San Diego Gas and Electric

R&D Involving Distributed Generation

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High DG Penetration Concerns

- **Operational Concerns (PV Variability / Intermittency)**
  - Monitoring and Ensuring resource adequacy
  - Frequency regulation
  - Voltage regulation
  - Impact is highly location dependent (urban vs rural)
  - O&M impacts
- **Engineering / Planning**
  - Production assumptions for capacity planning (size, location, time, guaranteed production)
  - Volt/ VAr planning
  - Conservation Voltage Reduction impacts
- **Mitigation Measures**
  - Smart PV Inverters (IEEE 1547.8)
  - Dynamic voltage support
  - Monitoring and control of PV Inverters

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SDG&E R&D Technical Studies Simulating High Levels of Distributed Generation

- Technical Studies simulating high levels of distributed generation
  - EPRI High PV Penetration Study –
    - Evaluates increasingly high levels of PV Penetration
    - Includes monitoring of PV generation along actual distribution circuits and simulation of actual intermittency
    - Models customer load and generation for all hours of the year
    - Includes evaluation and optimization of energy storage to mitigate impacts of high PV concentration
    - Evaluate benefits of using Smart Inverters for PV
  - Quanta Technologies Study – Evaluates Transient and Dynamic Impacts of distributed generation (high PV concentrations)
    - PSCADD – Detailed modeling of inverters
  - High PV Penetration study with DOE and UCSD
    - Simulates SDG&E distribution circuits
    - Conducted by EDSA

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SDG&E R&D Demonstration Projects For Evaluating DG

- **SDG&E Borrego Springs Microgrid Project**
  - Demonstrate controlled islanding and load/DG balancing
  - Real Time Optimization and control of DG and energy storage
  - Automatic Volt/VAr control, feeder automation
- **Power Quality Field Measurement and Analysis Project**
  - Field data collection of distribution steady state and transient voltages on distribution circuits with high levels of DG
  - Data analysis and evaluation of DG impact
- **Dynamic voltage support project on distribution circuit with known voltage regulation issues due to high levels of DG**
  - Contracted General Electric to conduct analysis to size and locate dynamic voltage support devices
  - GE to install dynamic voltage support device to evaluate feasibility and benefits
- **Energy Storage Projects to Mitigate Impacts of DG**
  - CEC funded Projects
  - EPRI demonstration of CESS
  - SDG&E Smart Grid Energy Storage projects

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SDG&E Future Planned Projects To Mitigate T&D Impact of DG*

- **General Rate Case Smart Grid Projects ($ 54 Million* – Yr 2012)**
  - Distributed Energy Storage ($ 34 Million*)
  - Dynamic Line Ratings for distribution ($ 4 Million*)
  - Synchrophasors for distribution ($ 8 Million*)
  - Dynamic Voltage support ($ 3 Million*)
  - Distributed Energy Resource Management System ($ 5 Million*)

* Costs shown in 2009 dollars, unloaded. Cost to mitigate 120 – 130 MW of DG on SDG&E system in yr 2012, does not include T&D costs of meeting 12,000 MW DG goal by 2020.

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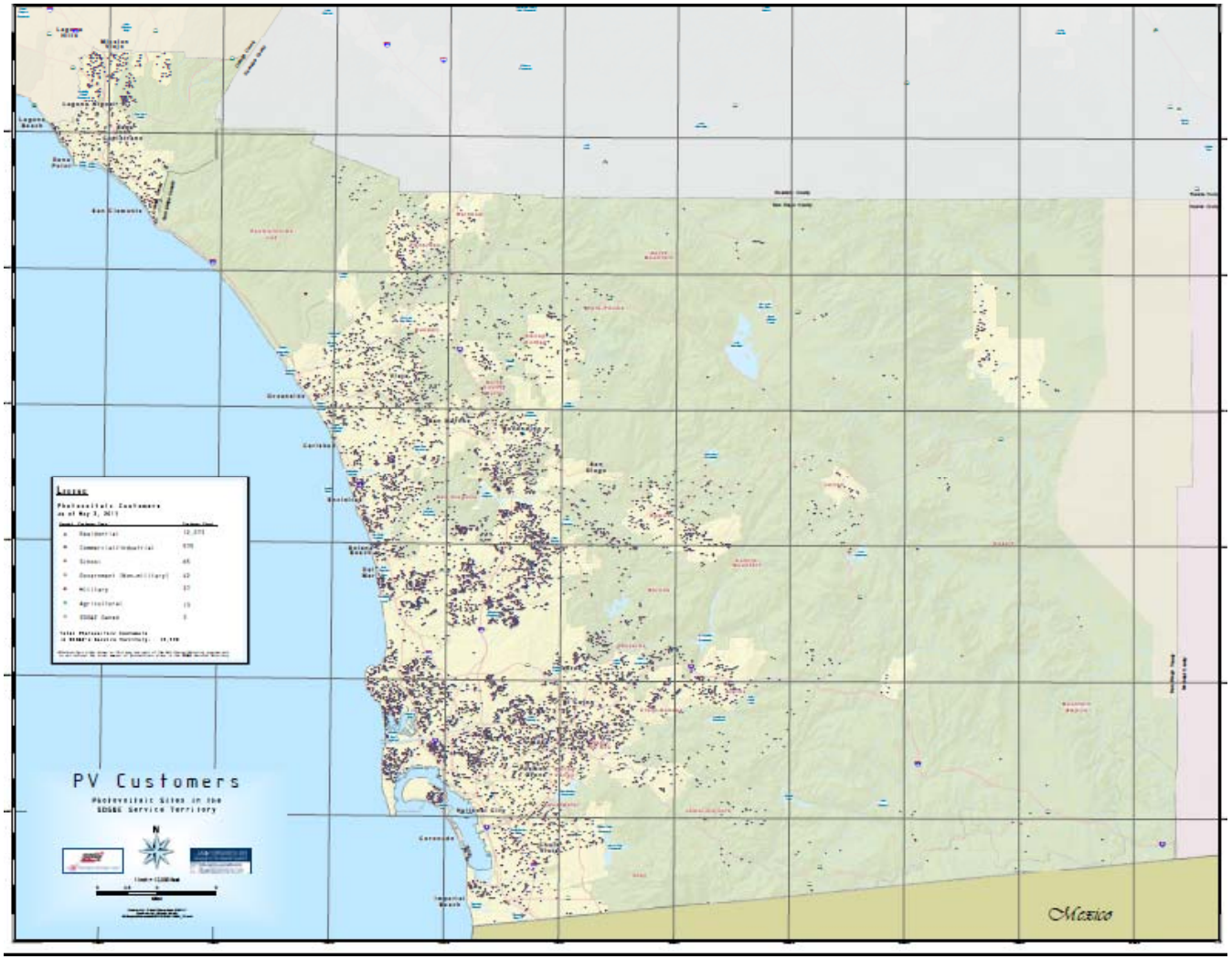
Map of Current Roof Top Solar PV Installations



- Current level 99 MW, 12,798 customers with NEM
- Current practice of uncontrolled site selection for DG could cause significant impacts to the T&D system with a more rapid increase in DG

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Additional Impacts of High Levels of DG on the Grid

- Voltage
  - Overvoltage
  - Voltage fluctuations
  - LTC/regulator/cap bank impact
  - Unbalance
- Protection
  - Unintentional islanding “potential”
    - Load mismatch
    - Interconnect transformer connection
  - load rejection overvoltage
  - Reverse power (directional relaying)
  - Voltage events
  - Frequency events
- Operational
  - Intermittency/Variability
  - Observability/ Monitoring
  - Forecasting DG levels
  - Off Peak production
- Demand/Energy
  - PV impact on peak demand/load growth
  - Annual losses
  - Annual energy consumption
  - Impact on CVR
- Thermal overloads
- Power Quality
  - Harmonics
  - Flicker
  - CEBMA Violations
- Review of Utility Safety Practices
  - Lineman practices
  - Hotline/deadline work
  - Improved mapping and tracking of DG to ensure safety

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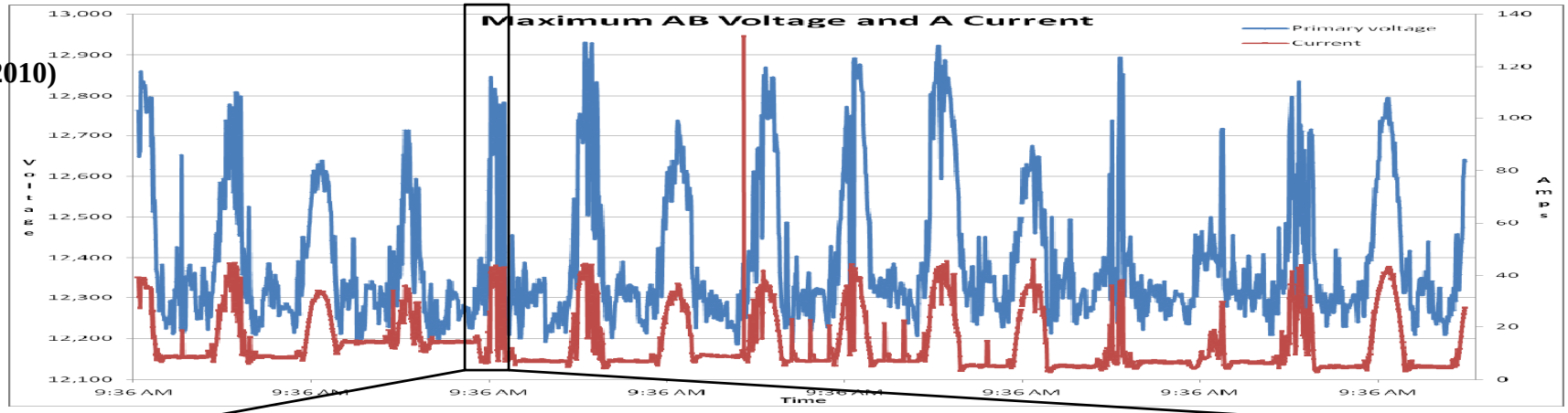
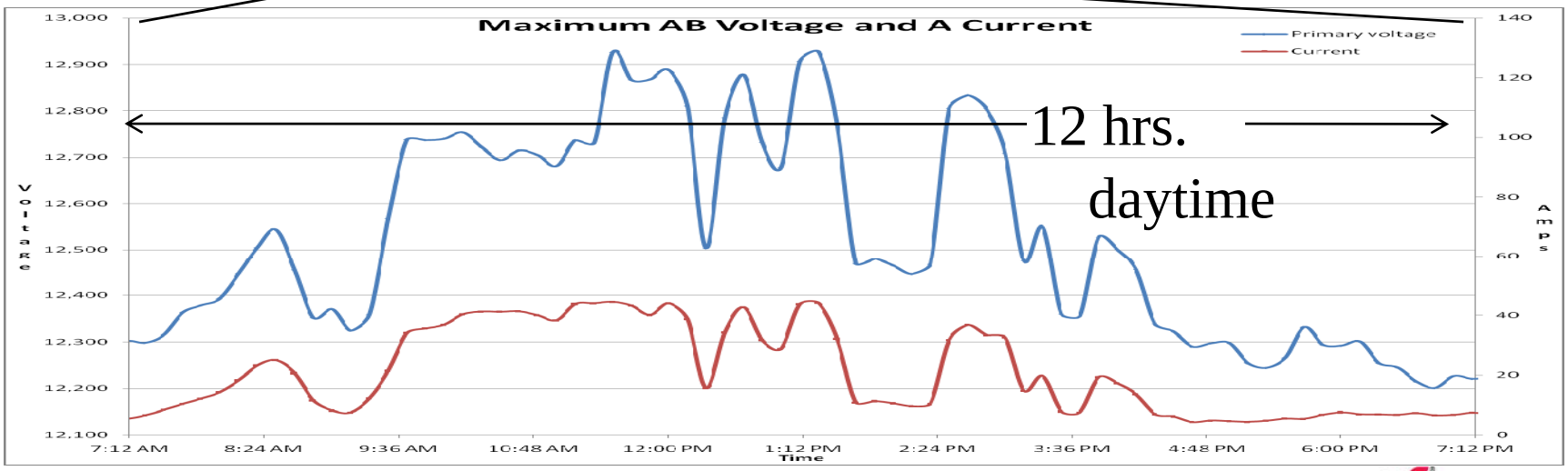
Typical PV Intermittency SDG&E DG Causes Resource Forecasting Problems on a Daily Basis

Daily PV Generation (2/23 – 3/10,2010)



Variability within a typical day (2/28/10)



Each data point recorded at 10 min intervals

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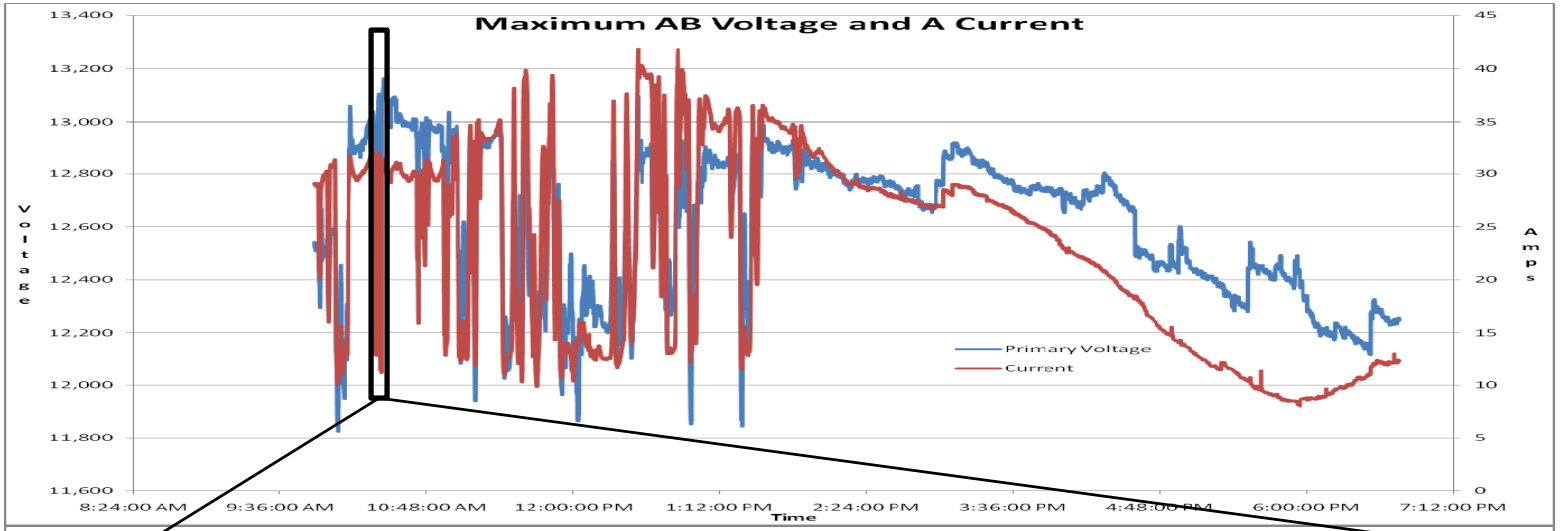
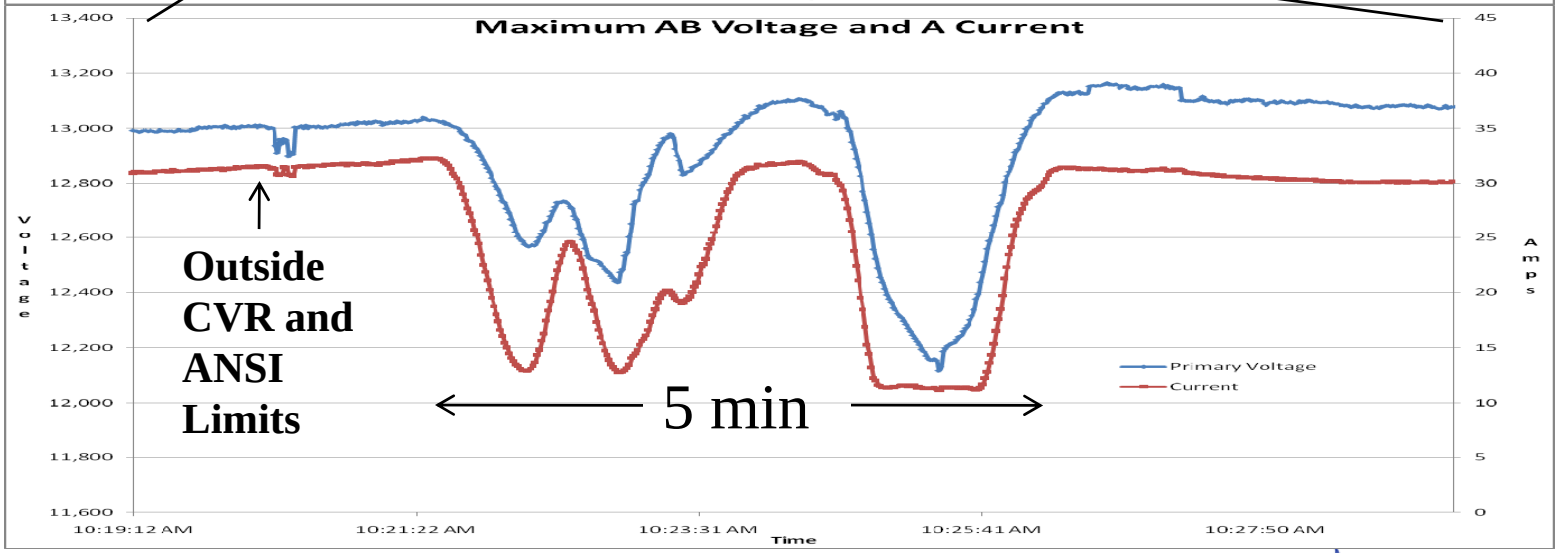
Voltage Regulation Problems and Reduced System Efficiency and Increased Operational Cost Caused by Intermittency of PV

One Typical Day (5/11/10)



Snapshot of one 5min period



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Data recorded in intervals of 1 second

Regulatory and Standard Changes Needed To Accommodate Higher DG Penetration

- **Regulatory**
  - Interconnection Tariffs (Rule 21, WDAT) modification
    - Threshold for periods of low load high PV output
    - Low voltage ride through
    - Frequency droop requirements
  - **Rule 2 modification**
    - Harmonics
    - Voltage
  - **Cost Causation**
    - Rates & incentives
  - **Smart Inverters**
    - IEEE 1547.8
    - Modify WDAT to accept smart inverters

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Summary

- Increased DG Levels are expected to have significant impacts and resulting costs for the Electric T&D System
- Technical studies and demonstration projects are underway to quantify impacts of additional DG, and help design mitigation of impacts
- Actual field measurements indicate significant impacts to system performance on distribution circuits with high levels of conventional DG
- Changes in Regulatory and Technical standards are also required to accommodate increased levels of DG
- Adopt lessons learned in European countries

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Questions ?

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