ Voltage Impact Ratio > 20
- ✓ Max voltage impact: 1%

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

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

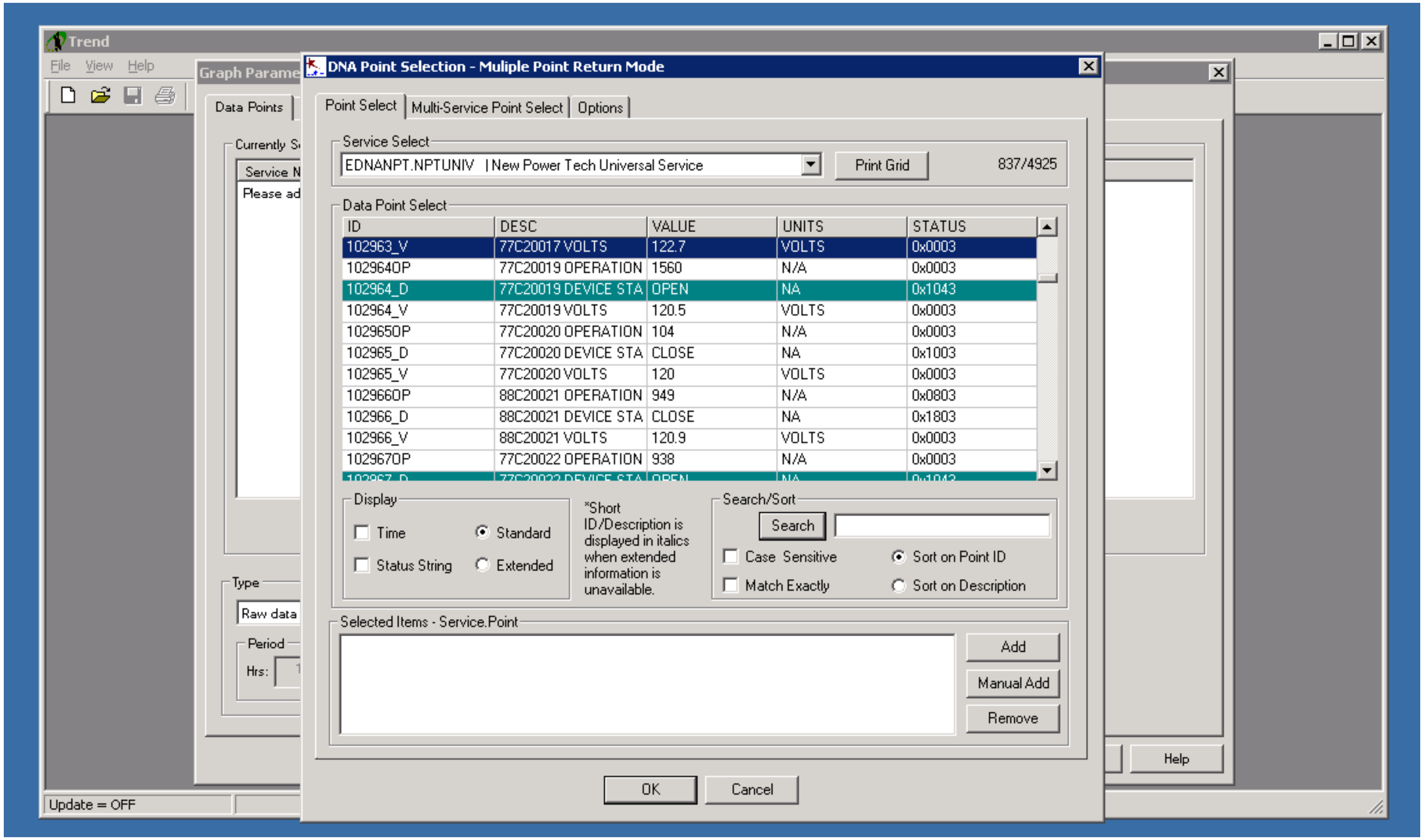


Energynet EV Evaluation App



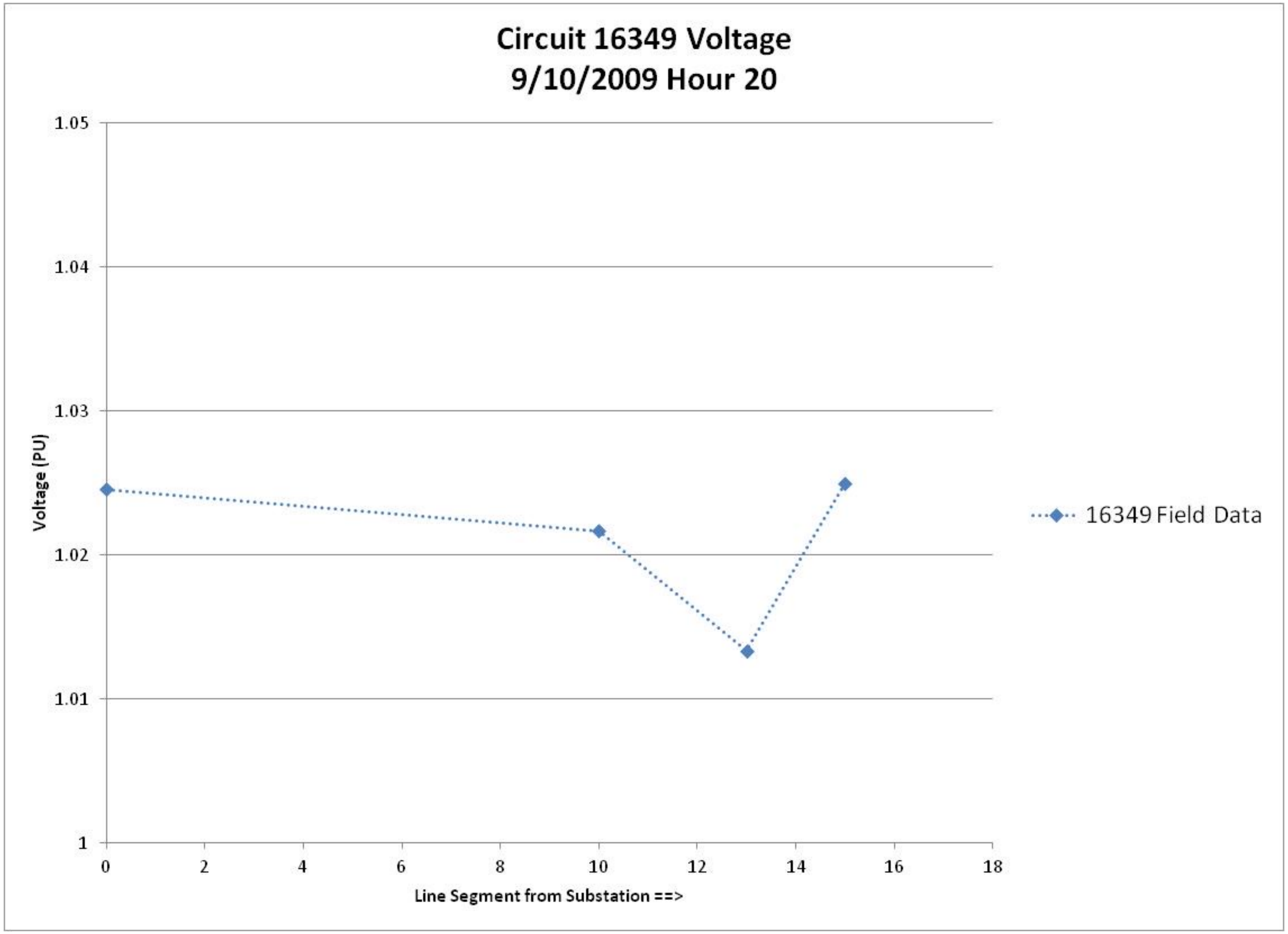
- **Charging station site assessment in one click**

Turning data into situational awareness: Legacy Data

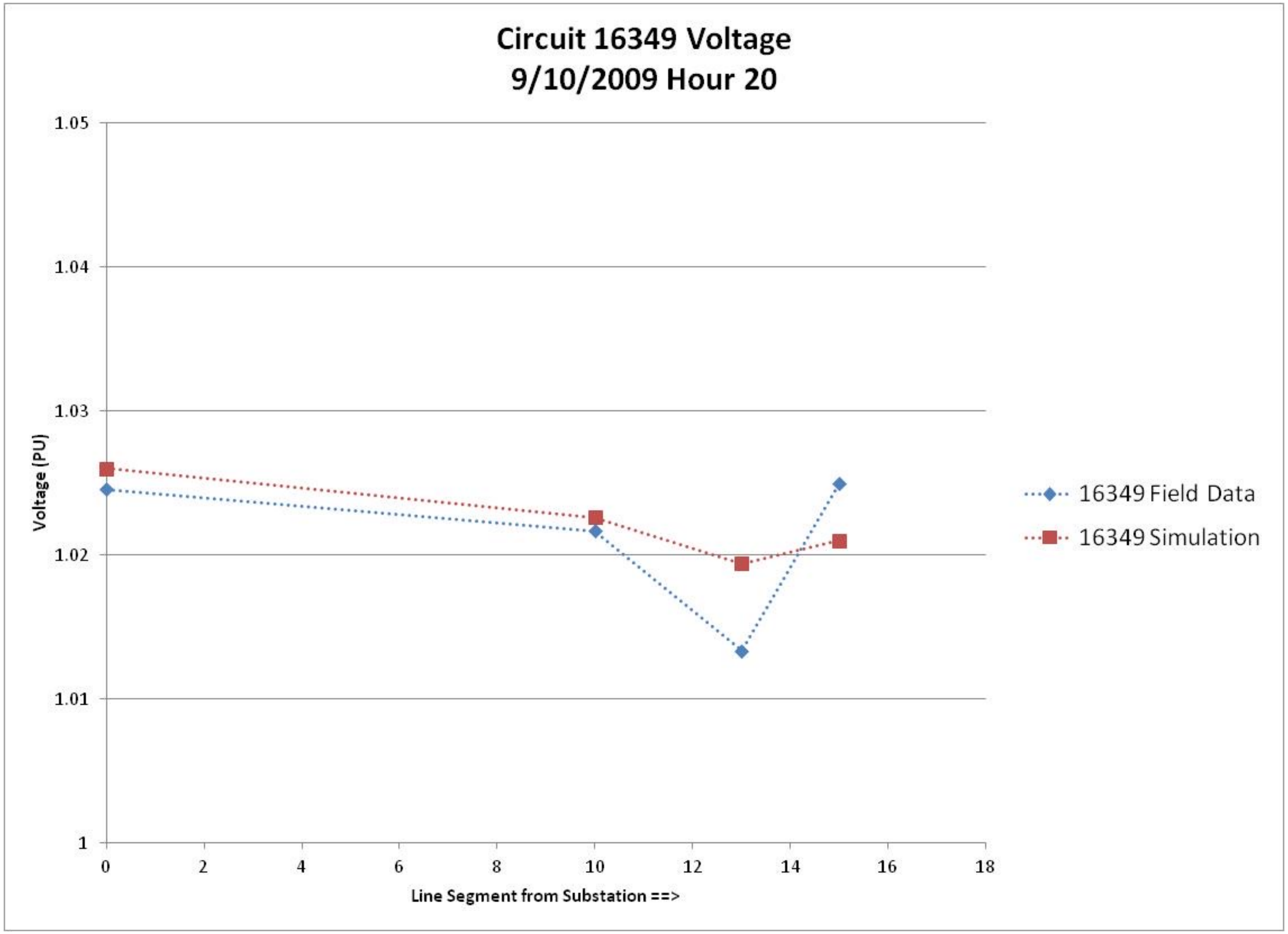


Existing tabular data without topological cues

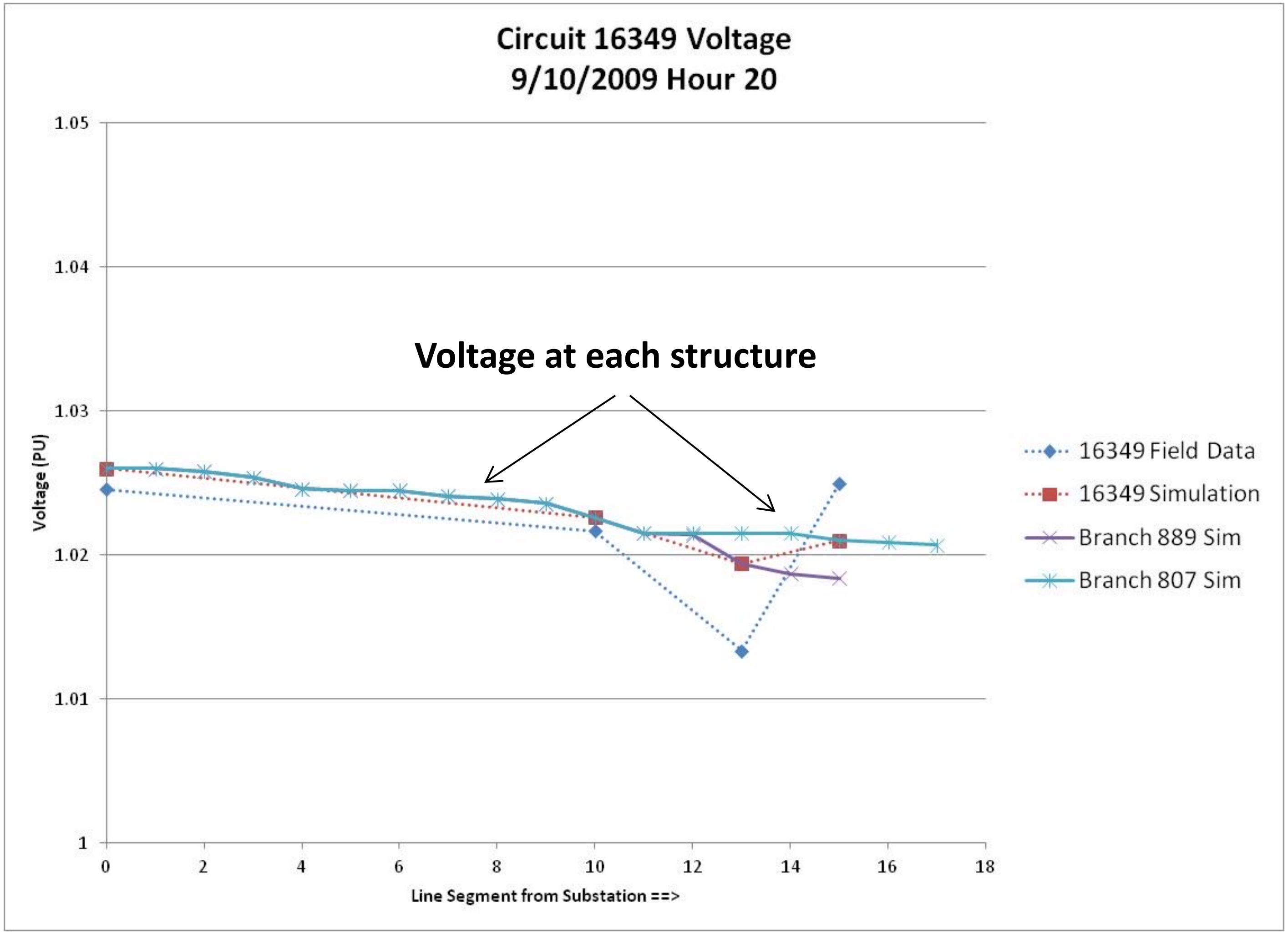
Turning data into situational awareness: => Field Circuit Voltage Profile



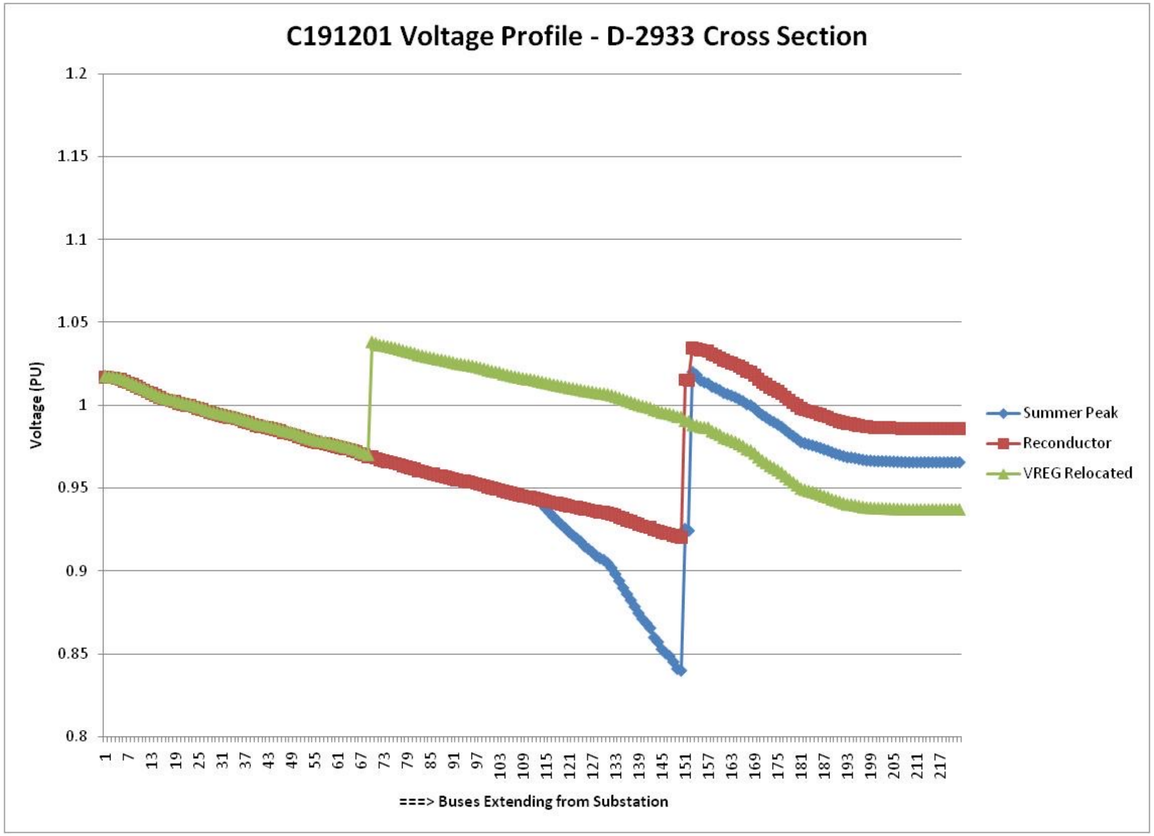
Turning data into situational awareness:
=> *Energynet* Simulation Validation



Turning data into situational awareness: *Energynet* Distribution Device-Level Visibility



Project Assessment - C191201 Reconductoring



➔ The impacts of individual projects are directly observable.

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References

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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>

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