# High Penetration FOA

# Analysis of High-Penetration Levels of PV into the Distribution Grid in California

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Program Team - Systems Integration

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# Overview



## Timeline

- Project start date: 2010
- Project end date: 2014
- Percent complete: 5%

## Barriers

- Barriers addressed
  - Reducing costs and barriers to deployment of high penetration PV

## Budget

- Total project funding
  - DOE share ($3,600K)
  - Contractor share ($900K)
- Funding for FY10 - $600K

## Partners

- Southern California Edison
- Clean Power Research
- Electrical Distribution Design
- Satcon

# Challenges, Barriers or Problems



- The project team will conduct modeling and simulation, laboratory testing, and field demonstrations of the affect of high penetrations of PV on electrical distribution systems.
- This project addresses the issues with integrating high levels of PV into the electrical distribution system by fully examining the issues, developing solutions, and transitioning those solutions to the field for large-scale deployment.

**Project Background:**

- Southern California Edison's (SCE) plan to install 500MW of distributed solar in its service territory over the next 5 years.
- This will include 250MW of utility-owned solar and 250MW of independently-owned solar.
- SCE expects that the majority of these systems will be commercial-scale rooftop photovoltaic (PV) systems connected at various points in the distribution system.
- This installation will represent the highest level of distributed PV in any utility service territory in the United States and have several distribution circuits with high penetrations of PV.

# Relevance

**Objectives:**

- Use field verification to improve the ability to model and understand the impacts and develop solutions for high penetration PV deployments in electric utility systems.
- Disseminate information on the modeling tools that are developed and used
- Develop performance datasets that show the impact of the PV systems on the electric grid
- Publicize the resulting lessons learned and best practices for adopting high levels of PV.

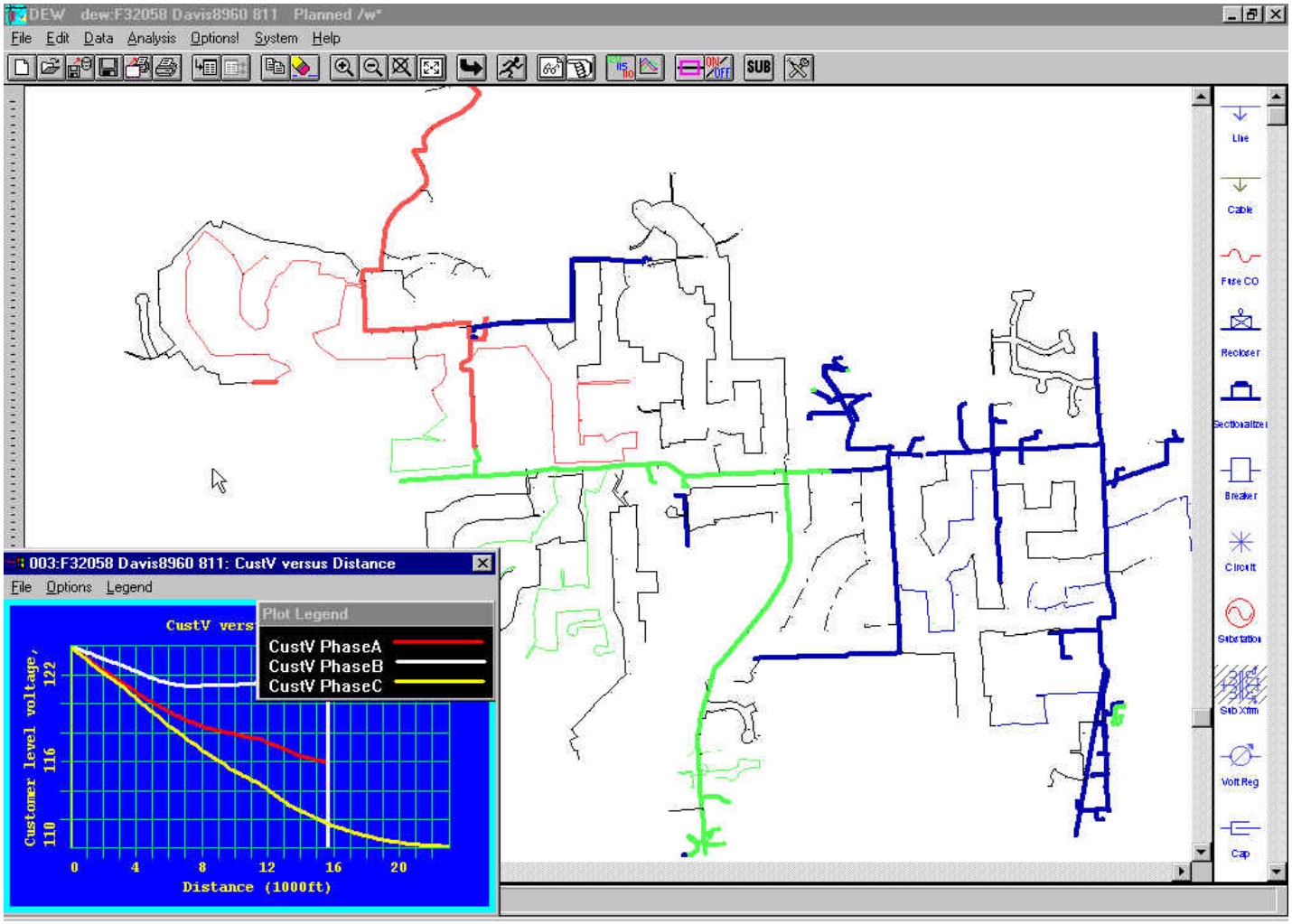
**Technical approach:**

- Distribution System Assessment
- Modeling and Simulation
- Laboratory Testing
- Field Testing
- Results Publication and Information Dissemination
- Project Management

# Distribution System Assessment

- Define prototypical distribution circuits in the existing service territory (a grouping of currently existing distribution circuits sharing some common characteristics)
- Define new circuit configurations and operating characteristics (newly built circuit designed to accommodate high-penetration PV levels, microgrids, and Smart Grid implementation)
- Identify which circuits would be the most likely to have high levels of PV installed on them in the future
- Determine modeling and simulation tools needed for high penetration scenario evaluations
- Define secure communications and controls for PV/utility system integration
- Define advanced PV system operations (voltage/VAr control, intentional islanding operation, fault contributions and ride-through capability, reduced false inverter trips)
- Define distribution system impacts to be evaluated including: voltage regulation, unintentional islanding prevention, reverse power flow on secondary distribution networks, protection coordination, and effects of clouds on system stability
- Develop a procedure to take the lessons learned from early years of the project lab and field testing and implement in subsequent years other locations sharing similar circuit characteristics.

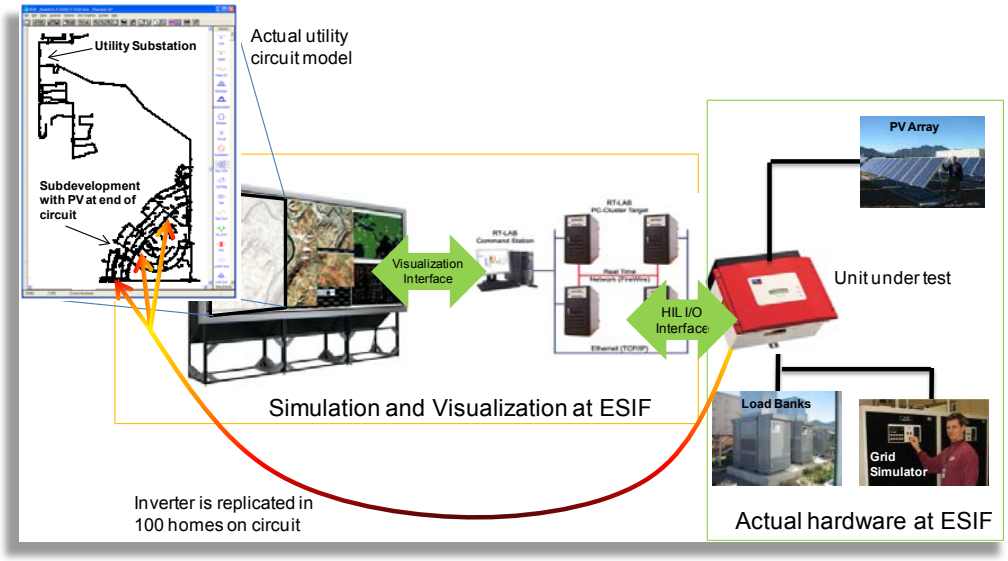
# Modeling and Simulation



# Laboratory Testing

- Lab testing will include conducting hardware-in-the-loop testing of new products by integrating dynamic simulation tools for evaluating the effects of high-penetration PV and devising solutions in lab testbeds prior to installing prototype hardware and software in the field.

- Under this task, the project team will define new hardware and software needs for inverters and PV systems that will improve our ability to control the PV systems and improve the integration of these systems at high penetration levels.



## Field Testing

- High resolution data collection will take place to gather information on PV system performance and impacts on distribution circuits.
- Several years of field performance data will be collected from both the PV systems and the distribution circuits to document the effects of high-penetration PV.
- This data will be used to verify simulations and develop effective solutions to turn the lessons learned into best practices for integrating solar.

## Results Publication and Information Dissemination

Publications from the project will include:

- Report on existing models for PV systems, inverters, and distribution systems (Phase 2)
- Report on field verification of impacts of PV systems (Phase 3)
- Report on new technology developments for integration of PV (Phase 4)
- Final reports on Modeling and Simulation tools that includes information on updated models for advanced PV systems, inverters, and distribution system operations. This report will include basic information on how to perform a PV system integration study. (Phase 5)
- High Penetration PV Handbook – This will be in the form of a distribution system planning handbook for utilities. It will include best practices, lessons learned and how to perform a cost/benefit analysis on the system installations. (Phase 5)

# Year 1 Plans – FY10

- **Report on Distribution System Assessments and Modeling and Simulation:** Discuss the utility distribution system and modeling and simulation tools for helping to determine the impact of high penetrations of PV systems.
- **Report on Inverter Capabilities:** Determine advanced inverter capabilities needed to allow high penetration PV systems.
- **Report on Data Acquisition System and Field Testing:** Develop data acquisition systems and field testing for helping to determine the impact of high penetrations of PV systems.
- **Annual Summary Presentation:** This presentation will describe project activities and accomplishments for the year.

# Accomplishments / Progress / Results



- **Year 1** – Identify circuits to implement data collection and model. Define PV system requirements and inverter capabilities. Start data collection.
- **Year 2** – Develop models of inverter and circuits. Develop advanced inverters
- **Year 3** – Verification of models. Lab testing of advanced inverters.
- **Year 4** – Deploy new inverter in field.
- **Year 5** – Complete models for distributed PV systems. Complete field testing of advanced inverters. Publish final reports.

# Future Plans (FY 2011 and beyond)



| Task | Phase 1 (12 months) | Phase 2 (12 months) | Phase 3 (12 months) | Phase 4 (12 months) | Phase 5 (12 months) |
|---|---|---|---|---|---|
| **Distribution System Assessment** | Define prototypical circuits and new circuits<br>Define communications, PV operations, and grid operational requirements | - | - | - | - |
| **Modeling and Simulation** | Determine existing modeling and simulation tools for determining system impacts | Model circuits with existing models<br>Develop generic inverter models | Verify models on existing fielded sites | Develop new models of advanced PV systems and inverters | Verify new models on new sites<br>Identify full suite of modeling and simulation tools for high penetration PV |
| **Lab Testing** | Define new inverter capabilities | Develop new inverter hardware | Conduct lab-level testing of new inverter | - | - |
| **Field Testing and Verification** | Define and install additional DAS on several circuits<br>Start data collection | Continue data collection on PV systems and circuits | Continue data collection on PV systems and circuits | Install new PV systems with advanced functionality | Complete field testing and verification of high penetration PV scenarios |
| **Result and Information Dissemination** | Summary paper on project | Publication on existing models for PV systems, inverters, and distribution systems | Publication on field verification of impacts of PV systems | Publication on new technology developments for integration of PV | Publish final reports on Modeling and Simulation<br>Publish high penetration PV handbook |
| **Project Management** | Monthly Reports, Annual Report, ARRA Report | Monthly Reports<br>Annual Report | Monthly Reports<br>Annual Report | Monthly Reports<br>Annual Report | Monthly Reports<br>Annual Report |

# Collaborations



- **NREL** - project management and laboratory testing as well as conducting modeling and analysis of fielded systems.
- **Southern California Edison (SCE)** - host utility and will install high penetration PV systems on a number of distribution circuits in their service territory. They will also participate in developing the distribution practices for installing high penetrations of PV.
- **Clean Power Research (CPR)** - develops, manages, and operates the world's most comprehensive suite of PV software tools that will be used to analyze PV system impacts for this project.
- **Electrical Distribution Design (EDD)** - existing simulation models for electrical power systems and new tools to address high penetration scenarios. These will be integrated into an open source framework for conducting simulations of high penetration PV systems in electrical distribution systems.
- **Satcon** - advanced inverter technology and responsible for the development of advanced control systems for inverters and integration with the electric power system.

# Summary Slide



- This project will demonstrate the integration of high penetrations of PV on commercial distribution circuits.
- The project will develop and validate models to help with distribution analysis.
- The project will deploy advanced inverter technology to increase the amount of PV that can be integrated into the distribution system.
- The project will summarize knowledge gained into a handbook for integrating high levels of PV into the distribution system