i-PCGRID
Integration of PV on the Distribution System

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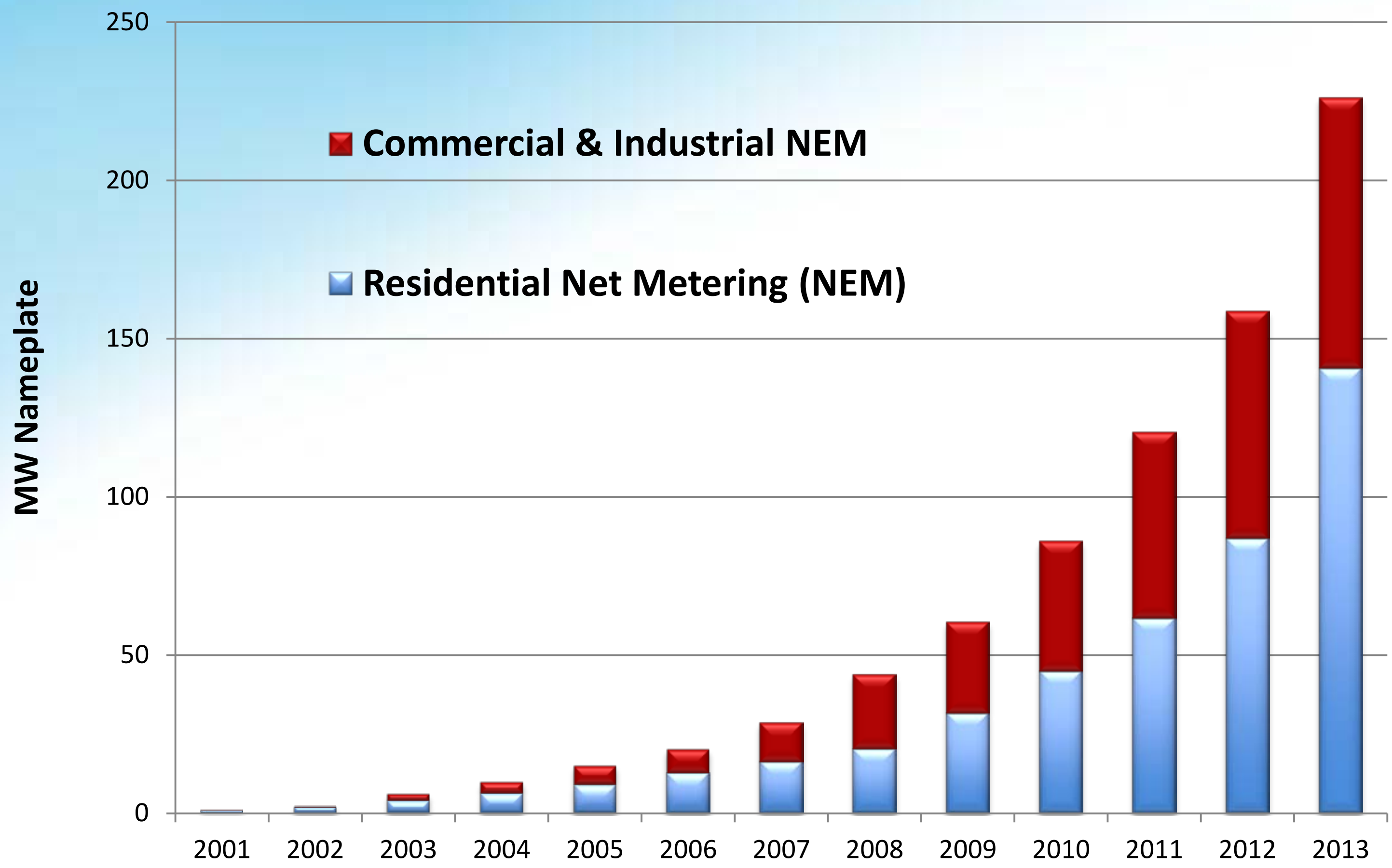
Commercial & Residential Generation



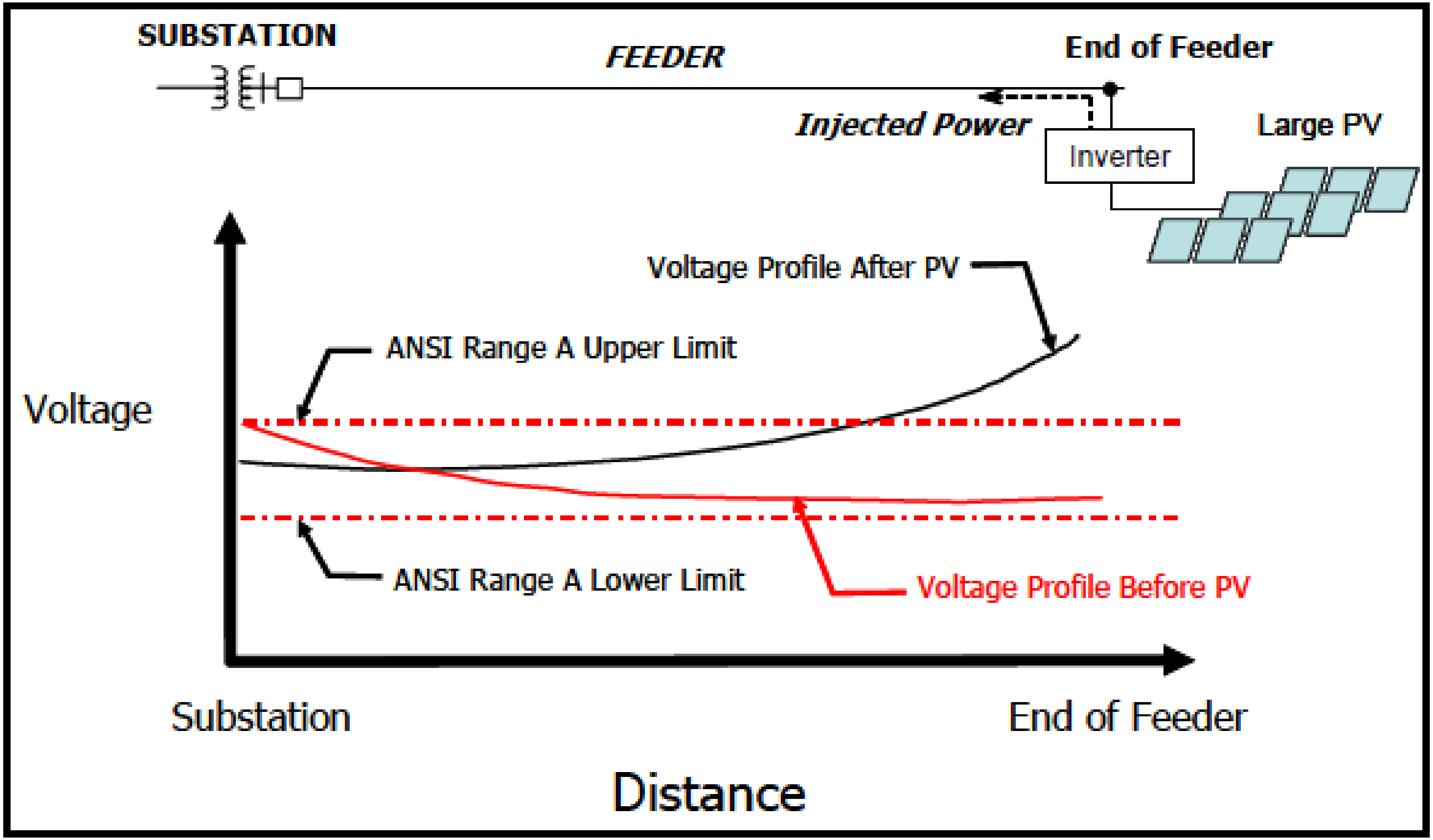
PV Integration Considerations

- High Concentration of PV on circuits can impact Reliability and Power Quality

- Distribution System designed and operated expecting power flow from substation to the customer. With large amounts of DER, can have reverse power flow.
  - Can cause high voltages that exceed our standards and damage customer equipment
  - With intermittent cloud cover, PV DER can cause severe voltage fluctuations that exceed our standards and damage customer equipment
  - Can cause high loads and excessive load fluctuations on our equipment causing higher maintenance costs and possible damage
  - Will mask the real load that needs to be restored following an outage

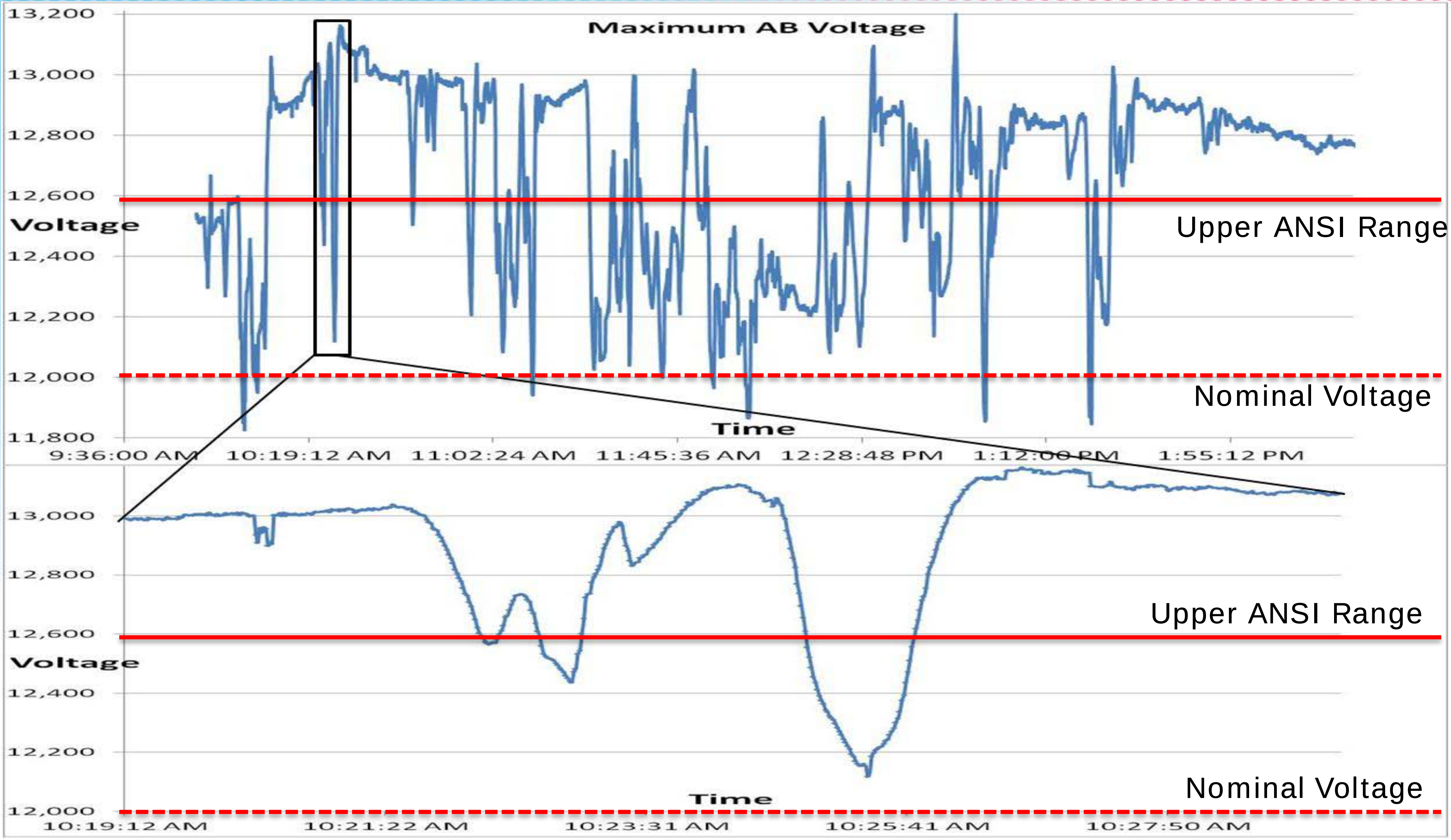
- Today no significant issues. However as PV continues to grow it will be a problem in a few years if we don't proactively mitigate. In recent months added about 1000 new NEM per month

Voltage Impact from Reverse Power Flow



Sandia National Labs – Solar Energy Grid Integration Systems – Program Concept Paper October 2007

PV Issues - Intermittency



Top half of graph: one day of 1 second voltage readings at 12 kV transformer near a customer's 1 MW PV system
Bottom half of graph: 10 minutes of 1 second data magnified from the one day data above

Distribution Planning & Operations for DER

SDGE connected
A Sempra Energy utility

- Distribution Planning based on DER not being operational during peak periods to ensure distribution system has sufficient capacity
  - No guarantee DER will be operation when required
    - No PV at night time
    - Many circuits peak at late afternoon or later
    - DER required to trip off line during an outage and wait following restoration

- Proposed large DER projects receive detailed dynamic analysis for potential impacts and mitigation. Non-NEM applicants required to pay for system upgrades

- Pursuing enhanced distribution system operations and planning models to effectively simulate wide scale DER including NEM

- Solar prediction models efforts underway to improve load forecasts

Monitoring & Mitigation for DER Impacts

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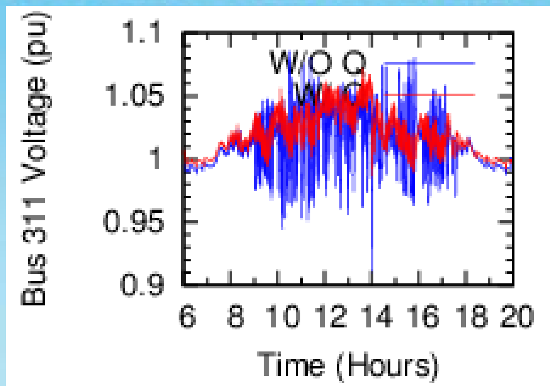
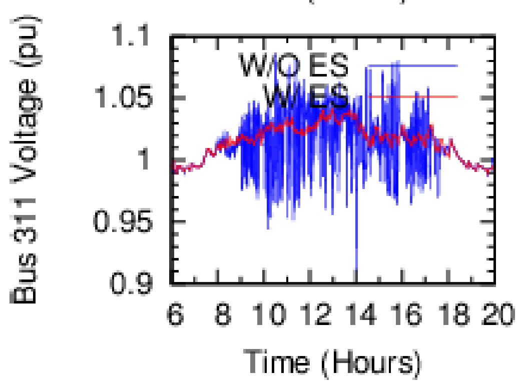
- Increasing level of Voltage monitoring to proactively identify potential voltage issues before they occur
  - Voltage reads from field SCADA equipment
  - Distribution Synchrophasors
  - Smart Transformer monitors
  - AMI
- System upgrades currently used for mitigation
- Advanced Energy Storage installed on distribution system can help mitigate impacts from intermittency
- Dynamic Voltage Controllers installed on distribution system can also help mitigate impacts from intermittency
- Smart Inverters installed on PV systems can mitigate impacts. California Rule 21 efforts underway to require installation on new systems

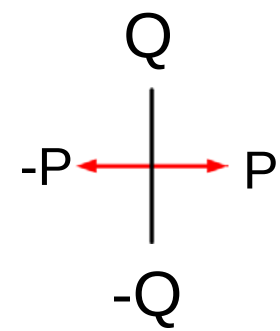
PV Intermittency Mitigation Based Upon Modeling with Smart Inverters

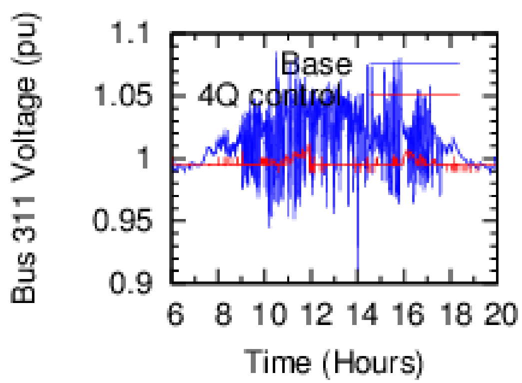


With and without dynamic VAr device

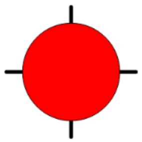


With and without energy storage





With and without dynamic VAr device and storage:
4 quadrant control



Red = With Blue = Without

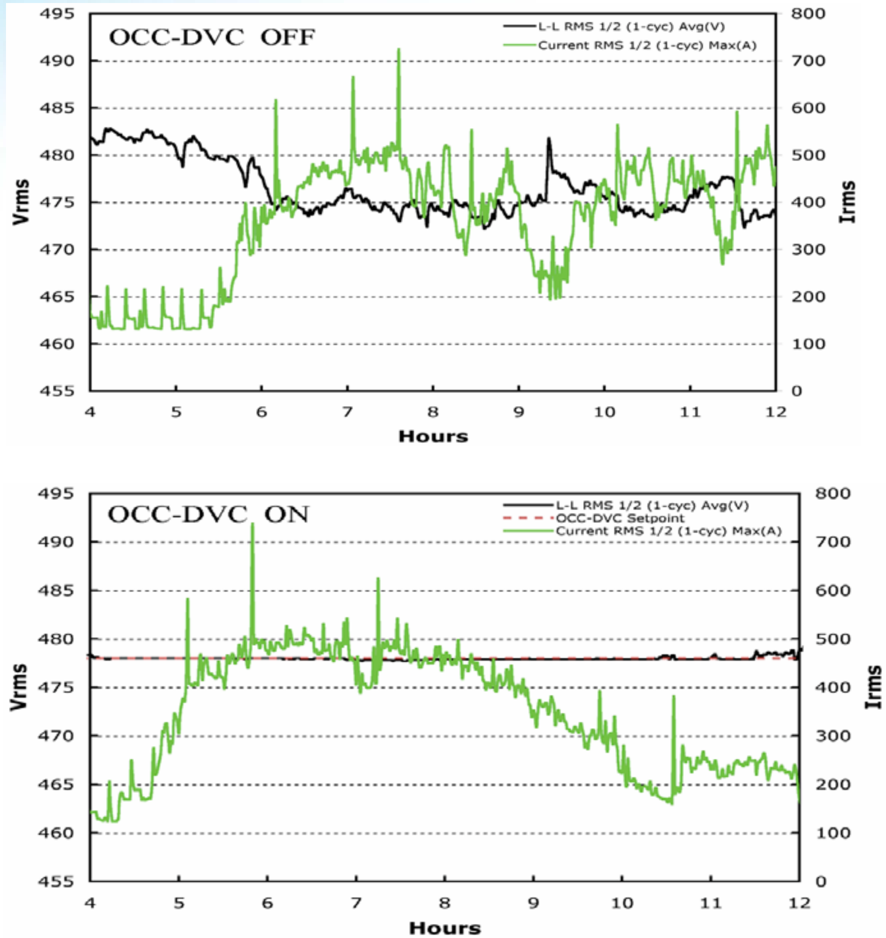
Dynamic Voltage Control

Purpose

- Develop and install tools to maintain proper voltage due to intermittency of renewable energy sources.

Scope

- Two manufacturers' solid state inverters installed to automatically adjust reactive power support to maintain voltage and reduce voltage swings due to solar intermittency.



Summary

- Distribution system designed to accommodate one way power flow and voltage drop from substation to customer
- Today current mitigation efforts sufficient. Additional work in progress to deal with future PV growth
- PV and other intermittent DG sources will have significant impact on the distribution system if we don't proactively mitigate
- Key mitigation efforts include:
  - Large PV installations studied for impacts and mitigation requirements
  - Enhanced voltage monitoring
  - Improved distribution system modeling tools
  - Advanced Energy Storage
  - Dynamic Voltage Controllers
  - Smart Inverters