HI-PENETRATION PV INITIATIVE

PROJECT PARTICIPANTS: Sacramento Municipal Utility District (SMUD), Hawaiian Electric Company (HECO), Maui Electric Company (MECO), Hawaiian Electric Light Company (HELCO), BEW Engineering (a DNV Company)

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I. BACKGROUND

INTRODUCTION

This two year project will develop the methodology, visualization and modeling capabilities to investigate and analyze the potential impacts of high PV penetrations on individual distribution feeders and the entire distribution grid. Modeling requirements define feeder grid characteristics of each single phase and poly-phase inverter on the grid.

Analysis includes circuit voltage impacts, regulation, flicker, islanding, fault current, transient analysis, tap change-capacitor bank-inverter coordination.

The information within this poster focuses on the modeling efforts of Task 2, and 3 of the Hi-Penetration PV Initiative. Ultimately, the goal is to enable appropriate capability to reliably plan and operate with high penetration of variable renewable resources on the grid especially during high impact conditions (e.g. variable weather, peak loads, minimum loads, contingencies).

TASK 2 & TASK 3

MODELING OBJECTIVES AND PROCESS ENHANCEMENTS

1. Develop modeling capability to rapidly determine PV impact associated with feeders and the entire distribution grid.

2. Develop a standard methodology and process for utilities to find cost effective and reliable integration solutions and communicate options with developers, federal/state agencies and other interested parties.

To develop a more robust model, enhancements are applied to the model, such as modifying the inverter operational characteristics or incorporating high resolution PV data. Taking into account weather impacts and the effects of variable resources will also make for a more robust model. In addition, single phase distribution impacts are quantified using these detailed models, as well as defining the interaction of load tap changers, capacitors, and multiple inverters.

HI-PENETRATION PV INITIATIVE TASK OVERVIEWS

Task 1 – Project Overview: Management, Status, and Technical Outreach
- Interim reports, deliverables, and coordination of meetings
- Budget and resource management
- Submission of project abstracts to various industry conferences
- Utility partnerships helping to inform development of new industry tools

Task 2 – Baseline Modeling of distribution feeders for SMUD & HECO Companies
- Identification of Cases (i.e. high penetration circuits with interesting characteristics)
- High Penetration Circuits Data Collection (Voltage, Loads, Production, Faults)
- Distribution Systems Modeling/Visualization (SynerGEE modeling integrated with PowerWorld identify high value locations for PV, identify problem areas)

Task 3 – Monitoring equipment installation, data collection and simulation model validation for 25 utility feeders
- Simulation, testing and validation efforts to address grid impacts using SynerGEE and PowerWorld
- Sensitivity analysis on varying PV penetration levels to define interaction with grid reliability
- Develop a methodology for extending findings to expedite interconnection studies at higher penetration levels

Task 4 – Data Visualization Pilot
- Graphical (GIS-based) display of PV and wind resource areas
- Results of Distribution System Modeling/Visualization (SynerGEE modeling integrated with PowerWorld)
- Develop and pilot visualization analysis tool for planning and operations

Task 5 – PV Production Forecasting
- Deployment of Network of 70 Solar Irradiance monitors, cell modem data collection, 1 minute data
- Modeling/solar forecasting using NOAA weather forecasts, validated using ground network

II. PRELIMINARY ASSESSMENT

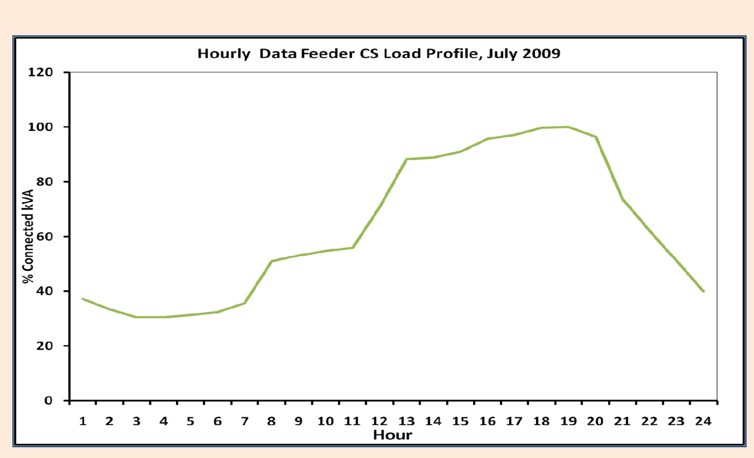
EXAMPLE OF A PV PENETRATION ANALYSIS

The typical workflow of analyzing a feeder located within Sacramento's Municipal Utility District (SMUD) is briefly stepped through in this example.

1. IDENTIFY BASELINE CHARACTERISTICS

- Losses
  - 3.2% including substation transformer
  - 2.6% for distribution feeders only
- Load is allocated based on distribution section points
- All Caps on:
  - Max V = 128 V
  - Min V = 120 V
- Feeder 1 loaded to 53% Maximum, Feeder 2 to 43%
- Total distributed demand is 8.9 MVA at substation
- 3.2 MVAr capacitor (6 Units) available on the circuit
- Tap changer position circuit 1: 5R
- Tap changer position circuit 2: 2R
- Only Feeder 1 has existing PV

2. EXAMINE AND CONVERT LOAD DATA

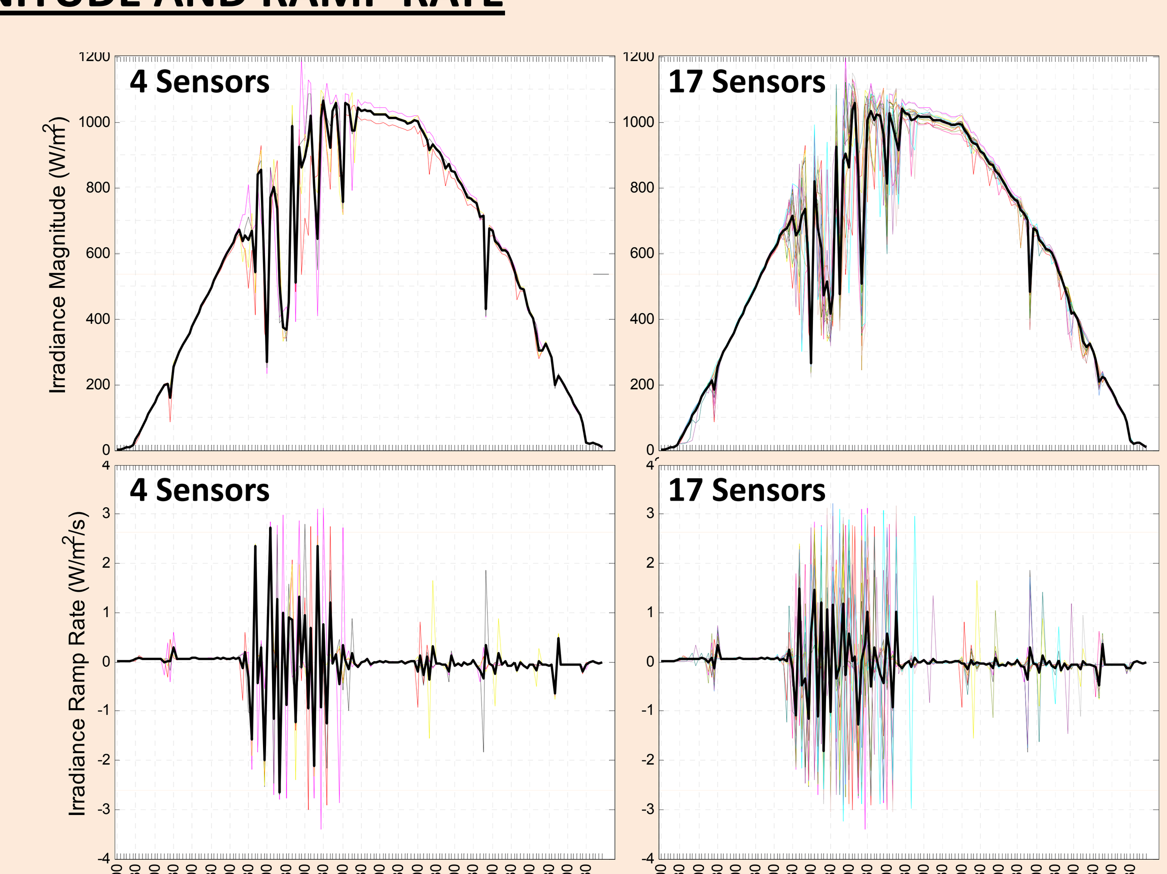


5 minute load data was provided and converted into a 24-hour format used in SynerGEE Electric.

3. EXAMINE IRRADIANCE MAGNITUDE AND RAMP RATE

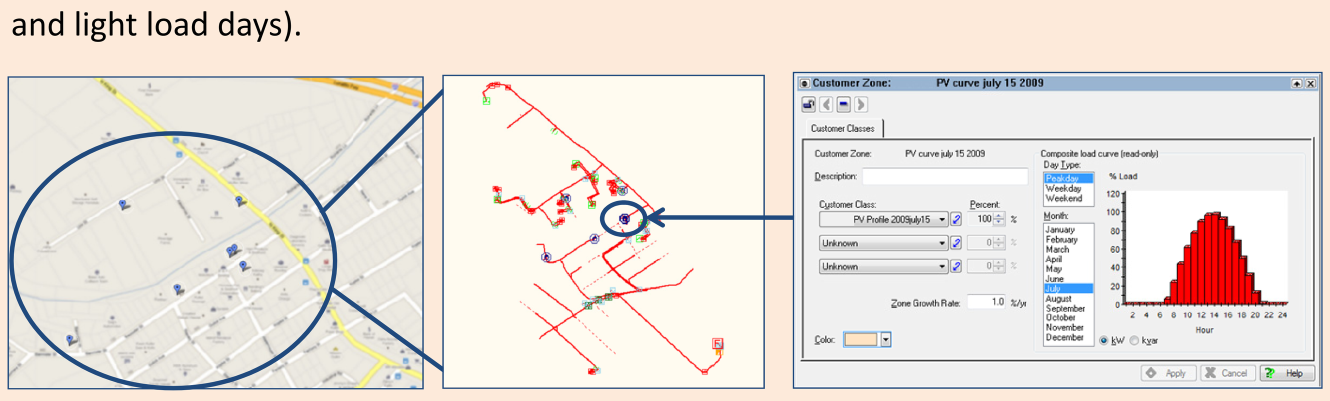
All sensor output raw data is received in 1-sec. interval and averaged to 5-minute time steps.

The effect of multiple sensors and panels are examined to reduce individual sensor errors. Compared to the individual sensor outputs, the averages exhibit a reduction in fluctuation of irradiance magnitude and ramp rate.



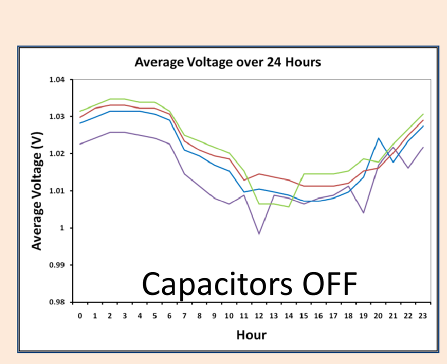
4. DEVELOP ANALYSIS PROCESS & EVALUATION SCENARIOS

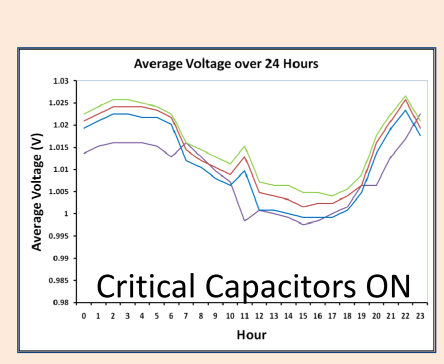
The 24-hour load and PV profiles are added as customer zones to SynerGEE for the distribution feeders 1 and 2, and for each of the PV locations. These profiles can be applied for various "day types" over a 12 month period (e.g. peak day, minimum day, and light load days).



PV units are modeled as Large Customers with a Scheduled Generation PV profile. The power factor is determined by the inverter. Spot Loads are added at PV sections equal to the PV size to compensate for inclusion of PV at sub-transmission or distribution level demand metering.

5. VOLTAGE LEVEL ANALYSIS

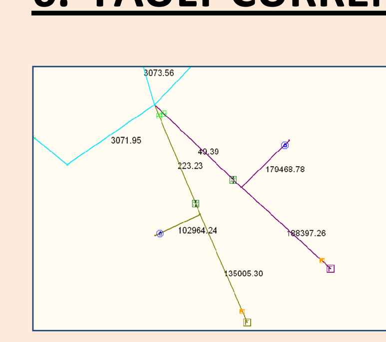




Prior to conducting the voltage level analysis, a balanced load allocation (by connected kVA) was completed. The load was allocated with all of the capacitors initially turned off. This load profile is applied at Customer Zones to all sections in the feeders and substation. The voltage levels of the distribution feeder is analyzed over the 24-hour period at different PV levels.

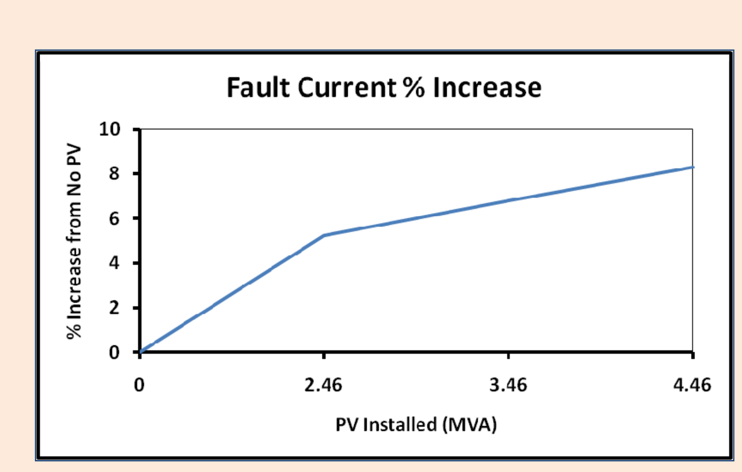
- No PV
- No PV + Spot Loads to account for displaced peak time load
- Existing PV + Spot Loads
- Existing PV + 1 MW potential PV at single location
- Existing PV + 2 MW potential PV at single location

6. FAULT CURRENT SIMULATION AND INITIAL RESULTS



In order to perform the fault current simulation, the inverter information for each installation is collected. The inverter location is based on the closest node phasing. The total fault current contribution is based on the number and type of inverter. An equivalent impedance model is then used to simulate the fault current contribution.

The total fault current contribution from 0 MW of PV on the system to 4.5 MW of potential PV is 8.3%. The initial conclusion is that the additional PV on the system, does not negatively impact this particular feeder.



The fault current analysis is performed at different loading stages on the feeder. This process is applied to and additional distribution circuits for the area.

III. SUMMARY AND FUTURE EFFORTS

This project started June 2010, and Tasks 1, 2, and 3, are currently underway. Task 4 and Task 5 are in the preliminary stages. Data is being collected to validate simulation and analysis results. By completing this analysis, we will define the positive and negative impacts of high penetration solar generation on the distribution network.

- Validation of modeling and analysis against metered power data
- Continue baseline analysis and scaling of PV after recommendations
- Model inverter parameters upon next update of SynerGEE Electric
- Document circuit scenario analysis results including low-load day
- Complete surveys for key circuits identified by utilities
- Complete utility distribution models and continue with PV analysis
- Consider implementation of data conversion tool for detailed analysis in other software platforms