National Renewable Energy Laboratory
Innovation for Our Energy Future

Impact of SolarSmart Subdivision on SMUD's Distribution System

Peter McNutt
Josh Hambrick
NREL

Mike Keesee
Dave Brown
SMUD

IPRW II
Tempe
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Outline

- Anatolia Project Introduction
- SolarSmart Homes
- Distribution System Basics
- Monitoring Equipment
- Anatolia System
- Results
- Modeling

Introduction to Anatolia Project

- Joint NREL/SMUD Anatolia Research Project
  - Three-year project began March 2008
- Analyze distribution impacts of high penetrations of grid-integrated PV-equipped SolarSmart Homes
- 795-home community will have 600 SolarSmart Homes, each with ~ 2.0 kW_{ac} PV system
  - only 115 homes built, so far
  - no energy storage

Anatolia Project Areas of Investigation

- Will there be excessive service or substation voltage due to exporting PV systems?
- Do PV inverters trip offline due to utility line voltage transients?
- Will inverter generation be limited by distribution system operating voltage?
- Can more SolarSmart Homes be connected to each distribution transformer, or can the transformers be smaller for the same number of homes?

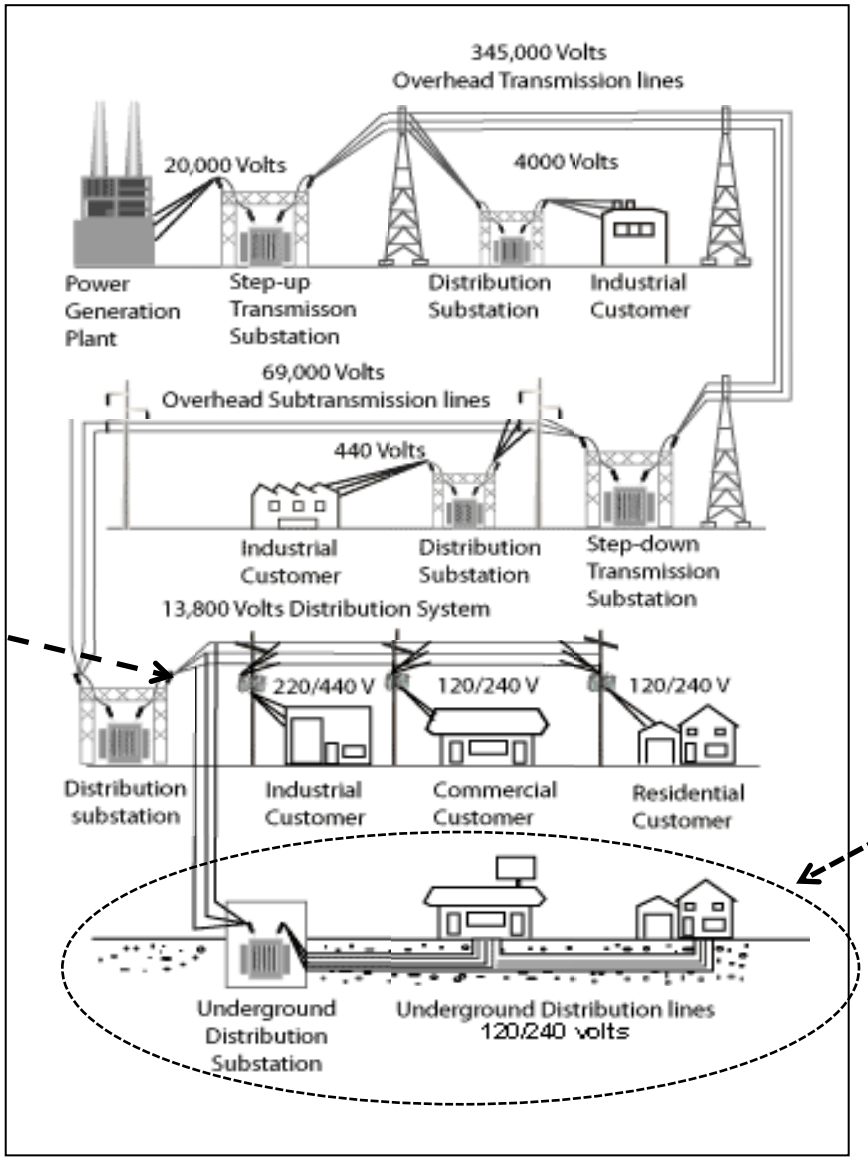
Anatolia SolarSmart Homes

Anatolia SolarSmart Homes typically include:

- Radiant barriers to reflect summer heat
- High-efficiency furnaces & HVAC systems
- Compact-fluorescent lighting
- ENERGY STAR-qualified windows
- Independent third-party verification to confirm all energy-efficiency measures are installed and operating correctly
- ~ 2.0-kW_{ac} PV systems generating a major portion of the electrical energy consumed in the homes (most PV systems comprise 36 SunPower 63-watt SunTile roof-integrated modules feeding into a SunPower SPR-2800x positive-ground, grid-connected inverter)

Distribution System Interconnection

"Typical" distribution system

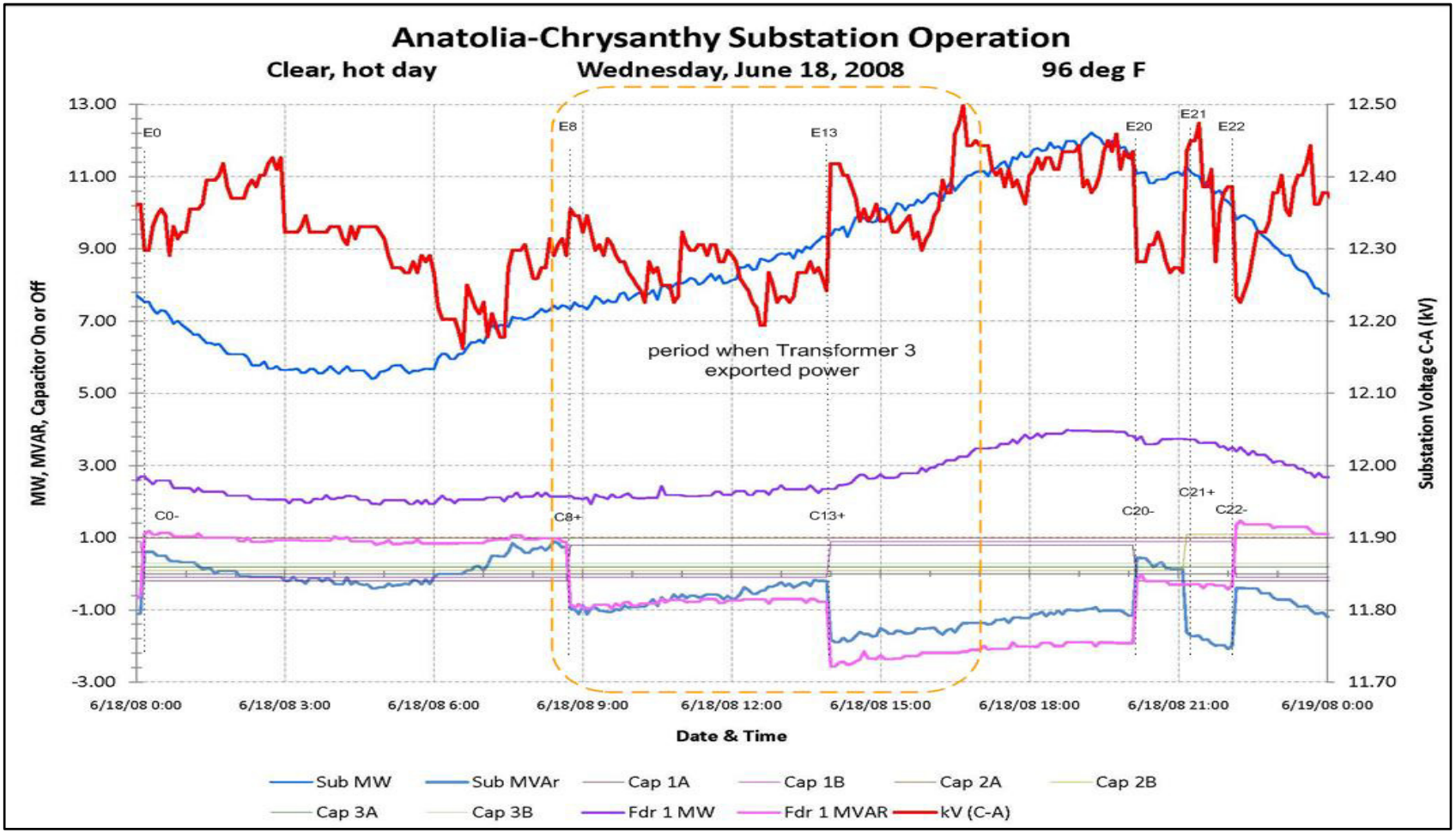


load-tap changer & capacitors regulate voltage

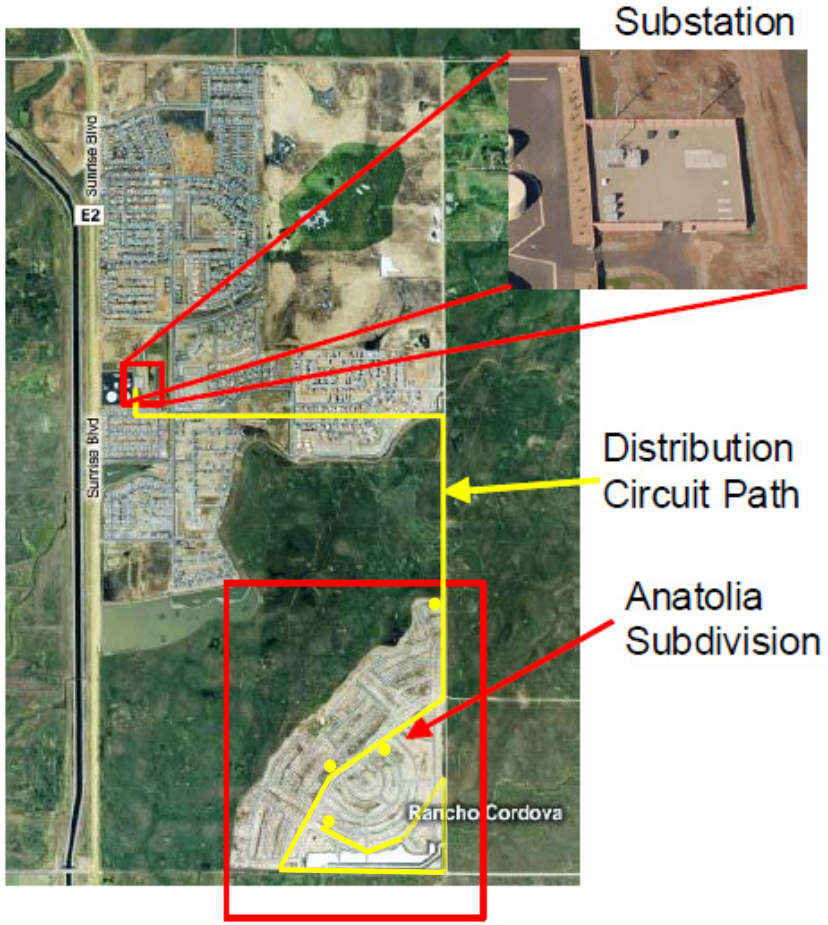
SMUD Anatolia - actual
20 MVA / 12.47 kV underground distribution system
85 single-phase distribution transformers
23 are 75 kVA
62 are 50 kVA

Distribution Voltage Affected by Capacitor Changes

Capacitors can change states based on unmonitored inputs from transmission level, affecting distribution voltage



Anatolia Overview & Monitor Points

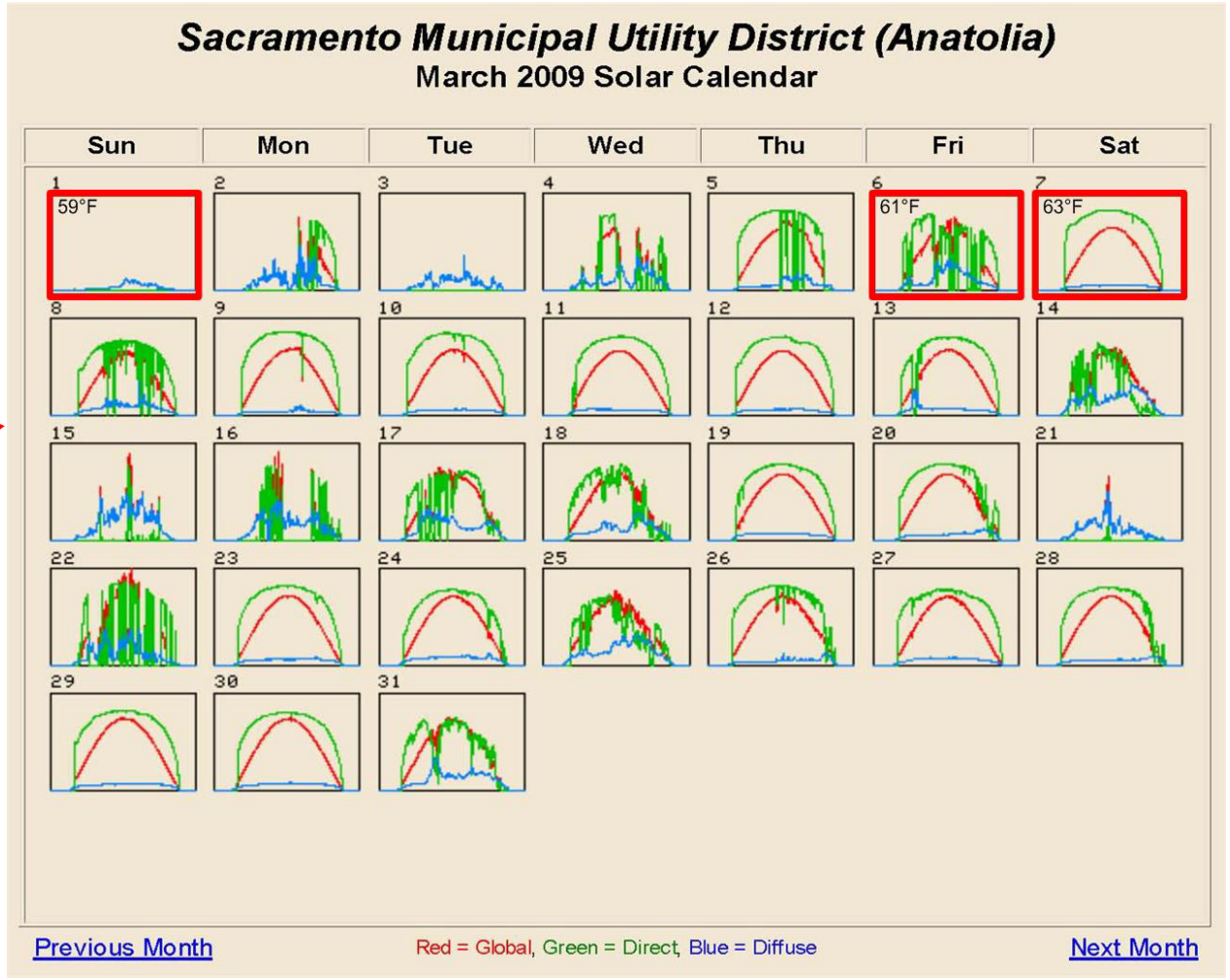


Monitoring at four distribution transformers

Monitoring at four homes

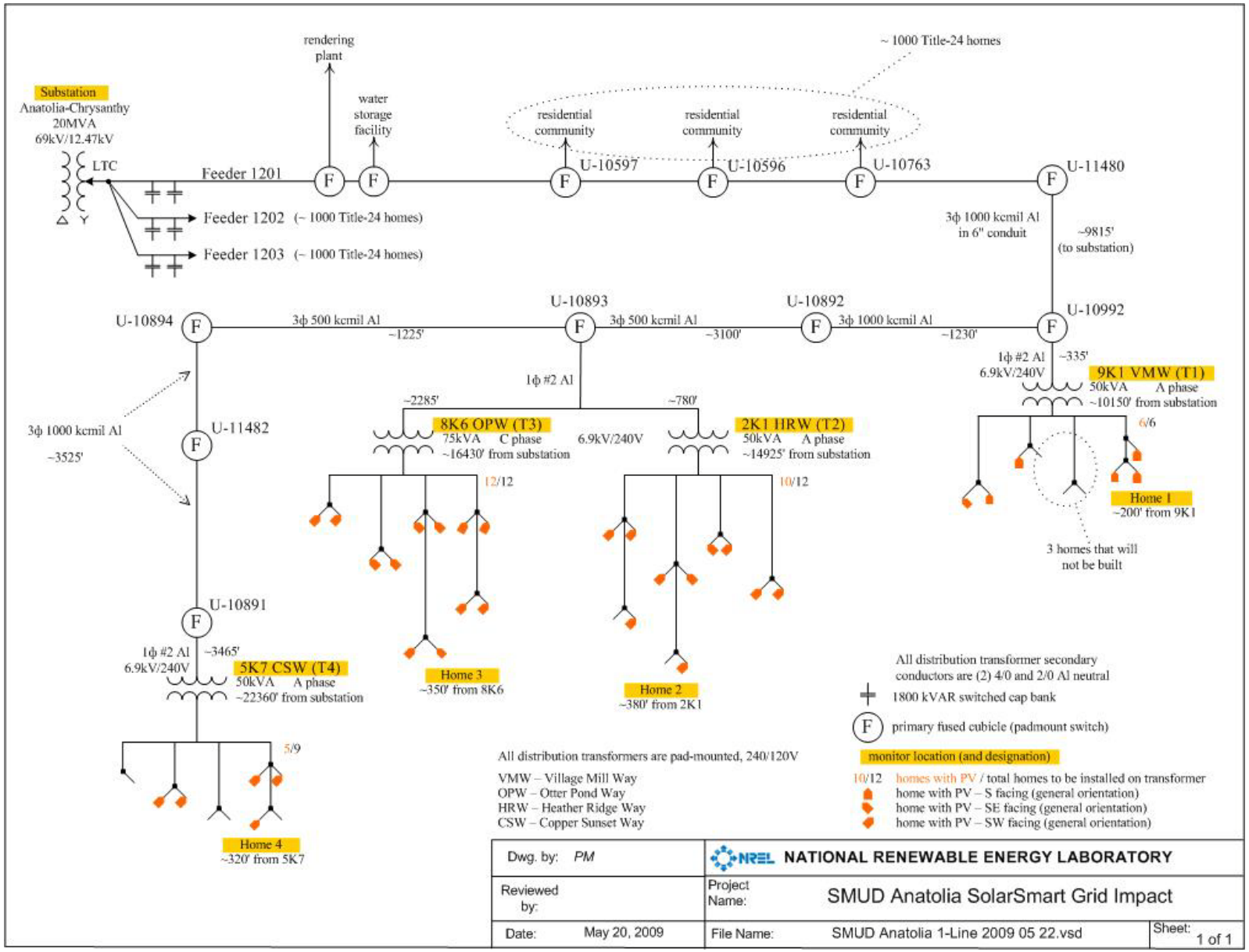
Anatolia Solar Resource Monitor

Solar monitor – RSR2

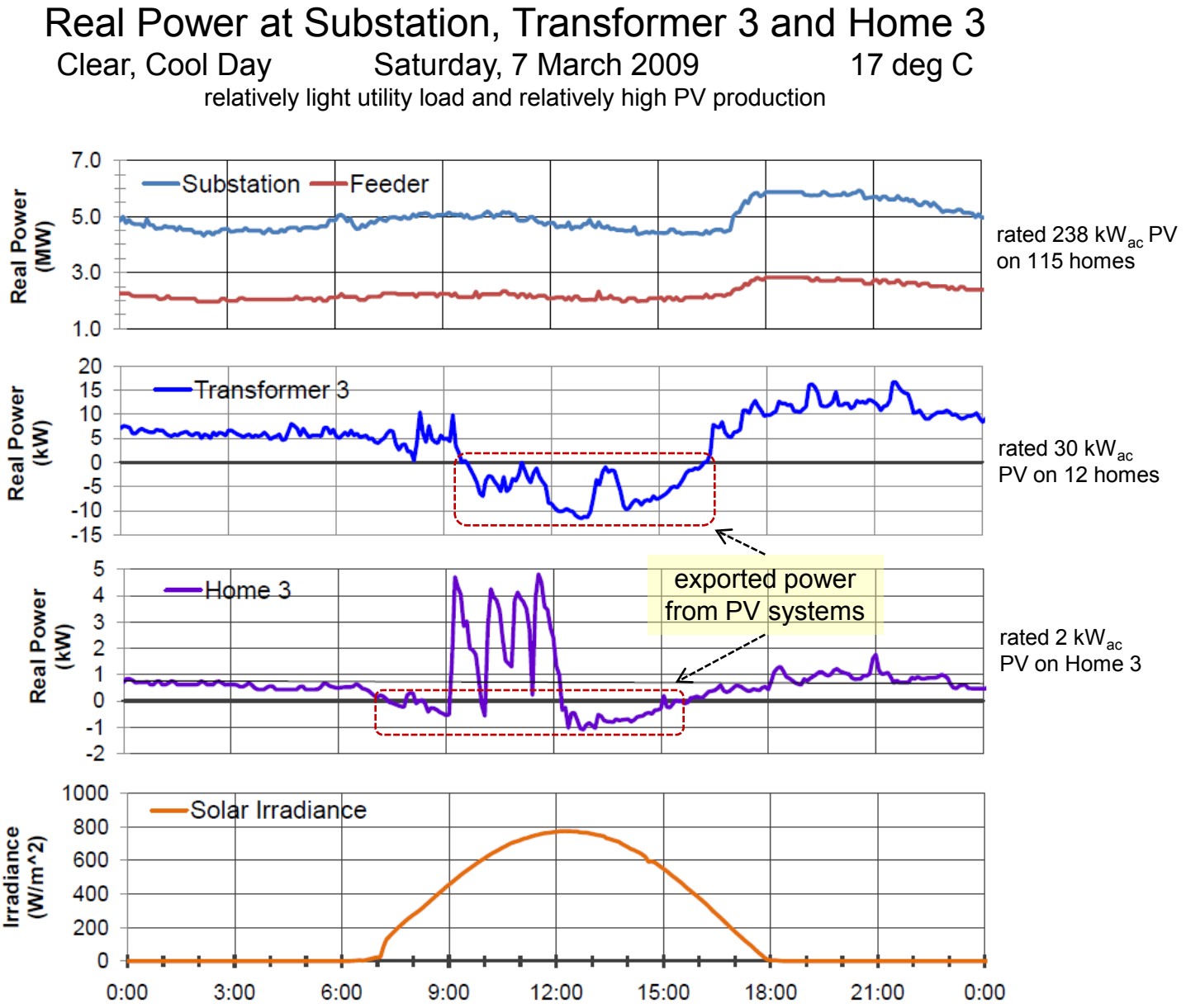


Solar calendar for March 2009
available at http://www.nrel.gov/midc/

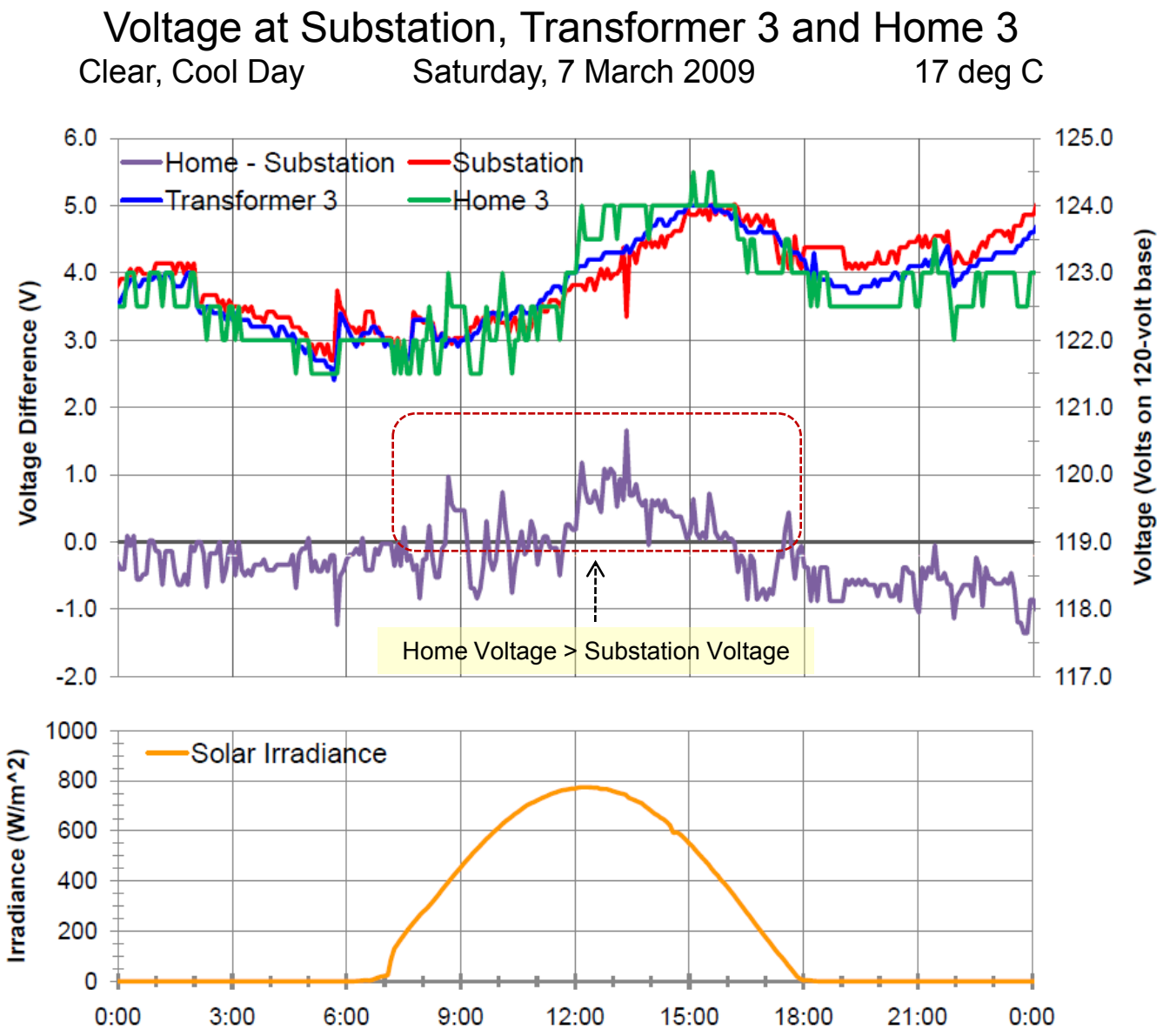
Anatolia System Layout & Monitor Points



Anatolia Results – Power (Cool Day)

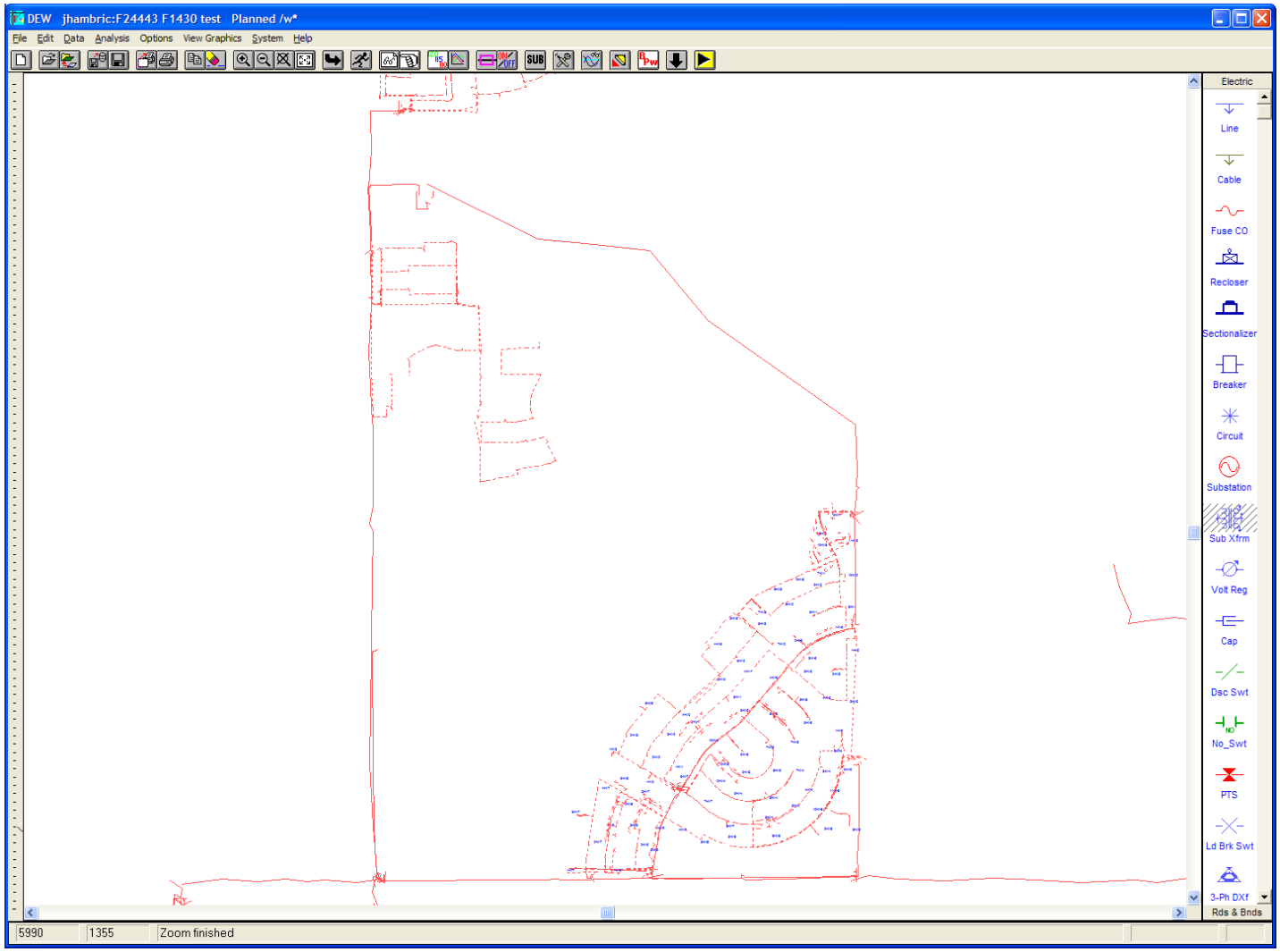


Anatolia Results – Voltage (Cool Day)



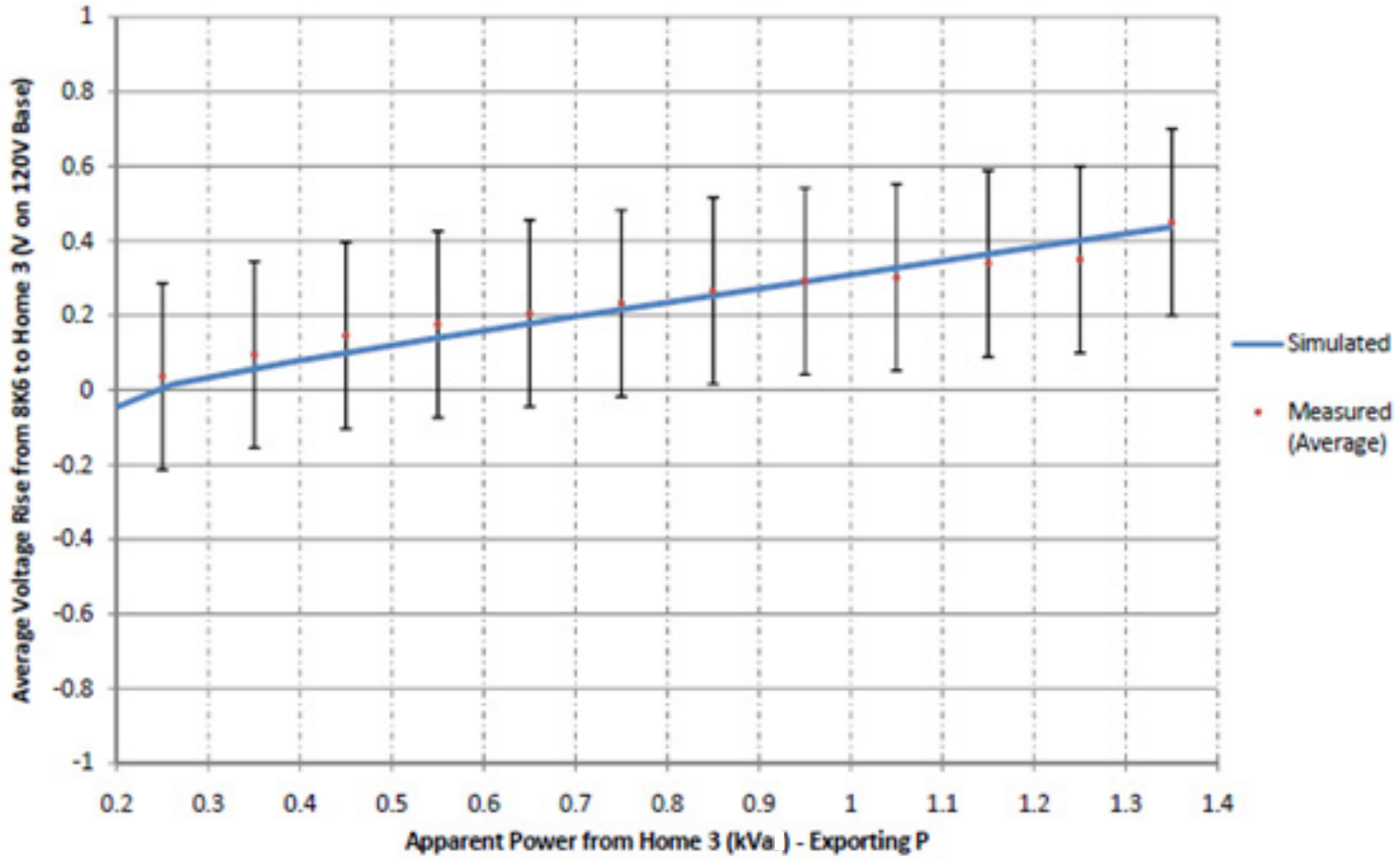
Anatolia Model Development

Anatolia system model created using
Distributed Engineering Workstation (DEW)



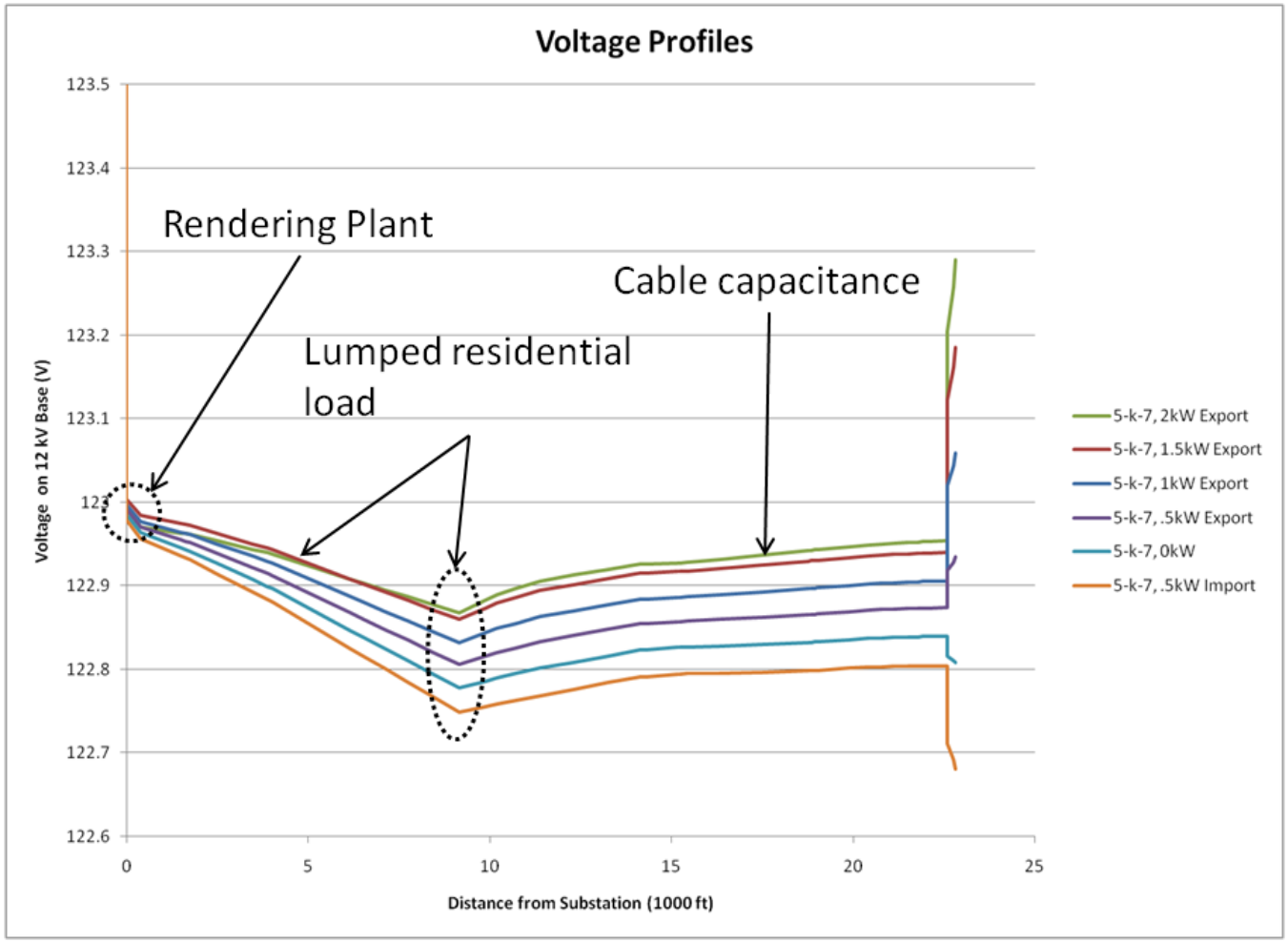
Anatolia Model Verification

Good agreement between modeled and measured
Voltage Rise from Home 3 to Transformer 3



Anatolia Modeled Voltage

Modeled voltage profiles for Transformer 3 for various levels of uniform customer loading and generation



Anatolia Conclusions

NREL/SMUD Anatolia Research Project –

After one year, PV systems have not adversely affected the Anatolia distribution system

- PV penetration levels on the feeder were no greater than 13% under lightly-loaded conditions (2.0 MW) and about 4.0% during heavy load
- There was no excessive service or substation voltage due to reverse power flow from exporting PV systems
- It was possible to see the effects of the PV systems on the voltage at the individual homes and the distribution transformers

Anatolia Future Work

NREL/SMUD Anatolia Research Project –

- Use the model to determine acceptable levels of PV penetration
- Find load loggers that can withstand heat, measure distribution transformer primary & secondary load, fit within transformer enclosures, and offer automatic communication
- Isolate loads outside Anatolia community
- Work with SunPower to encourage more homeowners to voluntarily connect their PV systems to the internet for monitoring

Contact Information

technical report available at:
http://www.nrel.gov/docs/fy09osti/46093.pdf

Peter McNutt
Peter.McNutt@nrel.gov
303-384-6767

Thanks